ANSWER KEY ➤ Open Channel Flow

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

DETAILED EXPLANATIONS

1. (d)
As some flow is taken out from system it will spatially varied flow.

2. (c)
Neglecting variation in transverse direction.

3. (b)
Given, $Q = 40\ m^3/s,\ B = 4\ m$

$$q = \left(\frac{Q}{B}\right) = 10\ m^3/s$$

$$\text{Critical depth} = \left(\frac{q^2}{g}\right)^{1/3} = 2.168\ m$$

For rectangular channel, $E_C = 1.5\ y_c = 3.25\ m$

5. (b)

as for triangular channel, $E_C = 1.25\, y_c$

9. (a)

Strickler formula, $n = \dfrac{d_{50}^{1/6}}{21.1}, d_{50}$ in meter

Given, $d_{50} = 2\text{mm} = 0.002 \text{ m}$

$$n = \frac{(0.002)^{1/6}}{21.1} = 0.017$$

10. (b)

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

For wide rectangular channel

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

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

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

$\therefore$ $$s_p \propto \frac{1}{y^{10/3}}$$

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

$$\frac{s_b}{s_0} = \left(\frac{y_0}{y_1}\right)^{10/3} \qquad \text{. . . (i)}$$

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

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

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

$\therefore$ $$\frac{dy}{dx} = so\left[\frac{1 - \dfrac{s_b}{s_o}}{1 - \dfrac{Q^2T}{gA^3}}\right] = so\left[\frac{1 - \left(\dfrac{y_0}{y}\right)^{10/7}}{1 - \left(\dfrac{y_c}{y}\right)^3}\right]$$

11. (b)

$$Q_1(\text{upstream discharge}) = ?$$
$$Q_2(\textit{downstream}\ \text{discharge}) = 25\ \text{m}^3/\text{s}$$

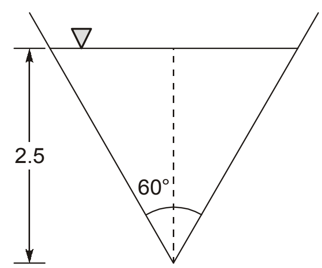
We know the for unsteady flow, continuity equation

$$\frac{dQ}{dx} + T\frac{dy}{dt} = 0$$
$$\frac{Q_2 - Q_1}{dx} + T\frac{dy}{dt} = 0$$
$$T = 20\ \text{m (given)}$$
$$\frac{dy}{dt} = 0.5\ \text{m/hr} = 1.388 \times 10^{-4}\ \text{m/sec}$$
$$\therefore \quad \frac{25 - Q_1}{2000} + 20 \times 1.388 \times 10^{-4} = 0$$
$$Q_1 = 30.55\ \text{m}^3/\text{s}$$

12. (a)

$$\text{Specific energy} = \frac{y_1^2 + y_1 y_2 + y_2^2}{(y_1 + y_2)} = \frac{(2)^2 + 2\times 3 + (3)^2}{(2+3)} = 3.8\ \text{m}$$

13. (a)



$$\text{Section factor } (z) = A\sqrt{\frac{A}{T}}$$

A = area, T = top width

$$\tan 30° = \frac{\frac{T}{2}}{2.5}$$
$$\Rightarrow \quad T = 2.88\ \text{m}$$
$$A = \left[\frac{1}{2} \times 2.88 \times 2.5\right] = 3.6\ \text{m}^3$$
$$Z = A\sqrt{\frac{A}{T}} = 3.6 \times \sqrt{\frac{3.6}{2.88}} = 4.02$$

14. (b)

$$F = \frac{V}{\sqrt{gy}} = 2$$

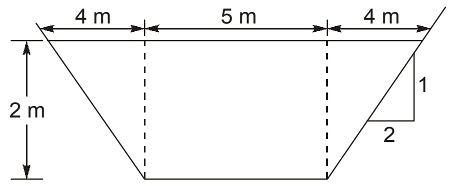
Given, $\quad y = 0.63\ \text{m}$

$\Rightarrow \quad V = 4.97\ \text{m}$

$\Rightarrow \quad q = Vy = 3.13$

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

15. (a)



$$A = \left(\frac{5+13}{2}\right)\times 2 = 18 \text{ m}^2$$

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

$$V = \frac{Q}{A} = 1.11 \text{ m/s}$$

$$T = 13 \text{ m}$$

$$\text{Froude Number} = \frac{V}{\sqrt{\frac{gA}{T}}} = \frac{1.11}{\sqrt{\frac{9.81\times 18}{13}}} = 0.301$$

16. (a)

We know that at critical flow over hump specific energy will correspond to critical specific energy.

$$E_1 = \text{specific energy at upstream section}$$

$$E_2 = E_c,\ OZ_m = \text{maximum hump height}$$

$\Rightarrow$ $$E_1 = E_2 + OZ_m$$

$\Rightarrow$ $$E_1 = E_c + OZ_m$$

$$E_C = 1.5\, y_c,\ y_c = \left(\frac{q^2}{g}\right)^{1/3}$$

$$\text{given, } Q = 12 \text{ m}^3/\text{s, B} = 3.5 \text{ m},\ y_1 = 1.2 \text{ m}$$

$$y_c = \left(\frac{q^2}{g}\right)^{1/3} = \left[\frac{\left(\frac{12}{3.5}\right)^2}{9.81}\right]^{1/3} = 1.062 \text{ m}$$

$\Rightarrow$ $$E_c = 1.5\, y_c = 1.593 \text{ m}$$

$$E_1 = y_1 + \left(\frac{v^2}{2g}\right) = 1.2 + \left[\frac{\left(\frac{12}{3.5\times 1.2}\right)^2}{2\times 9.81}\right] = 1.616 \text{ m}$$

$$E_1 = E_C + \Delta z_{max}$$

$$\Delta z_{max} = (1.616 - 1.593) = 0.023 \text{ m}$$

18. (a)

