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OPEN CHANNEL FLOW

MECHANICAL ENGINEERING

Date of Test : 18/09/2026

ANSWER KEY

1. (b)	7. (a)	13. (d)	19. (a)	25. (a)
2. (b)	8. (a)	14. (b)	20. (a)	26. (d)
3. (a)	9. (a)	15. (c)	21. (d)	27. (b)
4. (a)	10. (c)	16. (d)	22. (d)	28. (a)
5. (a)	11. (b)	17. (c)	23. (c)	29. (a)
6. (d)	12. (b)	18. (b)	24. (d)	30. (b)

DETAILED EXPLANATIONS

1. (b)

3. At critical flow, $\dfrac{V}{\sqrt{gL}} = 1$

$$\Rightarrow \quad V^2 = gL$$

$$\Rightarrow \quad \frac{V^2}{2g} = \frac{L}{2}$$

$$\Rightarrow \quad \text{Velocity head} = \frac{\text{Hydraulic depth}}{2}$$

4. Discharge is maximum for a given specific energy.

2. (b)

For most efficient trapezoidal channel,

$$\text{Bed width} = \frac{2y}{\sqrt{3}}$$

$$\frac{2y}{\sqrt{3}} = 4\sqrt{3}$$

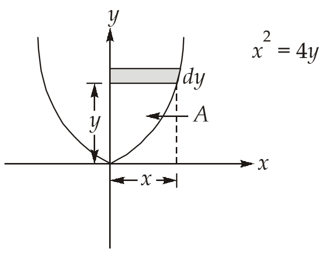
$$y = 6 \text{ m}$$

Also, for most efficient trapezoidal channel,

Hydraulic radius, $R = \dfrac{y}{2}$

$$R = \frac{6}{2} = 3 \text{ m}$$

3. (a)



$$\text{Top width of channel} = 2x = 2\times 2\sqrt{y} = 4\sqrt{y} = 4\sqrt{3} \text{ m}$$

4. (a)

$$\text{Hydraulic radius, } R = \frac{A}{P} = \frac{4\times 2}{4+2\times 2} = 1 \text{ m}$$

Now, $C = \dfrac{1}{n}R^{\frac{1}{6}}$

where 'n' is Manning's roughness coefficient

$$\Rightarrow \quad n = \frac{1}{C}R^{\frac{1}{6}} = \frac{1}{60}\times(1)^{\frac{1}{6}} = 0.0167$$

5. (a)

$$\text{Froude number,}\quad Fr = 0.74 = \frac{V}{\sqrt{gy}} = \frac{Q}{By\sqrt{gy}}$$

$$0.74 = \frac{20}{5\times\sqrt{9.81}\times y^{3/2}}$$

$$\Rightarrow \quad y^{3/2} = 1.726$$

$$\Rightarrow \quad y = (1.726)^{2/3}$$

$$= 1.44 \text{ m}$$

6. (d)

Given,
$$\frac{y_2}{y_1} = 8$$

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

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

$$\Rightarrow \quad 289 = 1+8F_1^2$$

$$\Rightarrow \quad F_1^2 = 36$$

$$\Rightarrow \quad F_1 = 6$$

7. (a)

$$y_c^{\,3} = \frac{2y_1^2y_2^2}{(y_1+y_2)}$$

$$= \frac{2\times 2.4^2\times 0.5^2}{2.4+0.5} = 0.993$$

$$\Rightarrow \quad y_c = 0.998 \text{ m}$$

9. (a)

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

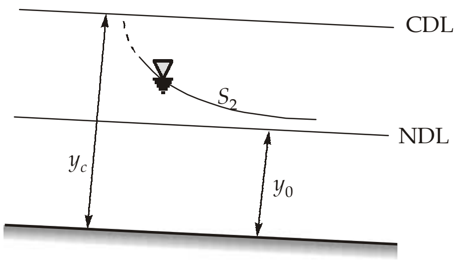
$$q = \sqrt{9.81\times y_c^3}$$

$$= \sqrt{9.81\times 1.1^3}$$

$$= 3.61 \text{ m}^3/\text{s}/\text{m}$$

Now,
$$\text{Bottom width} = \frac{Q}{q} = \frac{20}{3.61} = 5.53\,\text{m}$$

10. (c)



11. (b)

