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2 Marks Questions

1.
Sol. One dimensional flow analysis means neglecting the flow in transverse direction.
2.
Sol. The hydraulic mean depth of wide rectangular channel is
 $\therefore R = y(\text{depth of flow})$
3.
Sol. Supercritical flow exists when:
Froude no. > 1 it means depth of flow is less and velocity is more than critical depth and velocity respectively.
4.
Sol. Wave celerity is defined as the velocity of the wave with respect to the water.
$$\text{Wave celerity } (V_c) = \sqrt{gy}$$

where $g \rightarrow$ gravitational acceleration constant
 $y \rightarrow$ depth of flow
5.
Sol. Specific energy is the distance of total energy line from channel bed as datum.
$$E = y + \frac{v^2}{2g}$$
6.
Sol. Critical Energy $= \frac{3}{2} \times \text{critical depth}$ i.e. $E_c = 1.5y_c$
7.
Sol.
$$\frac{y_2}{y_1} = \frac{-1 + \sqrt{1 + 8F_{r1}}}{2}$$

where y_1 & y_2 are pre and post jump depth
 F_r is the Froude no. for the supercritical flow.
8.
Sol. A channel in which the cross-sectional shape, size and the bottom slope are constant is termed as a prismatic channel.
9.
Sol. A hydraulic jump occurs when supercritical flow meets a subcritical flow of sufficient depth.
10.
Sol. Hydraulic jump is used to dissipate the excess energy of water.
11.
Sol. The normal depth is associated with uniform flow in a channel. The depth of flow at which the specific energy is minimum is called critical depth.
12.
Sol.
$$Z_c = A \sqrt{\frac{A}{T}}$$
 , it is associated with critical flow.
13.
Sol. In open channel, flow occurs under atmospheric pressure and the component of weight along the direction of slope provides the driving force for flow in channels.
In closed conduits, flow occurs above atmospheric pressure and difference of pressure along the pipe i.e. pressure gradient provides the driving force for flow in pipes. Partially full conduits behave like open channels only.



14.

Sol. Theoretically circular channel section gives the minimum wetted perimeter for a given cross sectional area and hence it is the most efficient channel section.

Practically trapezoidal sections with curved bottom corners are used as efficient channel sections.

15.

Sol.

If $R_e < 500 \rightarrow$ laminar

If $R_e > 2000 \rightarrow$ Turbulent

where

$R_e =$ Reynold number

16.

Sol. Equation of hydraulic jump:

$$Q^2/Ag + A\bar{Z} = \text{constant}$$

where

$\bar{Z}$ = depth of centroid of flow area A

5 Marks Questions

17.

Sol. We know that,

$$V = C\sqrt{RS} \text{ (Chezy's equation)}$$

where,

$S \rightarrow$ Slope of energy line for uniform flow in open channel (i.e. $S = \frac{h_f}{L}$)

$\Rightarrow$

$$V^2 = C^2(RS)$$

$\Rightarrow$

$$V^2 = C^2 R \left(\frac{h_f}{L} \right) \quad \dots(i)$$

Also,

$$h_f = \frac{fLV^2}{2gD} \text{ (From Darcy's Weisbach equation)}$$

Substituting value of h_f in equation (i)

$\Rightarrow$

$$V^2 = C^2 R \frac{fLV^2}{2gDL}$$

$\Rightarrow$

$$1 = C^2 \left(\frac{D}{4} \right) \frac{f}{2gD} \left(\because R = \frac{D}{4} \right)$$

$\Rightarrow$

$$C = \sqrt{\frac{8g}{f}} \quad \dots(ii)$$

Now, comparing chezy's and Mannings equation

$$V = \frac{1}{n} R^{2/3} S^{1/2} = C\sqrt{RS}$$

$\Rightarrow$

$$C = \frac{1}{n} R^{1/6}$$

$\Rightarrow$

$$\sqrt{\frac{8g}{f}} = \frac{1}{n} R^{1/6} \quad \text{(From (ii))}$$



$$\Rightarrow \frac{8g}{f} = \frac{1}{n^2} R^{1/3}$$

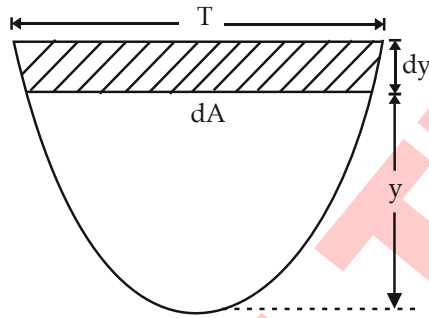
$$\Rightarrow f = \left(\frac{n^2}{R^{1/3}} \right) (8g)$$

18.

Sol. We know that,

$$\text{Specific energy (E)} = y + \frac{V^2}{2g}$$

$$E = y + \frac{Q^2}{2gA^2}$$



For E to be minimum at constant Q,

$$\frac{dE}{dy} = 0$$

$$\frac{d \left[y + \frac{Q^2}{2gA^2} \right]}{dy} = 0$$

$$\Rightarrow 1 - \frac{Q^2}{gA^3} \left(\frac{dA}{dy} \right) = 0 \quad \left[\begin{array}{l} \because dA = T dy \\ \Rightarrow \frac{dA}{dy} = T \end{array} \right]$$

$$\Rightarrow 1 - \frac{Q^2 T}{gA^3} = 0$$

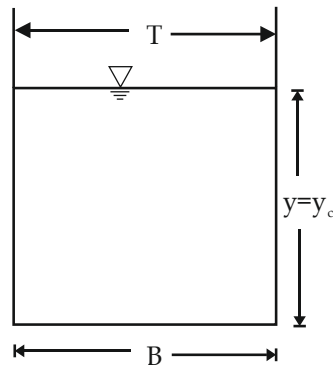
$$\Rightarrow \frac{Q^2 T}{gA^3} = 1$$

 $\therefore$ For a given discharge Q, E is minimum when

$$\frac{Q^2 T}{gA^3} = 1$$

19.

