CLASS TEST

Sl. : 03_SKCE_JKL_06092025

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OPEN CHANNEL FLOW

CIVIL ENGINEERING

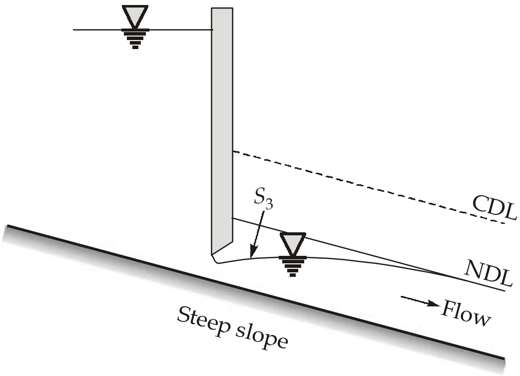
Date of Test : 06/09/2025

ANSWER KEY

1.	(d)	6.	(b)	11.	(a)	16.	(d)	21.	(a)
2.	(d)	7.	(c)	12.	(d)	17.	(b)	22.	(c)
3.	(c)	8.	(b)	13.	(a)	18.	(a)	23.	(c)
4.	(b)	9.	(b)	14.	(b)	19.	(a)	24.	(c)
5.	(b)	10.	(a)	15.	(c)	20.	(b)	25.	(d)

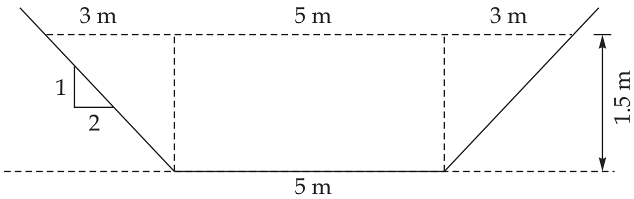
DETAILED EXPLANATIONS

1. **(d)**



2. **(d)**

3. **(c)**



Froude Number, $\text{Fr} = \dfrac{V}{\sqrt{gD}}$

$m = 2, \quad b = 5 \text{ m}, \quad y = 1.5 \text{ m}$

Cross-sectional area of the flow, $A = (b + my)\,y$

$\Rightarrow$ $A = (5 + 2 \times 1.5) \times 1.5$

$= 12 \text{ m}^2$

Top width of flow, $T = 5 + 3 + 3 = 11 \text{ m}$

Hydraulic depth, $D = \dfrac{A}{T} = \dfrac{12}{11} = 1.09 \text{ m}$

$Q = VA$

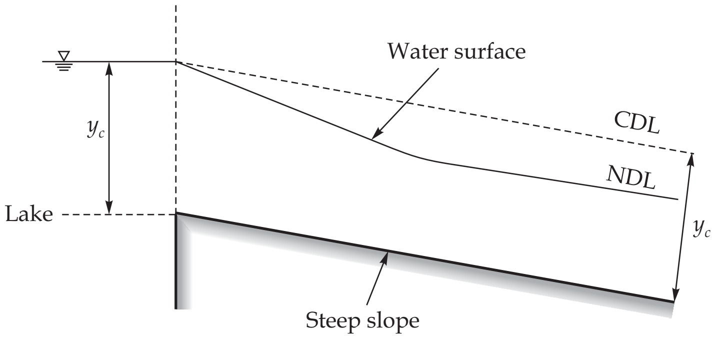
$\Rightarrow$ $V = \dfrac{15}{12} = 1.25 \text{ m/s}$

$\therefore$ $\text{Fr} = \dfrac{1.25}{\sqrt{9.81 \times 1.09}} = 0.382 < 1$

$\therefore$ The flow is subcritical or tranquil flow.

4. **(b)**

At the entrance to the steep channel, a control section exists i.e., the flow into the channel takes place at the critical depth, y_c. The water surface then joins the normal depth line as shown in figure.



