CLASS TEST

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OPEN CHANNEL FLOW

CIVIL ENGINEERING

Date of Test : 23/06/2025

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (b)

2. (b)

3. (a)

As piezometric head is sum of pressure head and elevation (datum) head

$$\text{Total head} = \text{pressure} + \text{datum head} + \text{velocity head}$$

Therefore difference between total head and piezometric head is velocity head.

4. (a)

We know that

if, y1 = 1 depth at vena contracta, y_2 = sequent depth if y_t = tailwater depth ten for y_1

for $y_2 > y_t$ repelled jump occur

⇒ for $y_2 < y_t$ = submered jump occur

⇒ $y_2 = y_t$ = free jump occur

5. (a)

Ratio of area and perimeter is hydraulic radius and for most efficient trapezoidal section

$$R = \frac{y}{2}$$

At $y = 2.8$ m

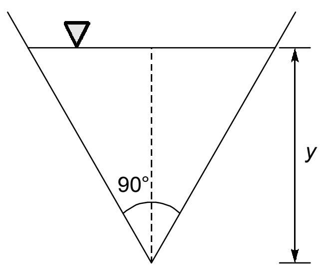
⇒ $R = 1.4$ m

6. (a)

Specific energy are same at alternate depth.

7. (a)

Froude number of triangular section given as $= \dfrac{\sqrt{2}V}{\sqrt{gy}}$



$$V = \frac{Q}{A}$$

$$A = y^2 = (3)^2 = 9$$

$$V = \left(\frac{Q}{A}\right) = \left(\frac{20}{9}\right) = 2.22 \text{ m/s}$$

$$F = \frac{\sqrt{2}\times 2.22}{\sqrt{9.81\times 3}} = 0.579$$

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8. (a)
- Supercritical state profiles are : S_2, S_3 and M_3
- If $\frac{dy}{dx}$ is positive, $\frac{dE}{dx}$ is positive only if $y > y_c$.

9. (a)

10. (b)

For most efficient trapezoidal channel section
- Top width is twice the sloping side.
- Hydraulic radius is half of depth of flow.
- Side slope width vertical is 30°.
- Sloping side are equal to bottom width.
- Area is $\sqrt{3}\,y^2$.

11. (a)

$$\text{Force on gate per unit width} = \frac{1}{2}\gamma_\omega \frac{(y_1 - y_2)^3}{(y_1 + y_2)}$$

Given, $y_1 = 3.8$ m, $y_2 = 0.8$ m

$$F = \frac{1}{2} \times 9.81 \times \frac{(3.8 - 0.8)^3}{(3.8 + 0.8)}$$

$$= 28.79 \text{ kN/m}$$

12. (a)

As per manning's formula

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

Where, A = area of section

R = Hydraulic radius

S = Slope of channel

For wide rectangular channel, $R = y$

$$\therefore \quad Q = B\frac{1}{n}y^{5/3}\sqrt{s}$$

$$Q \propto y^{5/3}$$

$$y_1 = 2.8 \text{ m}, \; y_2 = 3.8 \text{ m}$$

$$\frac{Q_2}{Q_1} = \frac{(3.8)^{5/3}}{(2.8)^{5/3}}$$

$$Q_2 = 1.6636\, Q_1$$

$$\text{\% increase in discharge} = \left(\frac{Q_2 - Q_1}{Q_1}\right) \times 100 = 66.36\%$$

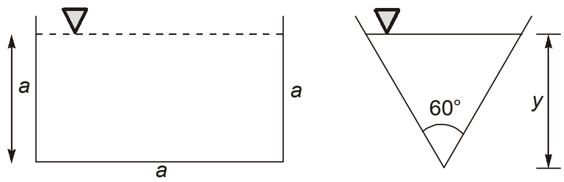
13. (c)

As per manning's formula

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

$$Q \propto \frac{1}{P^{2/3}}, P = \text{perimeter}$$

$$\left(\frac{Q_{\text{tringular}}}{Q_{\text{Rectangle}}}\right) = \left(\frac{P_{\text{Rectangle}}}{P_{\text{tringular}}}\right)^{2/3} \quad \text{... (i)}$$