We know that, $$h_f = \frac{fl v^2}{2dg}$$

from chezy equation, $$V = C\sqrt{RS} \quad ...(i)$$

$$S_0 = \frac{h_1}{L} = \frac{fv^2}{2dg} \quad ...(ii)$$

From (i) and (ii)

$$V = C\sqrt{\frac{RfV^2}{2dg}}$$

$$V = CV\sqrt{\frac{Rf}{2dg}}$$

For pipe of diameter d, $$R = \frac{d}{4}$$

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

Now, $$C = \frac{1}{n}R^{1/6} \text{ [from manning and chezy equation]}$$

$$\sqrt{\frac{8g}{f}} = \frac{1}{n}R^{1/6}$$

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

19. (b)

Discharge through channel

$$Q = (AV)$$

$$Q = (By)\left[\frac{1}{n}R^{2/3}\sqrt{s}\right]$$

For wide rectangular channel, ($R = y$)

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

as normal depth increase by 20%

$$y' = 1.2\text{ y}$$

$$Q' = \frac{1}{n}B\sqrt{s}(1.2y)^{5/3} = \frac{1.355}{\left(\frac{1}{n}B\sqrt{s}y^{5/3}\right)} = 1.355\text{ Q}$$

$$\%\text{ increase in discharge} = \left(\frac{Q'-Q}{Q}\right)\times 100 = 35.5\%$$

20. (a)

For most efficient channel

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

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

$$R = \frac{A}{P} \Rightarrow P = 2\sqrt{3}\,y$$

$$T = 2l,\ l = \text{slant height}$$

$$l = \frac{P}{3} = \frac{2}{\sqrt{3}}y$$

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

21. (c)

$$q = 1.2\ \text{m}^3/\text{s/m}$$

$$\text{Critical depth } (y_c) = \left(\frac{q^2}{g}\right)^{1/3} = 0.528\ \text{m}$$

Now for wide rectangular channel

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

$$1.2 = \frac{1}{0.013}(y)^{5/3}\sqrt{0.004}$$

$$y = 0.43$$

as $y < y_c$, slope will be steep

23. (a)

Give, $Q = 7.8\ \text{m}^3/\text{s},\ B = 5\ \text{m}$

$$y_1 = 0.32\ \text{m}$$

$$F_1 = \frac{V_1}{\sqrt{gy_1}}$$

$$V_1 = \left(\frac{Q}{A}\right) = \frac{7.8}{(5\times 0.32)} = 4.875\ \text{m/s}$$

$$F_1 = \frac{4.875}{\sqrt{9.81\times 0.32}} = 2.751$$

We know that

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

$$= \frac{1}{2}\left[-1+\sqrt{1+8\times 2.751^2}\right]$$

$$y_2 = 1.095\ \text{m}$$

24. (a)

$$y_2 = 2.5 \text{ m}, \; V_2 = 1.5 \text{ m/s}$$

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

$$F_2 = \frac{V_2}{\sqrt{gy_2}} = \frac{1.5}{\sqrt{9.81\times 2.5}} = 0.303$$

$$\frac{y_1}{2.5} = \frac{1}{2}\left[-1+\sqrt{1+8\times 0.303^2}\right]$$

$$y_1 = 0.396 \text{ m}$$

from continuity equation, $V_1 y_1 = V_2 y_2$

$$V_1 = 9.46 \text{ m/s}$$

25. (c)

If, $y_2 < y_t$ = submerged jump will occur

$y_2 > y_t$ = repelled jump

$y_t = y_2 \Rightarrow$ free jump

26. (b)

We know that, $$\frac{q^2}{g} = \frac{1}{2}\left[y_1 y_2 (y_1 + y_2)\right]$$

$\Rightarrow$ $$y_1 = 0.2, \; y_2 = 2 \text{ m}$$

$\Rightarrow$ $$\frac{q^2}{9.81} = \frac{1}{2}\times 0.2\times 2\times 2.2$$

$$q = 2.078 \text{ m}^3\text{/s/m}$$

27. (a)

Given, $y_1 = 0.5\text{m}, \; V_1 = 5$ m/s

$$F_1 = \frac{V_1}{\sqrt{gy_1}} = \frac{5}{\sqrt{9.81\times 0.5}} = 2.26$$

$$\frac{y_2}{y_1} = \frac{1}{2}\left[-1+\sqrt{1+8\times 2.26^2}\right]$$

$$y_2 = 1.371$$

Length of jump $= 6.9\,(y_2 - y_1) = 6.9 \times (1.31 - 0.5) = 6\text{m}$

29. (b)

We know that

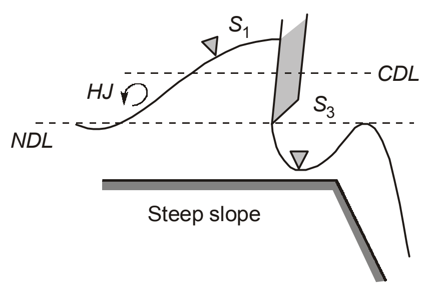
$$\text{Celerity} = \sqrt{\frac{1}{2} g \frac{y_2}{y_1}(y_1 + y_2)}$$

$$\text{given, } y_1 = 2,\ y_2 = 2.8$$

$$\text{Celerity} = \sqrt{\frac{9.81}{2} \times \frac{2.8}{2}(2 + 2.8)} = 5.74 \text{ m/s}$$

30. (b)

For steep slope critical depth line (CDL) is above normal depth line (NDL). On upstream of the gate there will be impounding of water therefore flow will change from NDL to actual depth (storage). A hydralic jump and S_1 curve will be an upstream side



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