Sol. Let us consider a rectangular channel section of width = B and having constant discharge Q, under a critical depth of flow $y = y_c$



For critical flow condition, $\frac{Q^2 T}{g A^3} = 1$

For rectangular section, $T = B$ and $A = B y_c$

$$\frac{Q^2 B}{g (B y_c)^3} = 1$$

$$\Rightarrow y_c^3 = \frac{Q^2}{B^2 g}$$

$$\Rightarrow y_c^3 = \frac{q^2}{g} \quad \left[\because q = \frac{Q}{B} \right]$$

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

Minimum specific energy $E_c = y_c + \frac{V_c^2}{2g}$

$$E_c = y_c + \frac{\left(\frac{q}{y_c} \right)^2}{2g}$$

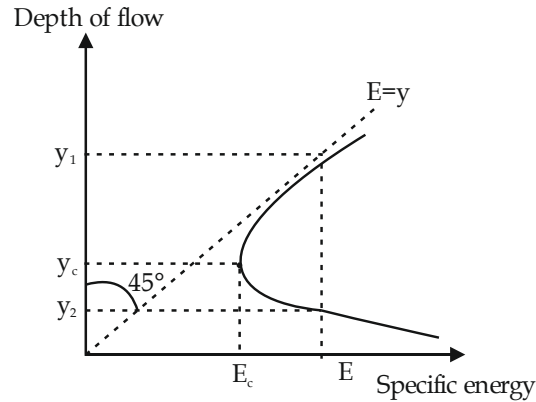
$$E_c = y_c + \frac{q^2}{2g y_c^2}$$

$$E_c = y_c + \frac{(y_c)^3}{2y_c^2} \quad \left[\frac{q^2}{g} = y_c^3 \right]$$

$$E_c = y_c + \frac{y_c}{2}$$

$$E_c = \frac{3}{2} y_c \quad \text{For rectangular section}$$

Depth of flow Vs specific energy curve:



Alternate depths:

Two depths of flow having same specific energy (E), (i.e. y₁ and y₂) are called alternate depth. y₁ corresponds to sub-critical flow depth and y₂ corresponds to super critical depth.

20.

Sol.

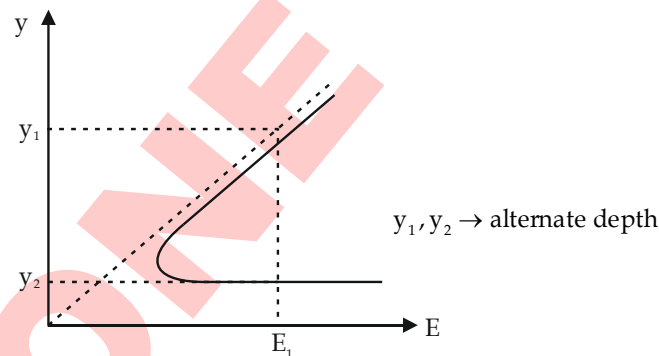
Given,

Width of channel = 15 m

Depth of flow = 0.8 m

Discharge, (Q) = 10 m³/sec

We know that alternate depths are the depths at which specific energy (E) are same.



$$E_1 = y_1 + \frac{q^2}{2gy_1^2}$$

$$= 0.8 + \frac{(0.67)^2}{2 \times 9.81(0.8)^2}$$

$$E_1 = 0.836 \text{ m}$$

$$y_2 + \frac{q^2}{2gy_2^2} = 0.836$$

$$\Rightarrow y_2 + \frac{(0.67)^2}{2 \times 9.81 \times y_2^2} = 0.836$$

$$\Rightarrow y_2^3 - 0.836y_2^2 + 0.0229 = 0$$

$$\left[q = \frac{Q}{B} = \frac{10}{15} = 0.67 \text{ m}^3 / \text{s} / \text{m} \right]$$

On solving, $y_2 = 0.8$ m (given flow depth)
 $y_2 = -0.15$ m (not possible)
 $y_2 = 0.188$ m
 $\therefore$ Alternate depth = 0.188 m

21.

Sol. Given,

Froude Number before the jump (F_1) = $\sqrt{6}$

We have to calculate the Froude number after the jump.

Let us assume the channel section to be horizontal, rectangular and frictionless.