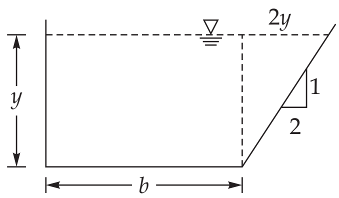
Critical depth, $y_c = \left(\dfrac{q^2}{g}\right)^{1/3}$

Given data: $Q = 35\ m^3/s,\ b = 4\ m,\ g = 9.81\ m/s^2$

$\therefore$ $q = \dfrac{Q}{B} = \dfrac{35}{4} = 8.75\ m^3/s/m$

$\therefore$ $y_c = \left[\dfrac{(8.75)^2}{9.81}\right]^{1/3} = 1.9836\ m \simeq 1.98\ m$

5. **(b)**



Given data:
$Q = 20\ m^3/s$
$V = 2\ m/s$
$n = 0.015$

Manning's formula, $V = \dfrac{1}{n}R^{2/3}S_0$

$\Rightarrow$ $S_0^{1/2} = \dfrac{nV}{R^{2/3}}$

$R = \dfrac{A}{P}$

For minimum bed slope (S_0), since V is constant at 2 m/s, it is the hydraulic radius R which has to be maximum. As the area of flow (A) is fixed at 10 m^2, the condition of minimum bed slope boils down to minimum wetted perimeter

$$S_0 \propto \frac{1}{R} \propto \frac{P}{A}$$

Cross-sectional area, $A = \dfrac{Q}{V} = \dfrac{20}{2} = 10\ m^2$

$$A = b \times y + \frac{1}{2} \times y \times 2y = by + y^2 \quad \ldots(i)$$

Perimeter, $P = b + y + \sqrt{y^2 + (2y)^2} = b + y + \sqrt{5}\,y$ ...(ii)

Using eq. (i), $b = \dfrac{A - y^2}{y} = \dfrac{A}{y} - y$

Substituting b in eq. (ii) $P = \dfrac{A}{y} - y + y + \sqrt{5}\,y$

$\Rightarrow$ $P = \dfrac{A}{y} + \sqrt{5}\,y$

For P to be minimum, $\dfrac{dP}{dy} = 0$

$\Rightarrow$ $\dfrac{A}{y^2} = \sqrt{5}$

$\Rightarrow$ $y = \sqrt{\dfrac{A}{\sqrt{5}}} = \sqrt{\dfrac{10}{\sqrt{5}}}$

$\Rightarrow$ $y = 2.115$ m

$\therefore$ $b = \dfrac{A}{y} - y = \dfrac{10}{2.115} - 2.115$

$\Rightarrow$ $b = 2.613 \text{ m} \simeq 2.61 \text{ m}$

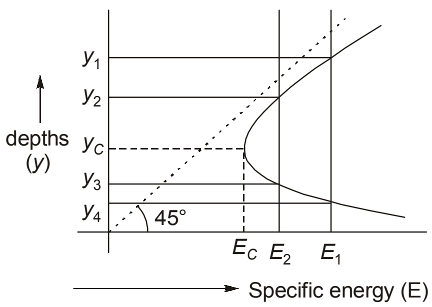
6. (b)

7. (c)

Energy loss, $E_L = \dfrac{(y_2 - y_1)^3}{4y_1y_2}$

$= \dfrac{(1.8 - 0.6)^3}{4 \times 0.6 \times 1.8} = 0.4 \text{ m}$

8. (b)



$E_2 < E_1$

$y_4 < y_3$

where y_1, y_2 are subcritical depths

and y_3, y_4 are supercritical depths.

Thus for supercritical flow, if specific energy decreases than corresponding depth increases.

9. (b)

Length of GVF profile is more than the length of hydraulic jump.

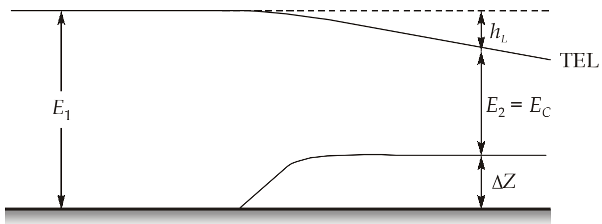
10. (a)

11. **(a)**

Types of Jump		**Pre-Jump Froude Number (Fr_1)**
A. Undular jump	**1.**	1 to 1.7
B. Weak jump	**2.**	1.7 to 2.5
C. Oscillating jump	**3.**	2.5 to 4.5
D. Steady jump	**4.**	4.5 to 9
E. Strong jump	**5.**	Greater than 9

