CLASS TEST

Sl. : 01IGCE_ABC_24062024

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OPEN CHANNEL FLOW

CIVIL ENGINEERING

Date of Test : 24/06/2024

ANSWER KEY ➤

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

DETAILED EXPLANATIONS

1. (d)

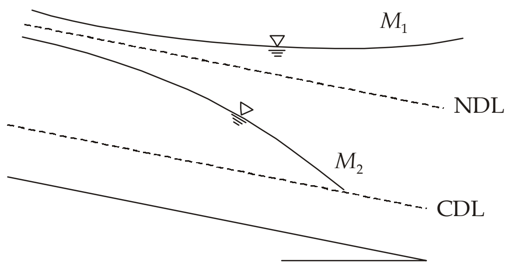
$$F_r = \frac{V}{\sqrt{gl}}$$

$$l = \frac{\text{Area (A)}}{\text{Top width (T)}}$$

Also known as hydraulic depth.

2. (c)

Mild slope profile.

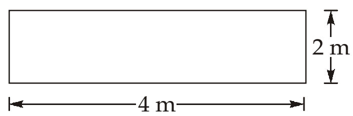


$\therefore$ $y_0 > y > y_c$

3. (a)

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

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



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

4. (c)

$$y = 1.5\text{ m}$$
$$y_n = 2.2\text{ m}$$
$$y_c = \left(\frac{q^2}{g}\right)^{1/3} = \left(\frac{\left(\frac{9.4}{3}\right)^2}{9.81}\right)^{1/3} = (1)^{1/3}$$
$$y_c = 1\text{ m}$$
$$y_n > y > y_c$$

As $y_n > y_c$ mild slope

$\Rightarrow M_2$ profile.

5. (d)

$$F_1 = \sqrt{\frac{q^2}{gy^3}} = \sqrt{\frac{25}{9.81 \times (0.3)^3}}$$

$$F_1 = 9.72 > 9$$

⇒ Strong jump

6. (a)

For a wide rectangular channel, the hydraulic radius R = depth of flow y

Hence, discharge intensity,
$$q = Vy = \left(\frac{1}{n} y^{2/3} S_0^{1/2}\right) y = \frac{1}{n} y^{5/3} S_0^{1/2}$$

$$1.30 = \frac{1}{0.02} \times y^{5/3} \times (0.0004)^{1/2}$$

$$y^{5/3} = 1.30$$

$$y = 1.17 \text{ m}$$

7. (b)

As,
$$\frac{dy}{dx} = \frac{S_0 - S_b}{1 - \frac{Q^2 T}{gA^3}}$$

For wide rectangular channel

$$Q = \frac{1}{n}(By)R^{2/3}\sqrt{s_b}$$

$$Q = \frac{1}{n}BR^{5/3}\sqrt{s_b} \qquad \text{(for wide rectangular channel, } R = y\text{)}$$

$$Q = \frac{1}{n}By^{5/3}\sqrt{s_b}$$

∴
$$s_p \propto \frac{1}{y^{10/3}}$$

(a)
$$y_0 = \text{Normal depth } s_b = s_0$$

$$\frac{s_b}{s_0} = \left(\frac{y_0}{y}\right)^{10/3} \qquad \text{. . . (i)}$$

(b)
$$\frac{Q^2 T}{A^3 g} = \frac{Q^2 T}{B^3 y^3 g} \quad \text{for rectangular channel, } T = B$$

$$= \left(\frac{y_c}{y}\right)^3$$

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

∴
$$\frac{dy}{dx} = so\left[\frac{1 - \frac{s_b}{s_o}}{1 - \frac{Q^2 T}{gA^3}}\right] = so\left[\frac{1 - \left(\frac{y_0}{y}\right)^{10/3}}{1 - \left(\frac{y_c}{y}\right)^3}\right]$$

8. (b)

For triangular channel,

Minimum specific energy = critical energy, $E_c = \frac{5}{4} y_c$

So, $E_c = 1.25 \times 1.4 = 1.75$ m

9. (c)

$$\frac{dE}{dx} = \left(1 - F^2\right)\frac{dy}{dx}$$

If $y < y_c$, i.e. supercritical flow ($F > 1$) and $\frac{dE}{dx}$ will be negative.

If $y > y_c$, i.e. subcritical flow ($F < 1$) and $\frac{dE}{dx}$ will be positive.