For this type of channel section,

$$\frac{y_1}{y_2} = \frac{1}{2} \left[\sqrt{1 + 8F_2^2} - 1 \right] \quad \dots(i)$$

and
$$\frac{y_2}{y_1} = \frac{1}{2} \left[\sqrt{1 + 8F_1^2} - 1 \right] \quad \dots(ii)$$

Multiply equation (i) & (ii), we have

$$\frac{1}{4} \left[\sqrt{1 + 8F_2^2} - 1 \right] \left[\sqrt{1 + 8F_1^2} - 1 \right] = 1$$

$$\frac{1}{4} \left[\sqrt{1 + 8F_2^2} - 1 \right] \left[\sqrt{1 + 8(6)} - 1 \right] = 1$$

$$\Rightarrow \left[\sqrt{1 + 8F_2^2} - 1 \right] = \frac{2}{3}$$

$$\Rightarrow F_2 = 0.471$$

$\therefore$ Froude number after the jump = 0.471

Alternatively

$$F_2^2 = \frac{8F_1^2}{\left(\sqrt{1 + 8F_1^2} - 1 \right)^3} = \frac{8 \times 6}{\left(\sqrt{1 + 8 \times 6} - 1 \right)^3} = 0.471$$

22.

Sol. Energy Loss in Hydraulic Jump

$$h_L = E_1 - E_2$$

$$= y_1 + \frac{v_1^2}{2g} - y_2 - \frac{v_2^2}{2g}$$

$$= y_1 + \frac{q^2}{y_1^2 \cdot B^2 \cdot 2g} - y_2 - \frac{q^2}{y_2^2 B^2 \cdot 2g}$$

$$= y_1 + \frac{q^2}{y_1^2 \cdot 2g} - y_2 - \frac{q^2}{y_2^2 \cdot 2g}$$

$$E_L = (y_1 - y_2) + \frac{q^2}{2g} \left[\frac{1}{y_1^2} - \frac{1}{y_2^2} \right] \quad \dots(i)$$

$$\frac{q^2}{g} = \frac{y_1 y_2 (y_1 + y_2)}{2} \quad \dots(ii)$$

By using equation (i) & (ii) we calculate energy loss in Hydraulic Jump

$$E_L = \frac{(y_2 - y_1)^3}{4y_1 y_2}$$

23.

Sol.

$$Q_{\text{actual}} = \frac{8}{15} C_d \sqrt{2g} \tan\left(\frac{\theta}{2}\right) H^{5/2}$$

$$15 = \frac{8}{15} \times 0.62 \times \sqrt{2 \times 9.581} \times \tan 30^\circ H^{5/2}$$

$\Rightarrow$

$$H = 0.5 \text{ m}$$

$$\Delta H = .001 \text{ m}$$

$\Rightarrow$

$$\frac{DQ}{Q} = \frac{5}{2} \times \frac{\Delta H}{H}$$

$\Rightarrow$

$$\Delta Q = \frac{5}{2} \times \frac{\Delta H}{H} \times Q$$

$\Rightarrow$

$$\Delta Q = \frac{5}{2} \times \frac{0.001}{0.5} \times 150$$

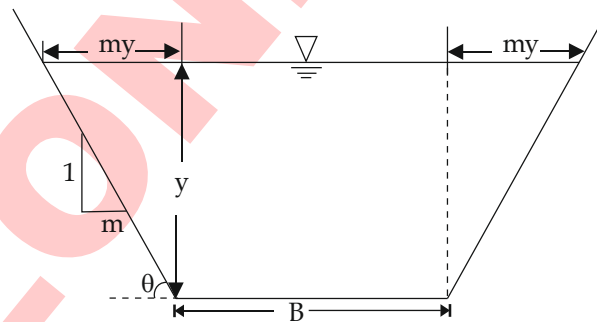
$\Rightarrow$

$$\Delta Q = 0.75 \text{ litre/sec}$$

20 Marks Questions

24.

Sol: Let us consider a trapezoidal channel section of bottom width 'B' and depth of flow = y, having side slope of 1 V: mH as shown in the figure below.



We know that a section is said to be most efficient, if for a given cross-sectional area, its discharge carrying capacity is maximum. And for discharge to be maximum for a given area, perimeter should be minimum (because if perimeter is minimum, resistance offered by the perimeter will be minimum). In short, for most economical and most efficient channel, section perimeter should be minimum. In this case, there are three variables, B, y and m. So, to start with we will assume the side slopes to be fixed. So, the number of variables left out are two, y and B.

Area, $A = \frac{1}{2} [B + B + 2my] \times y$

$$A = (B + my)y$$



$$\Rightarrow B = \frac{A}{y} - my \quad \dots(i)$$

Top width, $T = B + 2my$

Perimeter, $P = B + 2y\sqrt{1+m^2}$

Substituting value of B from (i) in above equation

$$\Rightarrow P = \frac{A}{y} - my + 2y\sqrt{1+m^2}$$

We know that, for efficient channel section of a given area A, perimeter should be minimum.