As area of both channel is same

$$a^2 = \frac{y^2}{\sqrt{3}}$$

$$y = 1.316a \quad \text{...(ii)}$$

$$\text{Permieter of rectangular section} = 3a \quad \text{....(iii)}$$

$$\text{Permieter of triangular channel} = 2\sqrt{y^2 + \left(\frac{y}{\sqrt{3}}\right)^2}$$

$$= 2.309y$$

$$= 3.039\,a \quad \text{...(iv)}$$

$$\therefore \quad \left(\frac{Q_{\text{triangular}}}{Q_{\text{rectangular}}}\right) = \left(\frac{P_{\text{rectangular}}}{P_{\text{triangular}}}\right)^{2/3} = \left(\frac{3a}{3.039a}\right)^{2/3} = 0.991$$

14. (b)

As per manning formula

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

$$\therefore \quad A \propto \sqrt{s}$$

$$\frac{Q_2}{Q_1} = \sqrt{\frac{s_2}{s_1}}$$

$$s_2 = \frac{1}{1000}, \; s_1 = \left(\frac{1}{1000}\right)$$

$$\frac{Q_2}{Q_1} = \sqrt{\frac{1200}{1000}}$$

$$\frac{Q_2}{Q_1} = 1.095$$

$$Q_2 = 32.86 \text{ m}^3/\text{s}$$

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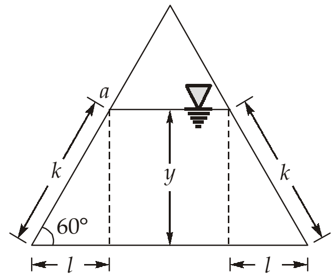
15. (c)



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

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

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

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

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

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

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

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

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

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

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

16. (b)

Froude number is unity at critical flow

- specific energy is minimum at critical flow.
- discharge is maximum for given specific force at critical condition.

17. (b)

For rectangular channel

$$y_c^3(\text{critical depth}) = \frac{2y_1^2y_2^2}{(y_1+y_2)}$$

y_1, y_2 are alternate depth

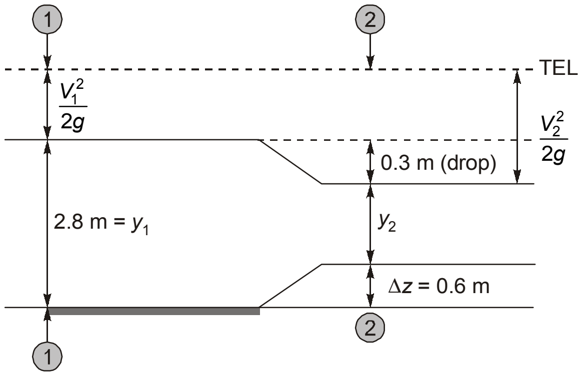
$$\text{given, } y_1 = 3.8 \text{ m}, \; y_2 = 0.8 \text{ m}$$

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

$$y_c = \left[\frac{2\times(3.8)^2(0.8)^2}{(3.8+0.8)}\right]^{1/3} = 1.59 \text{ m}$$

Specific energy (E_c) at critical flow for rectangular channel = 1.5 y_c = 2.39 m

18. (c)



$$y_1 = y_2 + \Delta z + 0.3$$

Given, $y_1 = 2.8$ m, $\Delta z = 0.6$ m, drop in water level = 0.3 m

$\therefore$ $y_2 = 2.8 - 0.6 - 0.3 = 1.9$ m

As there is no loss

Total energy at (1) – (1) = Total energy at (2) – (2)

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

$$2.8 + \frac{Q^2}{2g(A_1)^2} = y_2 + \Delta z + \frac{Q^2}{2(A_2)^2 g}$$

$$2.8 + \frac{Q^2}{2 \times 9.8(2.8 \times 4.8)^2} = 1.9 + 0.6 + \frac{Q^2}{2 \times 9.81(3.6 \times 1.9)^2}$$

$$2.8 + \frac{Q^2}{3544.03} = 2.5 + \frac{Q^2}{917.93}$$

$$Q = 19.278 \text{ m}^3/\text{s}$$

19. (a)