12. **(d)**

$$Q = 12\ m^3/s$$
$$B = 5\ m$$
$$y_1 = 1.5\ m$$
$$h_L = \text{Upstream velocity head} = \frac{V_1^2}{2g}$$

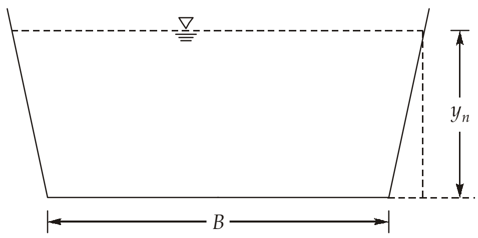


$$E_1 = \Delta Z + E_C + h_L$$
$$\Rightarrow \quad \Delta Z = E_1 - E_C - h_L$$
$$= y_1 + \frac{V_1^2}{2g} - \frac{3}{2}y_c - \frac{V_1^2}{2g} = y_1 - \frac{3}{2}y_c$$
$$y_c = \left(\frac{q^2}{g}\right)^{1/3} = \left[\left(\frac{12}{5}\right)^2 \times \frac{1}{9.81}\right]^{1/3}$$
$$\Rightarrow \quad y_c = 0.8374\ m$$
$$\therefore \quad \Delta Z = 1.5 - \frac{3}{2} \times 0.8374 = 0.244\ m$$
$$\therefore \quad \Delta Z = 0.244\ m = 24.4\ cm$$

13. **(a)**

Given,
$$Q = 20\ m^3/s$$
$$S_0 = 0.004\ m/m$$
$$n = 0.030$$

It is half hexagonal channel, so it is most the efficient trapezoidal channel.



For the most efficient trapezoidal channel

$$A = \sqrt{3}y_n^2$$

and $$R = \text{Hydraulic radius} = \frac{y_n}{2}$$

$\therefore$ $$Q = AV = A\frac{1}{n}R^{2/3}S_0^{1/2}$$

$\Rightarrow$ $$20 = \sqrt{3}y_n^2 \times \frac{1}{0.030} \times \left(\frac{y_n}{2}\right)^{2/3} \times \sqrt{0.004}$$

$\Rightarrow$ $$y_n = 2.25 \text{ m}$$

14. (b)

$$y_1 = \text{upstream flow depth} = 2 \text{ m}$$
$$y_2 = \text{downstream flow depth} = 1 \text{ m}$$

Head loss or energy loss = 10% of kinetic head at downstream = $0.1\frac{V_2^2}{2g}$

Applying energy equation between upstream (1) and downstream (2) of sluice gate

$$E_1 = E_2 + E_L$$

$\Rightarrow$ $$y_1 + \frac{V_1^2}{2g} = y_2 + \frac{V_2^2}{2g} + 0.1\frac{V_2^2}{2g}$$

$\Rightarrow$ $$2 + \frac{Q^2}{B^2y_1^2 2g} = y_2 + 1.1\frac{V_2^2}{2g} = y_2 + 1.1\frac{Q^2}{B^2y_2^2 2g}$$

$\Rightarrow$ $$2 + \frac{Q^2}{4^2 \times 2^2 \times 2 \times 10} = 1 + \frac{1.1 \times Q^2}{4^2 \times 1^2 \times 2 \times 10}$$

$\Rightarrow$ $$1 = \frac{1}{4^2 \times 2 \times 10}Q^2\left(1.1 - \frac{1}{4}\right)$$

$\Rightarrow$ $$Q^2 = 376.47$$

$\Rightarrow$ $$Q = 19.40 \text{ m}^3/\text{s}$$

Now $$F_{r2}^2 = \frac{Q^2T}{gA_2^3} = \frac{376.47 \times 4}{10 \times (4 \times 1)^3}$$

$\therefore$ $$F_{r2} = 1.5$$

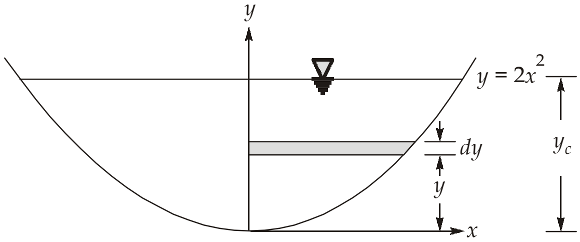
15. (c)