For perimeter to be minimum, $\frac{dP}{dy} = 0$

$$\frac{dP}{dy} = -\frac{A}{y^2} - m + 2\sqrt{1+m^2} = 0$$

$$\Rightarrow \frac{A}{y^2} + m = 2\sqrt{1+m^2}$$

$$\Rightarrow \frac{A}{y} + my = 2y\sqrt{1+m^2} \quad \dots(ii)$$

Substituting $\frac{A}{y} = B + my$ [from (i)]

$$\Rightarrow B + 2my = 2y\sqrt{1+m^2}$$

$$\Rightarrow T = 2y\sqrt{1+m^2}$$

$$\Rightarrow \frac{T}{2} = y\sqrt{1+m^2} \text{ First condition}$$

Hydraulic radius, $R = \frac{A}{P}$

$$R = \frac{(B + my)y}{B + 2y\sqrt{1+m^2}}$$

$$= \frac{(B + my)y}{B + T} \quad [T = 2y\sqrt{1+m^2} \text{ (derived above)}]$$

$$= \frac{(B + my)y}{B + B + 2my}$$

$$R = \frac{y}{2} \text{ Second condition} \quad \dots(iv)$$

Now, when the side slope is varied,

$$A = (B + my)y$$

$$P = B + 2y\sqrt{1+m^2}$$

$$\Rightarrow P = \frac{A}{y} - my + 2y\sqrt{1+m^2}$$

Substituting value of $\frac{A}{y}$ from equation (ii)

$$\Rightarrow P = 2y\sqrt{1+m^2} - my - my + 2y\sqrt{1+m^2}$$

$$\Rightarrow P = 4y\sqrt{1+m^2} - 2my$$

For, $P \rightarrow \text{minimum } \frac{dP}{dm} = 0$

$$\Rightarrow \frac{dP}{dm} = \frac{4y(2m)}{2\sqrt{1+m^2}} - 2y = 0$$

$$\frac{4m}{\sqrt{1+m^2}} = 2$$

$$\Rightarrow 1+m^2 = 4m^2 \Rightarrow 3m^2 = 1$$

$$\Rightarrow m = \frac{1}{\sqrt{3}}$$

$$\Rightarrow \tan \theta = \frac{1}{m} = \sqrt{3}$$

$$\Rightarrow \theta = 60^\circ \text{ Third condition}$$

$\therefore$ For most efficient trapezoidal section with varying side slope, the value of side slope should be $1 : \sqrt{3}$ (1 : m).

Conclusion:-

For most efficient trapezoidal section, following condition should be satisfied:

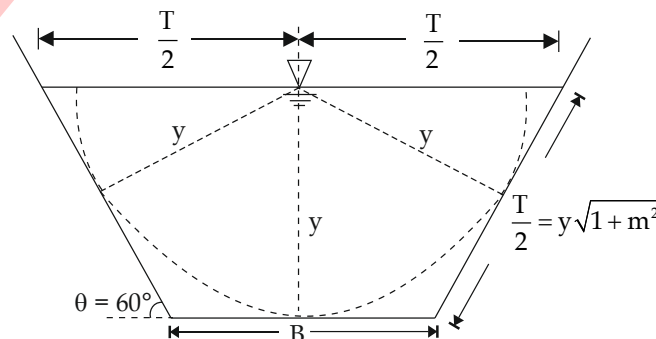
(i) $\frac{T}{2} = \text{Length of side slope}$

(ii) $R = \frac{y}{2}$

(iii) $\theta = 60^\circ$

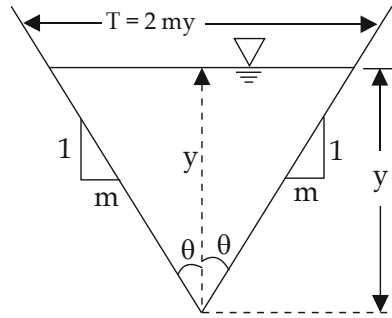
(iv) A circle of radius y (normal flow depth) should be inscribed in trapezoidal section.

Above conditions implies that most efficient trapezoidal section should be half of regular hexagon.



25.

Sol. Let us consider a triangular section having depth of flow 'y' and varying side slope of 1V: mH.



Top width, $(T) = 2my$

Area, $(A) = \frac{1}{2} \times 2my \times y = my^2$

Perimeter, $(P) = 2\sqrt{y^2 + m^2y^2} = 2y\sqrt{1 + m^2}$

We know that for most efficient section, perimeter should be minimum.

$$\frac{dP}{dm} = 0$$

$$P = 2\sqrt{\frac{A}{m}}\sqrt{1 + m^2}$$

$$\frac{d\left[2\sqrt{\frac{A}{m}}(\sqrt{1 + m^2})\right]}{dm} = 0$$

$$\Rightarrow \frac{d\left(\sqrt{\frac{1 + m^2}{m}}\right)}{dm} = 0$$

$$\Rightarrow \frac{1}{2\sqrt{\frac{1 + m^2}{m}}} \left[1 - \frac{1}{m^2}\right] = 0$$

$$\Rightarrow 1 - \frac{1}{m^2} = 0$$

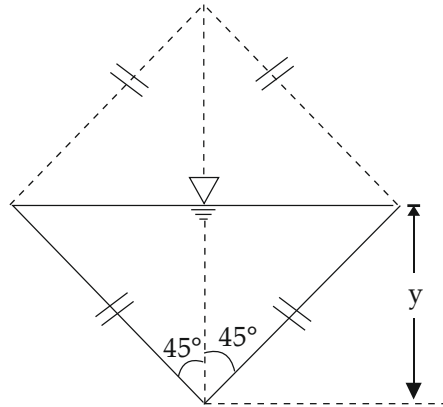
$$\Rightarrow \left(1 - \frac{1}{m}\right)\left(1 + \frac{1}{m}\right) = 0$$

$$\Rightarrow 1 - \frac{1}{m} = 0 \left(1 + \frac{1}{m} = 0; \text{not possible}\right)$$

$$\Rightarrow m = 1$$

$$\Rightarrow \tan \theta = \frac{1}{m} = 1 \Rightarrow \theta = 45^\circ$$

$$\Rightarrow R = \frac{A}{P} = \frac{my^2}{2y\sqrt{1+m^2}} = \frac{y}{2\sqrt{2}}$$



From the figure, it can be seen that the most efficient triangular c/s channel is half of square with its diagonal horizontal.