For wide rectangular channel,

$$R = y$$

Using Manning's formula $$Q = \frac{1}{n} A\, R^{2/3}\, S^{1/2}$$

Discharge, $$Q = \frac{1}{n} By\,(y)^{2/3}\, S^{1/2}$$

$$Q = \frac{1}{n} B.y^{5/3}.s^{1/2} \qquad \text{...(i)}$$

$$dQ = \frac{1}{n} B \cdot s^{1/2} \cdot \frac{5}{3} y^{2/3} \cdot dy \qquad \text{...(ii)}$$

$$\frac{dQ}{Q} = \frac{\frac{1}{n} B\, s^{1/3} \left(\frac{5}{3} y^{2/3}\right) \cdot dy}{\frac{1}{n} B\, s^{1/2} \cdot y^{5/3}}$$

$$\frac{dQ}{Q} = \frac{5}{3} \frac{dy}{y}$$

$$\frac{dQ}{Q} \times 100 = \frac{5}{3} \times 18$$

% increase in discharge = 30%

12. (b)

$$y_1 = 0.3 \text{ m}$$
$$y_2 = 1.2 \text{ m}$$
$$v_1 = 3 \text{ m/s}$$

Energy loss in hydraulic jump,

$$E_L = \frac{(y_2 - y_1)^3}{4 y_1 y_2} = \frac{(1.2 - 0.3)^3}{4 \times 0.3 \times 1.2} = \frac{0.9^3}{4 \times 0.3 \times 1.2} = 0.50 \text{ m}$$

$$E_1 = y_1 + \frac{v_1^2}{2g} = 0.3 + \frac{3^2}{2 \times 9.81} = 0.76 \text{ m}$$

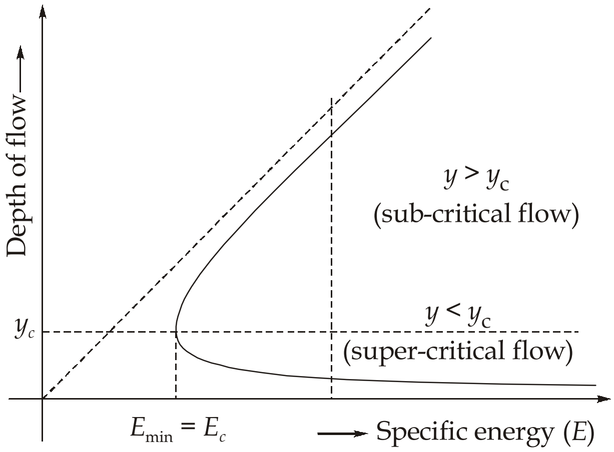
$$\text{Relative energy loss} = \frac{E_L}{E_1} \times 100 = \frac{0.50}{0.76} \times 100 = 66\%$$

13. (d)

- In subcritical flow, if the height of hump is increased then the flow depth over the hump will decrease then it will become constant equal to critical depth of flow.
- In super critical flow, if the height of hump is increased then the flow depth over the hump will increase then it will become constant equal to critical depth of flow.

14. (b)

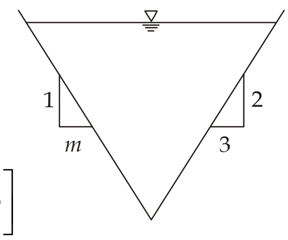
Specific energy curve:



For a given discharge, specific energy is minimum, flow will be critical i.e., Froude number is unity.

15. (c)

For a triangular channel,



$$\text{Critical depth, } y_c = \left(\frac{2Q^2}{gm^2}\right)^{1/5}$$

$$\Rightarrow \quad (0.3)^5 = \frac{2Q^2}{9.81 \times (1.5)^2} \qquad \left[\frac{1}{m} = \frac{2}{3} \Rightarrow m = \frac{3}{2} = 1.5\right]$$

$$\Rightarrow \quad Q = 0.164 \text{ m}^3/\text{s}$$

17. (c)

When trapezoidal channel is half of a regular hexagon, the channel becomes most efficient-channel. For such type of section,

$$\text{Wetted perimeter} = 2\sqrt{3}y$$

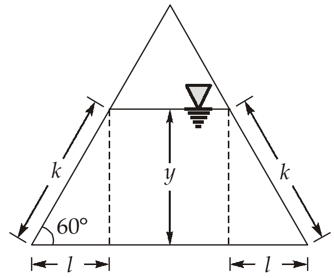
$$\text{Hydraulic radius} = \frac{y}{2}$$

$$\text{Now,} \quad \frac{\text{Wetted perimeter}}{\text{Hydraulic radius}} = \frac{2\sqrt{3}y}{y/2} = 4\sqrt{3}$$

$$\therefore \quad k\sqrt{3} = 4\sqrt{3}$$

$$\Rightarrow \quad k = 4$$

18. (b)