20. (c)

21. (b)

Equation of slope of water surface for gradually varied flow is

$$\frac{dy}{dx} = So\frac{\left[1 - \left(\frac{y_n}{y}\right)^{10/3}\right]}{\left[1 - \left(\frac{y_c}{y}\right)^{3}\right]}$$

If $y > y_n$ and $y > y_0$ then both term $\left(\frac{y_n}{y}\right)$ and $\left(\frac{y_c}{y}\right)$ will be less than one and numerator and denominator will be positive and $\frac{dy}{dx}$ will be ultimately positive.

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If $y < y_n$ and $y < y_c$, both term $\left(\frac{y_n}{y}\right)$ and $\left(\frac{y_c}{y}\right)$ will be greater than one and numerator and denominator will be negative and $\frac{dy}{dx}$ will finally be positive.

22. (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 $R = y$, $A = By$

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

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

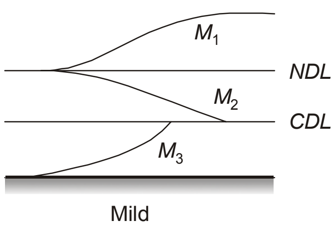
$$y_0 = \left[\frac{6\times 0.013}{\sqrt{0.006}}\right]^{3/5} = 1\text{m}$$

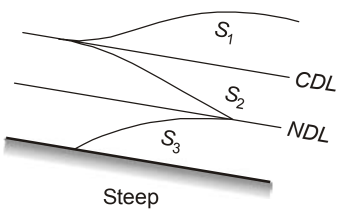
$$y_0 = \text{normal depth}$$

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.

23. (b)

24. (b)





25. (a)

Given data, $Q = 50\ m^3/s$

$S = 0.004$

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

hence, $$\frac{Q^2T}{A^3g} = 1$$

$$\frac{(50)^2 \times 5}{(5y)^3 \times 9.81} = 1$$

$$\frac{50 \times 50 \times 5}{125 \times y^3 \times 9.81} = 1$$

$\Rightarrow$ $$y = 2.168\ m \simeq 2.17\ m$$

26. (b)

We know that

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

given, $F_1 = 4.5$

$$\frac{y_2}{y_1} = \frac{1}{2}\left[-1+\sqrt{1+8\times(4.5)^2}\right]$$

$$\frac{y_2}{y_1} = 5.88$$

$\Rightarrow$ $$y_2 = 5.88y1 \qquad ...(i)$$

We know that, $$E_L = \frac{(y_2 - y_1)^3}{4y_1y_2}$$

$$8 = \frac{(5.88y_1 - y_1)^3}{4\times 5.88 y_1 \times y_1}$$

$\Rightarrow$ $$y_1 = 1.62\ m,\ y_2 = 9.53\ m$$

27. (c)

Given data, $$Q = 25\frac{m^3}{s},\ y_1 = 0.8\ m,\ B = 5\ m$$

$$V_1 = \left(\frac{Q}{A}\right) = \frac{25}{(0.8\times 5)} = 6.25\ m/sec$$

$$F_1 = \frac{V}{\sqrt{gy_1}} = \frac{6.25}{\sqrt{9.81\times 0.8}} = 2.23$$

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

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$$\Rightarrow \quad \frac{y_2}{(0.8)} = \frac{1}{2}\left[-1+\sqrt{1+8\times 2.232}\right]$$

$$\Rightarrow \quad y_2 = 2.15 \text{ m}$$

$$\text{Length of jump} = 6.9\,(y_2 - y_1)$$

$$= 9.32 \text{ m}$$

28. (b)

Given data, $y_1 = 3,\ y_2 = 3.8$ m

We know that for hydralic jump is rectangular channel,

$$\frac{q^2}{g} = \frac{1}{2}y_1y_2(y_1+y_2) = y_c^3$$

$$\therefore \quad \frac{q^2}{g} = \frac{1}{2}\times 0.3\times 3.8\times(0.3+3.8)$$

$$\Rightarrow \quad q = 4.78 \text{ m}^3\text{/s/m}$$

Now, $$y_c^3 = \frac{1}{2}y_1y_2(y_1+y_2)$$

$$y_c = 1.32 \text{ m}$$

29. (b)