Given: $Q = 4 \text{ m}^3/\text{s}$

For flow to be critical,
we know that

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

$\Rightarrow$ $$Q^2T = A^3g \quad \text{...(i)}$$

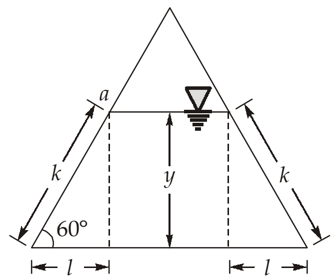


At
$$y = y_c$$
$$y_c = 2x_c^2$$
$$x_c = \sqrt{\frac{y_c}{2}}$$
$$\text{Top width (T)} = 2x_c = 2\sqrt{\frac{y_c}{2}}$$
$$dA = xdy$$
$$dA = \sqrt{\frac{y}{2}}\,dy$$
$$A = 2\int dA = 2\int_0^{y_c} \sqrt{\frac{y}{2}}\,dy$$
$$= \sqrt{2}\cdot\left[\frac{y^{3/2}}{3/2}\right]_0^{y_c} = \sqrt{2} \times \frac{2}{3}(y_c)^{3/2}$$

Now, using (i)
$$(4)^2 \times 2\sqrt{\frac{y_c}{2}} = g \times \left[\sqrt{2} \times \frac{2}{3}(y_c)^{3/2}\right]^3$$
$$(4)^2 \times 2\sqrt{\frac{y_c}{2}} = 9.81 \times \left[\sqrt{2} \times \frac{2}{3}(y_c)^{3/2}\right]^3$$
$$y_c = 1.288 \text{ m}$$

16. (d)

$$R = \frac{\text{Wetted area}}{\text{Wetted perimeter}} = \frac{A}{P}$$
$$A = \left(\frac{1}{2} \times \frac{y}{\sqrt{3}} \times y\right) \times 2 + \left(a - \frac{2y}{\sqrt{3}}\right)y$$
$$P = a + 2 \times \frac{2y}{\sqrt{3}}$$
$$\Rightarrow \quad A = \frac{y^2}{\sqrt{3}} + ay - \frac{2y^2}{\sqrt{3}} = ay - \frac{y^2}{\sqrt{3}}$$
$$\therefore \quad R = \frac{ay - \frac{y^2}{\sqrt{3}}}{a + \frac{4y}{\sqrt{3}}}$$



$$\tan 60° = \frac{y}{l} \Rightarrow l = \frac{y}{\sqrt{3}}$$
$$\sin 60° = \frac{y}{k} \Rightarrow k = \frac{2y}{\sqrt{3}}$$

For R to be maximum, $\frac{dR}{dy} = 0$

$$\frac{dR}{dy} = \frac{\left(a+\frac{4y}{\sqrt{3}}\right)\left(a-\frac{2y}{\sqrt{3}}\right)-\left(ay-\frac{y^2}{\sqrt{3}}\right)\left(\frac{4}{\sqrt{3}}\right)}{\left(a+\frac{4y}{\sqrt{3}}\right)^2} = 0$$

$\Rightarrow \quad 4y^2 + 2\sqrt{3}ya - 3a^2 = 0$

$\therefore \quad y = 0.535a \simeq 0.54a$

17. (b)

$$q_1 = \frac{Q}{B_1} = \frac{2.75}{2.5} = 1.1\ \text{m}^3/\text{s/m}$$

Upstream conditions: $V_1 = \frac{q_1}{y_1} = \frac{1.1}{0.9} = 1.222\ \text{m/s}$

$$F_1 = \frac{V_1}{\sqrt{gy_1}} = \frac{1.222}{\sqrt{10\times 0.9}} = 0.4073 < 1 \qquad (\because \text{Subcritical flow})$$

$$E_1 = y_1 + \frac{V_1^2}{2g} = 0.9 + \frac{(1.222)^2}{2\times 10} = 0.975\ \text{m}$$

At the maximum contraction, critical depth will occur at the contracted section. Thus, $y_2 = y_{c_2}$

Thus, $E_1 = E_2 = E_c = 0.975$ m

$$E_c = \frac{3}{2}y_c \Rightarrow y_{c_2} = \frac{2}{3}\times 0.975 = 0.65\ \text{m}$$