26.

Sol.

Given,

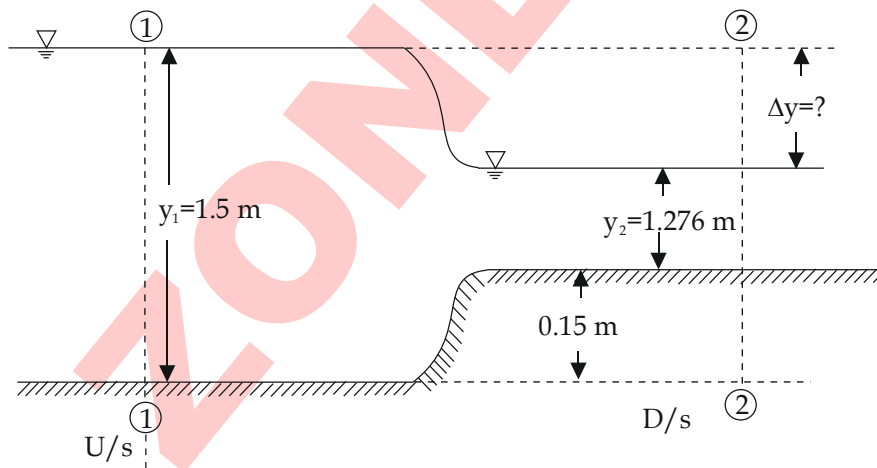
Width (B) = 2.4 m

Depth (y) = 1.5 m

Discharge (Q) = 7 m³/sec

Rise in bed level = 15 cm = 0.15 m

(i) The given condition can be shown as in the figure below:



At u/s section:

$$q = \frac{Q}{B} = \frac{7}{2.4} = 2.92 \text{ m}^3/\text{sec}/\text{metre}.$$

Critical depth, $y_c = \left(\frac{q^2}{g} \right)^{1/3} = 0.954 \text{ m} < 1.5 \text{ m}$

∴ Flow is sub-critical



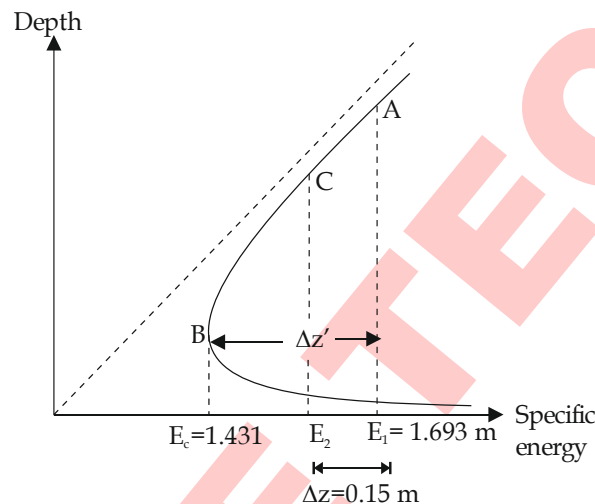
Specific energy, $E_c = \frac{3}{2} y_c = \frac{3}{2} \times 0.954 = 1.431$

$$E_1 = y_1 + \frac{V_1^2}{2g}$$

$$\Rightarrow E_1 = y_1 + \frac{q^2}{2gy_1^2} = 1.5 + \frac{(2.92)^2}{2 \times 9.81 \times (1.5)^2} = 1.693 \text{ m}$$

After rising the bed level, specific energy at the d/s section will decrease. If specific energy at d/s section (i.e. E_2) is greater than E_c then choking will not occur and u/s flow conditions will not change.

$$E_2 = E_1 - \Delta z$$



$$E_2 = (1.693 - 0.15) \text{ m} = 1.543 \text{ m}$$

$$E_2 > E_c$$

$\therefore$ Choking condition will not occur and u/s flow condition will not change.

Point A $\rightarrow$ Corresponds to sub-critical condition in u/s section.

Point B $\rightarrow$ Corresponds to critical specific energy for the rectangular section.

Point C $\rightarrow$ Corresponds to sub-critical condition in d/s section.

Calculation of depth of flow in d/s section:-

$$E_2 = y_2 + \frac{q^2}{2gy_2^2}$$

$$\Rightarrow 1.543 = y_2 + \frac{(2.92)^2}{2 \times 9.81 y_2^2}$$

$$\Rightarrow y_2^3 - 1.543 y_2^2 + 0.435 = 0$$

On solving, $y_2 = 1.276 \text{ m}$ (corresponds to sub-critical flow)

$y_2 = -0.465 \text{ m}$ (not possible)

$y_3 = 0.733 \text{ m}$ (corresponds to super-critical flow)

$\therefore y_2 = 1.276 \text{ m}$

$\therefore$ Change in water surface elevation

$$= (1.5 - 0.15 - 1.276) \text{ m} = 0.074 \text{ m}$$

(ii) Maximum rise in bed level = ?