Given data, Apex angle = 90°, depth of flow = 0.8 m

Q = 5 m^3/s, $A = y^2$ (as apex angle 90)

$$V = \left(\frac{Q}{A}\right) = \frac{5}{(0.8)^2} = 7.81 \text{ m/s}$$

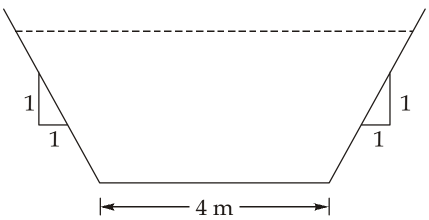
$$\text{Froude number for triangular section} = \frac{\sqrt{2}V}{\sqrt{9y}}$$

$$= \frac{\sqrt{2}\times 7.81}{\sqrt{9.81\times 0.8}} = 3.94$$

as F lies between 2.5 – 4.5, hence type of jump oscillating jump.

30. (d)

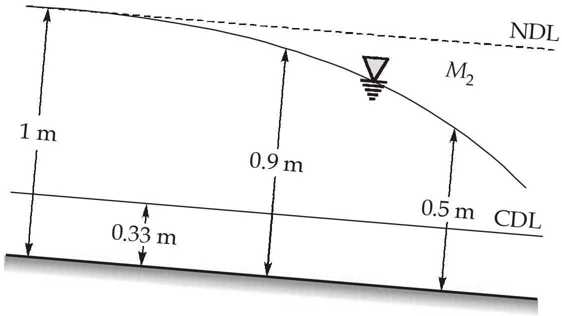
Given data: Normal depth, y_o = 1 m, Critical depth, y_c = 0.33 m



Since $y_o > y_c$ the given slope is mild and 0.9 m and 0.5 m lie between y_o and y_c so it is a type 2 profile namely M_2. It is a drawdown curve. Hence depth will change from 0.9 m and 0.5 m in downstream direction.

$y_1 = 0.9$ m, $\quad V_1 = \frac{2.485}{(4+0.9)0.9} = 0.563\text{ m/s} \quad \left\{V = \frac{Q}{A};\ A = (b+my)y\right\}$

$y_2 = 0.5$ m, $\quad V_2 = \frac{2.485}{(4+0.5)0.5} = 1.104\text{ m/s}$



Further,

Hydraulic radius, $\quad R_1 = \frac{A_1}{P_1} = \frac{(B+my_1)y_1}{B+2y_1\sqrt{1+m^2}} = \frac{(4+1\times0.9)0.9}{4+2\times0.9\sqrt{1+1}} = 0.674\text{ m}$

$$R_2 = \frac{(4+1\times0.5)0.5}{4+2\times0.5\sqrt{1+1}} = 0.416\text{ m}$$

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

$$E_1 = 0.9 + \frac{0.563^2}{2\times9.81} = 0.916\text{ m}$$

$$E_2 = 0.5 + \frac{(1.104)^2}{2\times9.81} = 0.562\text{ m}$$

$$V_1 = \frac{1}{n}R_1^{2/3}\sqrt{S_{f1}}$$

$$S_{f1} = \frac{V_1^2n^2}{(R_1)^{4/3}} = \frac{(0.563)^2\times(0.02)^2}{(0.674)^{1.333}} = 2.146\times10^{-4}$$

$$S_{f2} = \frac{V_2^2n^2}{(R_2)^{4/3}} = \frac{(1.104)^2\times(0.02)^2}{(0.416)^{1.333}} = 15.699\times10^{-4}$$

$$\bar{S}_f = \frac{S_{f1}+S_{f2}}{2} = 8.9225\times10^{-4} = 0.00089225$$

$$\Delta x = \frac{\Delta E}{S_o - \bar{S}_f} = \frac{0.562-0.916}{0.00015-0.00089225} = 476.928\text{ m} \simeq 476.93\text{ m}$$

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