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

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

$$R = \frac{\text{Wetted area}}{\text{Wetted perimeter}} = \frac{A}{P}$$

$$A = \left(\frac{1}{2} \times \frac{y}{\sqrt{3}} \times y\right) \times 2 + \left(a - \frac{2y}{\sqrt{3}}\right) y$$

$$P = a + 2 \times k = a + \frac{2 \times 2y}{\sqrt{3}}$$

$$\Rightarrow \quad A = \frac{y^2}{\sqrt{3}} + ay - \frac{2y^2}{\sqrt{3}} = ay - \frac{y^2}{\sqrt{3}}$$

$$\therefore \quad R = \frac{ay - \dfrac{y^2}{\sqrt{3}}}{a + \dfrac{4y}{\sqrt{3}}}$$

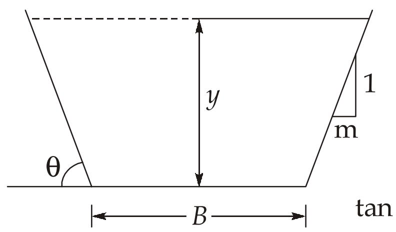
For R to be maximum, $\dfrac{dR}{dy} = 0$

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

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

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

19. (a)



$$\tan\theta = \frac{1}{m}$$

For most efficient trapezoidal section,

$$\theta = 60° \text{ i.e., } m = \frac{1}{\sqrt{3}}$$

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

But

$$B = \frac{2}{\sqrt{3}} y$$

$$\therefore \quad P = \frac{2}{\sqrt{3}} y + \frac{4y}{\sqrt{3}} = \frac{6y}{\sqrt{3}}$$

$$= \frac{6 \times 2.2}{\sqrt{3}} = 7.62 \text{ m}$$

20. (a)

Given, $Q = 20 \text{ m}^3/\text{s}$

$B = 2 \text{ m}$

For most efficient rectangular channel,

Normal depth, $y_n = B/2 = 2/2 = 1 \text{ m}$

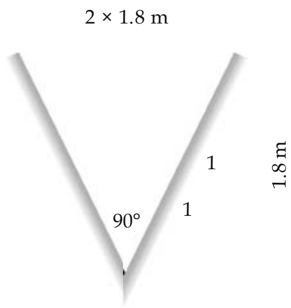
$$\text{Critical depth, } y_c = \left(\frac{q^2}{g}\right)^{1/3} \quad \text{(For rectangular channel)}$$

$$y_c = \left(\frac{(20/2)^2}{9.81}\right)^{1/3}$$

$$= \left(\frac{100}{9.81}\right)^{1/3} = 2.168 \text{ m}$$

i.e., $y_c > y_n$ $\quad\therefore$ Steep slope.

22. (d)



Given data: $F_r = 0.8, \quad y = 1.8 \text{ m}, \quad T = 2 \times 1.8 = 3.6 \text{ m}$

Froude number, $$F_r = \frac{\sqrt{2}V}{\sqrt{gy}}$$

$$\Rightarrow \quad 0.8 = \frac{\sqrt{2}V}{\sqrt{9.81 \times 1.8}}$$

$$\Rightarrow \quad V = \frac{0.8\sqrt{9.81 \times 1.8}}{\sqrt{2}} = 2.377 \text{ m/s}$$

Discharge, $Q = VA$

$$\Rightarrow \quad Q = 2.377 \times \frac{1}{2} \times 1.8 \times 3.6$$

$$\Rightarrow \quad Q = 7.7 \text{ m}^3/\text{s}$$

23. (c)

3 m   5 m   3 m

1

2

1.5 m

5 m

Froude Number, $$F_r = \frac{V}{\sqrt{gD}}$$

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

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

$\Rightarrow \quad A = (5 + 2 \times 1.5) \times 1.5 = 12 \text{ m}^2$

Top width of flow, $T = 5 + 3 + 3 = 11$ m

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

$$Q = VA$$

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

$\therefore$ $F_r = \frac{1.25}{\sqrt{9.81 \times 1.09}} = 0.382 < 1$

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

24. (d)

Celerity, $C = \sqrt{gy} = \sqrt{9.81 \times 1} = 3.13$ m/s

Velocity of wave upstream,

$$V_w = C - V$$
$$= 3.13 - 2.43$$
$$= 0.7 \text{ m/s}$$

25. (a)

Since both the channels are flowing at critical velocity and thus the flow is critical in both the channels.