10. (b)

Depending on the values of Froude number (Fr) of incoming flow, there are five distinct type of hydraulic jump:

Type of jump	Froude number (Fr)
Undular	$1.0 < Fr < 1.7$
Weak	$1.7 < Fr \le 2.5$
Oscillating	$2.5 < Fr \le 4.5$
Steady	$4.5 < Fr \le 9.0$
Strong or Choppy	$Fr > 9.0$

11. (b)

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

$\Rightarrow$ $V^2 = gL$

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

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

4. Discharge is maximum for a given specific energy.

12. (b)

For most efficient trapezoidal channel,

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

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

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

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

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

13. (b)

$$y_1 = 0.3 \text{ m}$$
$$y_2 = 1.2 \text{ m}$$
$$V_1 = 3 \text{ m/s}$$

Energy loss in hydraulic jump,

$$E_l = \frac{(y_2 - y_1)^3}{4y_1y_2} = \frac{(1.2-0.3)^3}{4\times 0.3\times 1.2} = \frac{0.9^3}{4\times 0.3\times 1.2} = 0.50 \text{ m}$$

$$E_1 = y_1 + \frac{V_1^2}{2g} = 0.3 + \frac{3^2}{2\times 9.81} = 0.75 \text{ m}$$

$$\text{Relative energy loss} = \frac{E_l}{E_1}\times 100 = \frac{0.50}{0.75}\times 100 = 67\%$$

14. (a)

$$\text{Fr} = 0.74 = \frac{V}{\sqrt{gy}} = \frac{Q}{By\sqrt{gy}}$$

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

$$y^{3/2} = 1.726$$
$$y = (1.726)^{2/3}$$
$$1.726 \approx 1.728$$
$$y = 1.44 \text{ m}$$

15. (d)

Sequent depth ratio, $\frac{y_2}{y_1} = 8$

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

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

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

$\Rightarrow$ $F_1^2 = 36$

$F_1 = 6$

16. (a)

$$y_c^3 = \frac{2y_1^2y_2^2}{(y_1+y_2)} = \frac{2\times 2.4^2\times 0.5^2}{2.4+0.5} = 0.993 \text{ m}^3$$

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

17. (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.

18. (c)

$\therefore$

$$Q = VA$$
$$15 = 2 \times 6 \times y$$
$$y = 1.25 \text{ m}$$
$$E = y + \frac{v^2}{2g} = 1.25 + \frac{2^2}{2 \times 9.81}$$
$$E = 1.45 \text{ m}$$

19. (b)

For a rectangular channel,
$$E_C = \frac{3}{2} y_c = \frac{3}{2}\left(\frac{q^2}{g}\right)^{1/3}$$
$$= \frac{3}{2} y_c = \frac{3}{2}\left(\frac{q^2}{g}\right)^{1/3} = \frac{8}{2}\left(\frac{3.13^2}{9.81}\right)^{1/3}$$
$\Rightarrow$ $$E_c = 1.5 \text{ m}$$
$\Rightarrow$ $$\Delta Z_{max.} = E_1 - E_C = 2 - 1.5$$
$\Rightarrow$ $$\Delta Z_{max.} = 0.5 \text{ m}$$

20. (c)

For a given discharge Q in a channel, there will be two depths for a given specific energy E. These two depths are known as the alternate depths.

21. (a)

For a critical flow condition

$$\frac{Q^2}{g} = \frac{A_C^3}{T_C}$$
$$A_C = \frac{\pi D^2}{8} = \frac{\pi (1.0)^2}{8} = 0.39 \text{ m}^2$$
$$T_C = D = 1.0 \text{ m}$$
$$\frac{Q^2}{g} = \frac{A_C^3}{T_C} = \frac{(0.39)^3}{1.0} = 0.06$$
$$Q^2 = 0.06 \times 10 = 0.6$$
$$Q = 0.77 \text{ m}^3/\text{s}$$