The maximum rise ($\Delta z'$) so that u/s flow depth remains unchanged will correspond to the condition

when energy at d/s section (i.e., E_2) becomes equal to the critical specific energy (i.e., E_c).

$$E_2 = E_c = E_1 - \Delta z'$$

$$\Rightarrow 1.431 = 1.693 - \Delta z'$$

$$\Rightarrow \Delta z' = 0.262 \text{ m}$$

$\therefore$ Maximum permissible rise = 0.262 m

27.

Sol.

Given,

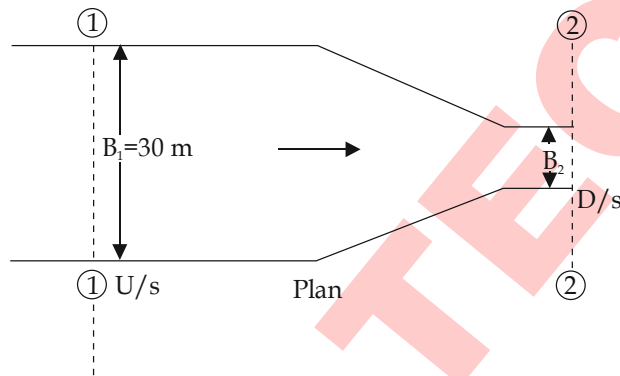
Width of rectangular channel (B_1) = 30 m

Discharge (Q) = 200 m³/sec

Depth of flow (y_1) = 4 m

Froude number at the contracted section (F_2) = 0.5

We have to calculate the depth of flow and the clear water way (i.e. the width) at the contracted section.



Velocity at u/s section,

$$V_1 = \frac{Q}{B_1 y_1} = \frac{200}{30 \times 4} = 1.67 \text{ ms}^{-1}$$

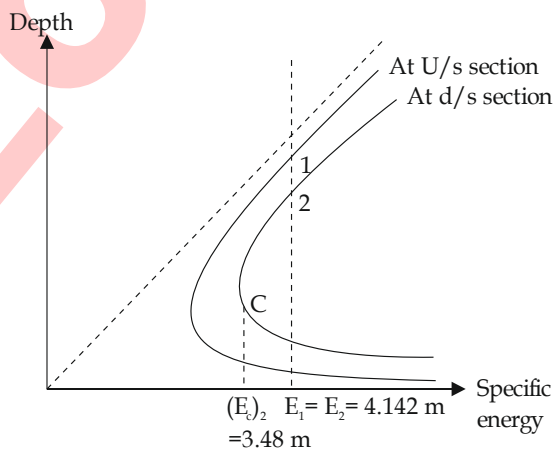
Froude number at u/s section,

$$F_1 = \frac{V_1}{\sqrt{g y_1}} = \frac{1.67}{\sqrt{9.81 \times 4}} = 0.267$$

$\therefore$

So, the flow is sub-critical

$$F_1 = 0.267 < 1$$



Specific energy, at u/s section,

$$E_1 = y_1 + \frac{V_1^2}{2g} = 4 + \frac{(1.67)^2}{2 \times 9.81}$$

$$= 4.142 \text{ m}$$

Since no loss is assumed, specific energy at the u/s and d/s section will be same.

$$\Rightarrow E_1 = E_2$$

$$\Rightarrow 4.142 = y_2 + \frac{V_2^2}{2g} \quad \dots(i)$$

Also, froude number at d/s section,

$$F_2 = 0.5$$

$$\frac{V_2}{\sqrt{gy_2}} = 0.5$$

$$\Rightarrow V_2^2 = (0.5)^2(gy_2)$$

$$\Rightarrow V_2^2 = 0.25(gy_2)$$

$$\Rightarrow \frac{V_2^2}{2g} = 0.125y_2$$

Substituting value of V_2^2 in equation (i), we have

$$\Rightarrow 4.142 = y_2 + 0.125 y_2$$

$$\Rightarrow y_2 = \frac{4.142}{1.125} = 3.682 \text{ m}$$

Velocity of d/s section,

$$V_2 = 0.5 \sqrt{gy_2}$$

$$= 0.5 \sqrt{9.81 \times 3.682}$$

$$V_2 = 3 \text{ ms}^{-1}$$

Width at d/s section,

$$B_2 = \frac{Q}{V_2 y_2} = \frac{200}{3 \times 3.682} = 18.11 \text{ m}$$

However flow at d/s section with the above specifications will be possible only if specific energy at d/s section is more than the critical specific energy for d/s section (E_{c2})

Calculation of (E_c)₂:

$$q_2 = \frac{Q}{B_2} = \frac{200}{18.11} = 11.044 \text{ m}^3/\text{sec}/\text{metre}$$

$$(y_c)_2 = \left(\frac{q_2^2}{g} \right)^{\frac{1}{3}} = \left(\frac{(11.044)^2}{9.81} \right)^{\frac{1}{3}}$$

$$= 2.32 \text{ m}$$

$$(E_c)_2 = \frac{3}{2} (y_c)_2 = \frac{3}{2} \times 2.32 = 3.48 < 4.142 \text{ m}$$

$\therefore (E_c)_2 < E_2$, so choking condition will occur and the flow will take place as computed above.