For critical flow,

Froude no. $F_r = 1$

Using the equation for critical flow,

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

For rectangular channel

$$\frac{Q_R^2 \times 2}{g \times A_R^3} = 1 \quad \text{...(i)}$$

For triangular channel

$$\frac{Q_T^2 \times 2}{g \times A_T^3} = 1 \quad \text{...(ii)}$$

From eq. (i) and (ii)

$$\frac{Q_R^2 \times 2}{g \times A_R^3} = \frac{Q_T^2 \times 2}{g \times A_T^3}$$

$\Rightarrow$ $$\frac{Q_R^2}{Q_T^2} = \left(\frac{A_R}{A_T}\right)^3$$

$$\Rightarrow \quad \left(\frac{Q_R}{Q_T}\right)^2 = \left(\frac{2\times1.5}{\frac{1}{2}\times2\times1}\right)^3 = \left(\frac{3}{1}\right)^3$$

$$\Rightarrow \quad \frac{Q_R}{Q_T} = \sqrt{3^3} = \sqrt{27} = 3\sqrt{3}$$

$$\Rightarrow \quad \frac{Q_R}{Q_T} = 5.2$$

26. (d)

This is a case of unsteady flow and the continuity equation will be used,

$$\frac{dQ}{dx} + T\frac{dy}{dt} = 0 \quad \text{...(i)}$$

Here, $$T\frac{dy}{dt} = \frac{20\times0.1}{60\times60} = 0.000556 \text{ m}^2/\text{s}$$

Also, $$\frac{dQ}{dx} = \frac{Q_2 - Q_1}{\Delta x}$$

From eq. (i) $$\frac{Q_2 - Q_1}{\Delta x} + T\frac{dy}{dt} = 0$$

$$Q_1 = Q_2 + T\frac{dy}{dt}\times\Delta x$$
$$= 25 + 0.000556 \times 1000$$
$$= 25.556 \text{ m}^3/\text{sec}$$

27. (b)

Given: $b = 10$ m

$y = 3$ m

$V = 1$ m/s

Bed slope, $$S_0 = \frac{1}{4000} = 0.00025$$

Slope of energy line, $S_f = 0.00004$

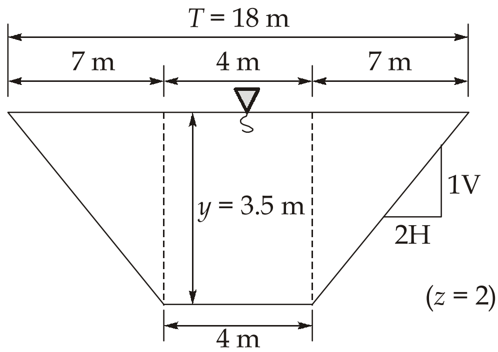
Rate of change of depth of water $= \dfrac{dh}{dx}$

$$\frac{dh}{dx} = \frac{S_0 - S_f}{1 - F_r^2} = \frac{S_0 - S_f}{\left(1 - \frac{V^2}{gy}\right)}$$

$$\Rightarrow \quad \frac{dh}{dx} = \frac{0.00025 - 0.00004}{1 - \frac{1^2}{9.81\times3}} = \frac{0.00021}{0.966}$$

$$= 0.000217$$

28. (a)



$$A = (B + zy) \times y$$

$$= (4 + 2 \times 3.5) \times 3.5 = 38.5 \text{ m}^2$$

$$F_r^2 = \frac{Q^2T}{gA^3} = \frac{100^2 \times 18}{9.81 \times (38.5)^3} = 0.3215$$

$$\Rightarrow \quad F_r = 0.567 < 1$$

Flow is sub-critical at given depth.

29. (a)

Given, $Q = 20 \text{ m}^3/\text{s}$

$B = 2 \text{ m}$

For most efficient rectangular channel,

Normal depth, $B = 2y_n$

$$y_n = B/2 = 2/2 = 1 \text{ m}$$

Fro critical depth, $y_c = \left(\dfrac{q^2}{g}\right)^{1/3}$ (For rectangular channel)

$$y_c = \left(\frac{(20/2)^2}{9.81}\right)^{1/3}$$

$$= \left(\frac{100}{9.81}\right)^{1/3} = 2.168 \text{ m}$$

i.e., $y_c > y_n$ $\therefore$ Steep slope.

30. (b)

For most efficient trapezoidal channel,

$$\text{Bed width} = \frac{2y}{\sqrt{3}}$$

$$\frac{2y}{\sqrt{3}} = 4\sqrt{3}$$

$$y = 6 \text{ m}$$

We know, hydraulic radius, $R = \dfrac{y}{2}$

$$R = \frac{6}{2} = 3 \text{ m}$$

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