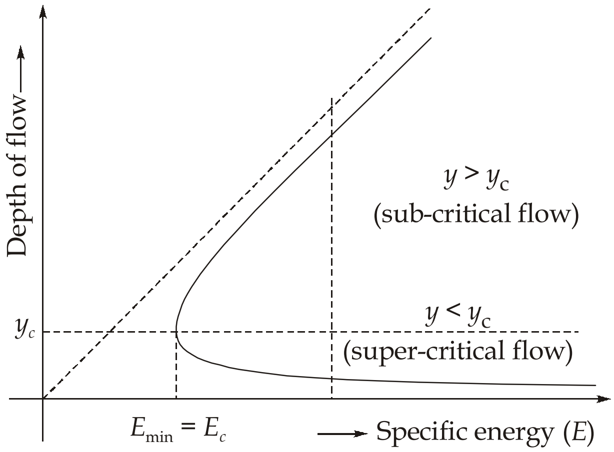
22. (c)

$$B = 4.0 \text{ m}$$
$$y_1 = 0.2 \text{ m and } y_2 = 1.0 \text{ m}$$

We know that,
$$\frac{2q^2}{g} = y_1 y_2 (y_1 + y_2)$$
$$q = \sqrt{\frac{9.81 \times 0.2 \times 1 \times (1.2)}{2}} = 1.085 \text{ m}^3/\text{s/m}$$
$$\therefore \quad Q = qB = 1.085 \times 4 = 4.34 \text{ m}^3/\text{s}$$

23. (b)

Specific energy curve:



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

24. (c)

At critical depth (velocity), specific energy is minimum.

25. (c)

Manning's equation
$$Q = \frac{1}{n} A R^{2/3} S^{1/2}$$
$$Q_{full} = \frac{1}{n} S^{1/2} B y_{full} (y_{full})^{2/3}$$
$$Q_{full} = \frac{1}{n} (S)^{1/2} B (y_{full})^{5/3}$$
$$Q_{half} = \frac{1}{n} (S)^{1/2} B (y_{half})^{5/3}$$
$$\because \quad \frac{Q_{full}}{Q_{half}} = 2$$
$$\Rightarrow \quad \frac{Q_{full}}{Q_{half}} = \left(\frac{y_{full}}{y_{half}}\right)^{5/3}$$
$$\Rightarrow \quad (2)^{3/5} = \frac{y_{full}}{y_{half}}$$

$$\Rightarrow \quad y_{half} = \frac{y_{full}}{(2)^{3/5}} = \frac{1.52}{1.515} \simeq 1.00 \text{ m}$$

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

27. (c)

28. (c)

The specific energy at 1 m depth

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

$$= 1.0 + \frac{(7)^2}{2 \times 10 \times (1.0)^2} = 3.45 \text{ m}$$

Critical depth for rectangular channel

$$y_c = \left(\frac{q^2}{g}\right)^{1/3} = \left(\frac{7^2}{10}\right)^{1/3} = 1.698 \text{ m}$$

Critical specific energy $(E_C) = 1.5y_c$

$= 2.55 \text{ m}$

$(\Delta Z)_{max} = E - E_C = 3.45 - 2.55$

$= 0.9 \text{ m}$

29. (c)

We know that Chezy's constant,

$$C = \sqrt{\frac{8g}{f}}$$

As given R_e i.e. is 320 is less than 2000, the flow would be laminar.

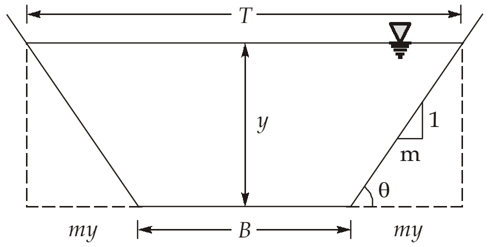
For laminar flow, $$f = \frac{64}{R_e}$$

$$f = \frac{64}{320} = \frac{1}{5}$$

$$C = \sqrt{\frac{8 \times 9.81}{\frac{1}{5}}}$$

$$C = 19.80\frac{\sqrt{m}}{s} \simeq 20\frac{\sqrt{m}}{s}$$

30. (d)



$$A = \frac{1}{2}(B+T)\cdot y = \frac{1}{2}[B+(B+2my)]\cdot y$$

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

$$P = B + \left(2\sqrt{1+m^2}\right)y$$

$$P = \left(\frac{A}{y} - my\right) + \left(2\sqrt{1+m^2}\right)y$$

For channel to be efficient, $\frac{dP}{dy} = 0$

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

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

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

Top width = 2 × side slope length

∴ Condition is true for any particular slope.

■■■■