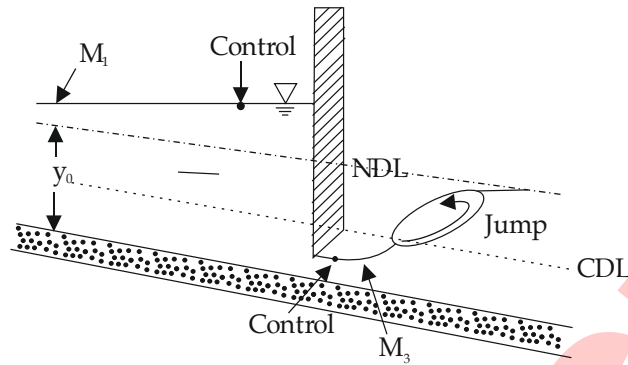
$\therefore$ Clear water-way, $B_2 = 18.11 \text{ m}$

Depth of flow, $y_2 = 3.682 \text{ m}$

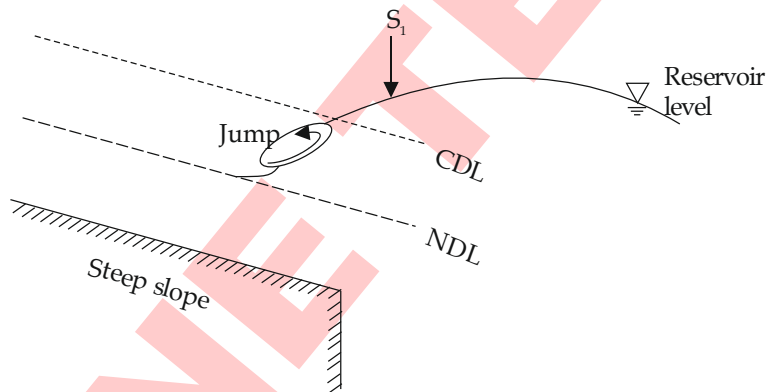


28.

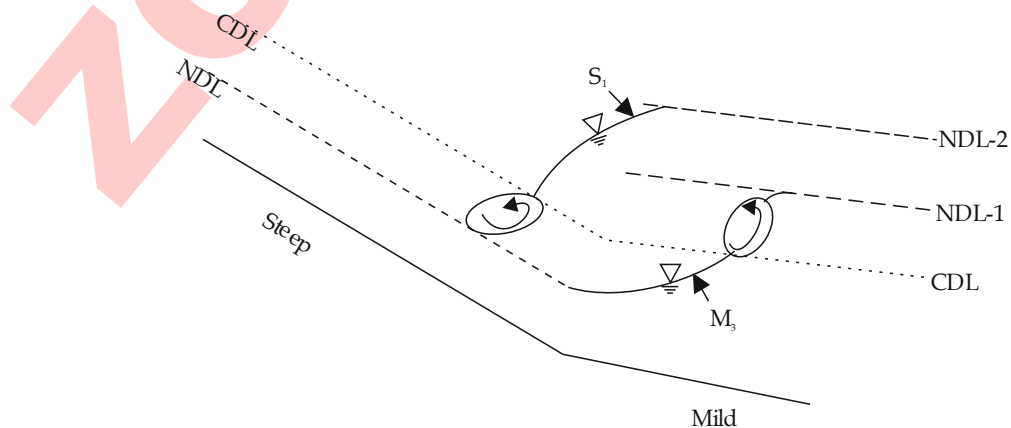
Sol. (i) Upstream and down stream of sluice gate on a mild sloped channel when critical depth line is above the gate opening.



(ii) A steep sloped channel ending in an abrupt drop having reservoir level on the d/s side above critical depth line.



(iii) Steep sloped channel followed by a mild sloped channel.

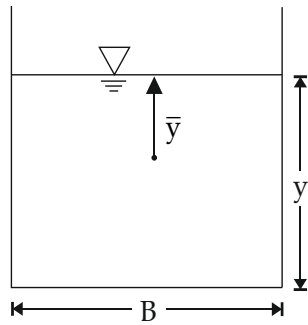


Either (jump + S_1) or (M_3 + jump) will form depending upon sequent depth requirement.

$$A\bar{y} + \frac{Q^2}{Ag} \rightarrow \text{constant}$$

Hydraulic jump in a horizontal, rectangular and frictionless channel:

Let us consider a horizontal, frictionless and rectangular channel of width = B and depth of flow = y



we know that,

$$A\bar{y} + \frac{Q^2}{gA} = \text{constant}$$

$$By\left(\frac{y}{2}\right) + \frac{q^2 B^2}{g(By)} = \text{constant} \quad \left[q = \frac{Q}{B} \right]$$

$$\Rightarrow \frac{y^2}{2} + \frac{q^2}{gy} = \text{constant}$$

If y_1 and y_2 are depth of flow at ends of hydraulic jump, then

$$\frac{y_1^2}{2} + \frac{q^2}{gy_1} = \frac{y_2^2}{2} + \frac{q^2}{gy_2}$$

$$\frac{q^2}{g} \left[\frac{1}{y_1} - \frac{1}{y_2} \right] = \frac{y_2^2 - y_1^2}{2}$$

$$\frac{2q^2}{g} = y_1 y_2 (y_1 + y_2) \quad \dots(1)$$

We know that, Froude Number for rectangular channel

$$F = \frac{V}{\sqrt{gy}} = \frac{q}{y\sqrt{gy}}$$

$$\Rightarrow F^2 = \frac{q^2}{gy^3}$$

$$\Rightarrow \frac{q^2}{g} = F_1^2 y_1^3 = F_2^2 y_2^3$$

Substituting value of $\left(\frac{q^2}{g}\right)$ in equation (1)

$$2F_1^2 y_1^3 = y_1 y_2 (y_1 + y_2)$$

$$2F_1^2 = \frac{y_2}{y_1^2} (y_1 + y_2)$$

$$= \left(\frac{y_2}{y_1} \right) + \left(\frac{y_2}{y_1} \right)^2$$

$$\Rightarrow \left(\frac{y_2}{y_1} \right)^2 + \left(\frac{y_2}{y_1} \right) - 2F_1^2 = 0$$