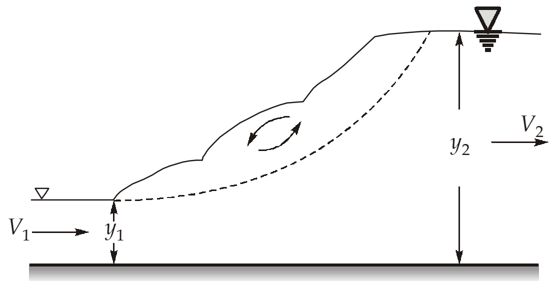
We know that, $y_{c_2} = \left(\frac{q^2}{g}\right)^{1/3}$

$\Rightarrow \quad q = \left[(0.65)^3 \times 10\right]^{1/2} = 1.657\ \text{m}^3/\text{s/m}$

$\Rightarrow \quad \frac{Q}{B} = 1.657$

$\Rightarrow \quad B = B_{min} = \frac{2.75}{1.657} = 1.66\ \text{m}$

18. (a)



Given data: Depth of flow = 0.6 m, E_i = 10 m

$$E = y + \frac{V^2}{2g}$$

$$\Rightarrow \quad 10 = 0.6 + \frac{V^2}{2 \times 9.81}$$

$$\Rightarrow \quad V = 13.58 \text{ m/s}$$

$$F_1 = \frac{V}{\sqrt{gy}} = \frac{13.58}{\sqrt{9.81 \times 0.6}} = 5.597 > 1 \text{ (Super critical flow)}$$

Using the relation, $$\frac{y_2}{y_1} = \frac{1}{2}\left(-1 + \sqrt{1 + 8F_1^2}\right)$$

$$\Rightarrow \quad \frac{y_2}{0.6} = \frac{1}{2}\left(-1 + \sqrt{1 + 8 \times (5.597)^2}\right)$$

$$\Rightarrow \quad y_2 = 4.459 \text{ m} \simeq 4.46 \text{ m}$$

19. (a)

20. (b)

$$y_c = \left(\frac{q^2}{g}\right)^{1/3} = 1.54 \text{ m}$$

As per manning's formula

$$Q = A\frac{1}{n}R^{2/3}\sqrt{s_0}$$

For wide rectangular channel $R = y$, $A = By$

$$q = \frac{1}{n}y^{5/3}\sqrt{s_0}$$

$$y_0^{5/3} = \frac{qn}{\sqrt{s_0}}$$

$$y_0 = \left[\frac{6 \times 0.013}{\sqrt{0.006}}\right]^{3/5} = 1 \text{ m}$$

$$y_0 = \text{normal depth}$$

Now as $y_0 < y_c$ (slope is steep) and local depth y = 1.2 which is $y_0 < y < y_c$ hence flow profile is S_2.

21. (a)

Given data,
$$Q = 50 \text{ m}^3/\text{s}$$
$$S = 0.004$$

We know that under free fall condition depth of flow at free fall location will be critical flow.

Hence,
$$\frac{Q^2 T}{A^3 g} = 1$$
$$\frac{(50)^2 \times 5}{(5y)^3 \times 9.81} = 1$$
$$\frac{50 \times 50 \times 5}{125 \times y^3 \times 9.81} = 1$$
$$\Rightarrow \quad y = 2.168 \text{ m} \simeq 2.17 \text{ m}$$

22. (c)

23. (c)

$$\frac{V}{\sqrt{gy}} = Fr_1$$
$$\Rightarrow \quad Fr_1 = \frac{V_1}{\sqrt{gy_1}} = \frac{12}{\sqrt{9.81 \times 1}} = 3.83$$
$$\because \quad y_1 = 1 \text{ m}$$
$$\frac{y_2}{y_1} = \frac{1}{2}\left[-1 + \sqrt{1 + 8Fr_1^{\,2}}\right]$$
$$y_2 = 4.94 \text{ m}$$

24. (c)

25. (d)

When a S_2 profile ends with a sudden drop of bed, the surface drops suddenly and it is called hydraulic drop. This can happen with any profile except A_2.
There can be no hydraulic jump in S_2 profile.

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