On solving above equation,

$$\frac{y_2}{y_1} = \frac{-1 \pm \sqrt{1 + 8F_1^2}}{2}$$

$$\Rightarrow \frac{y_2}{y_1} = \frac{1}{2} [\sqrt{1 + 8F_1^2} - 1]$$

Similarly,

$$\frac{y_1}{y_2} = \frac{1}{2} [\sqrt{1 + 8F_2^2} - 1]$$

From above derived relations, it is clear that y_1 and y_2 are functions of Froude's number only.

30.

Sol.

Given,

Hydraulic jump in a horizontal channel.

Froude number before jump, $(F_1) = 10.0$

Energy loss $(F_L) = 3.2 \text{ m}$

We know that,

$$\frac{y_2}{y_1} = \frac{1}{2} [\sqrt{1 + 8F_1^2} - 1] \quad [\text{Assuming rectangular channel}]$$

$$\text{or} \quad \frac{y_2}{y_1} = \frac{1}{2} \times [\sqrt{1 + 8 \times 10^2} - 1]$$

$$\text{or} \quad \frac{y_2}{y_1} = 13.65$$

$$\text{or} \quad y_2 = 13.65 y_1$$

$$\text{or} \quad E_L = \frac{(y_2 - y_1)^3}{4y_1 y_2}$$

$$\text{or} \quad 3.2 = \frac{(13.65y_1 - y_1)^3}{4 \times 13.65y_1 \times y_1}$$

$$\text{or} \quad 3.2 \times 4 \times 13.65 = \frac{12.65^3 \times y_1^3}{y_1^2}$$

$$\therefore y_1 = \frac{3.2 \times 4 \times 13.65}{12.65^3} = 0.086 \text{ m}$$

$$\text{So,} \quad y_2 = 13.65 \times 0.086 = 1.17 \text{ m}$$

Hence, final sequent depths are 0.086 m, 1.17 m.

Now using $y_1 y_2 (y_1 + y_2) = \frac{2q^2}{g}$

or $0.086 \times 1.17 (0.086 + 1.17) = \frac{2 \times q^2}{9.81}$

$$q = 0.787 \text{ m}^3/\text{sec.m}$$

Calculation of Froude's number after jump (F_2)

$$F_2^2 = \frac{8F_1^2}{(\sqrt{1+8F_1^2} - 1)^3}$$

or $F_2^2 = \frac{8 \times 10^2}{(\sqrt{1+8 \times 10^2} - 1)^3}$

$$F_2 = 0.198$$

31.

Sol.

Given:

Width of stream = 25 m

Depth of flow = 2.5 m

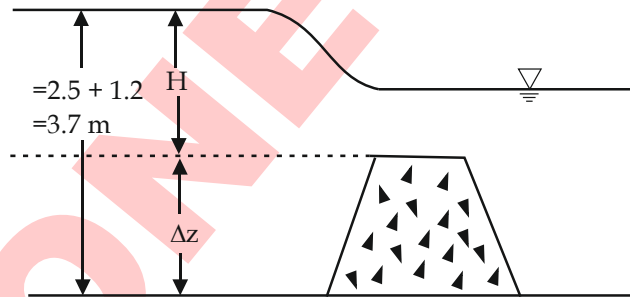
Mean velocity = 1.10 ms⁻¹

Coefficient of discharge (C_d) = 0.90

We have to find the height of a weir to be built on the stream floor which will raise the water level by 1.2 m on u/s side of the weir.

∴ Depth of flow u/s of weir = (2.5 + 1.2)m = 3.7 m

In the question, the type of weir to be built on the stream floor is not mentioned. But we know that $C_d = 0.90$, corresponds to broad-crested weir, so we will assume it to be a broad-crested weir.]



$$\begin{aligned} \text{Discharge in the stream (Q)} &= A \times V \\ &= (25 \times 25 \times 1.1) \\ &= 68.75 \text{ m}^3/\text{sec} \end{aligned}$$

$$\text{Approach velocity (V}_a\text{)} = \frac{Q}{A} = \frac{68.75}{3.7 \times 25} = 0.743 \text{ ms}^{-1}$$

$$\text{Approach velocity head (h}_a\text{)} = \frac{V_a^2}{2g} = \frac{(0.743)^2}{2 \times 9.81} = 0.0281 \text{ m}$$

We know that discharge for a broad crested weir is given by

$$\begin{aligned} Q &= 1.7 C_d (H + h_a)^{3/2} L \\ 68.75 &= 1.7 \times 0.9 (3.7 - \Delta Z + 0.0281)^{3/2} \times 25 \\ 3.7281 - \Delta Z &= 1.4783 \end{aligned}$$

⇒

$$\Delta Z = 2.25 \text{ m}$$

∴ Height of weir above stream floor = 2.25 m

