CLASS TEST

Sl. : 01IGCE_ABC_11062024

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# HYDROLOGY

## CIVIL ENGINEERING

Date of Test : 11/06/2024

## ANSWER KEY

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

## DETAILED EXPLANATIONS

**2. (b)**

$$\text{Total rainfall} = (1.4 + 3.2 + 4.3 + 2.6 + 2.3 + 1) \times \frac{1}{2}\text{cm} = 7.4 \text{ cm}$$

**Trial 1**

$$\phi_{\text{index}} = \frac{7.4 - 3}{3} = 1.467 \text{ cm/hr}$$

**Trial 2**

$$\phi_{\text{index}} = \frac{(3.2 + 4.3 + 2.6 + 2.3) \times \frac{1}{2} - 3}{2} = 1.6 \text{ cm/hr}$$

**Check :**

$$\text{Runoff} = [(3.2 - 1.6) + (4.3 - 1.6) + (2.6 - 1.6) + (2.3 - 1.6)] \times 0.5$$

= 3 cm which is same as given in question

**4. (a)**

$$\frac{1}{2} \times 250 \times 42 \times 60 \times 60 = 10^{-2} \times A$$

$\Rightarrow$ $A = 1890 \times 10^6 \text{ m}^2$

$\Rightarrow$ $A = 1890 \text{ km}^2$

**5. (d)**

$$i = 1 \text{ cm/hr}$$

$$P = 1 \times 5 = 5 \text{ cm}$$

$$\text{Total runoff} = \frac{20000}{200 \times 10^4} \times 100 \text{ cm} = 1 \text{ cm}$$

Precipitation not available to runoff = 5 – 1 = 4 cm

**8. (b)**

$$\text{Equilibrium discharge } Q_e = 2.778 \times \frac{300}{3} = 277.8 \text{ m}^3/\text{s}$$

**9. (c)**

Double mass curve technique is used to check the consistency of rainfall data.

**11. (b)**

±10% of normal annual rainfall at station III = 72 cm and 88 cm < Normal annual rainfall at station IV

∴ Using normal rational method

$$P_3 = \frac{N_3}{3}\left[\frac{P_1}{N_1} + \frac{P_2}{N_2} + \frac{P_4}{N_4}\right]$$

$$= \frac{80}{3}\left[\frac{90}{70} + \frac{65}{75} + \frac{75}{105}\right] = 76.44 \text{ cm}$$

**12. (c)**

$\because \quad Q \propto \sqrt{S}$

$\therefore \quad \dfrac{Q_2}{Q_1} = \sqrt{\dfrac{S_2}{S_1}} \qquad S_1 = \dfrac{1}{5000}$

$\Rightarrow \quad \dfrac{Q_2}{180} = \sqrt{\dfrac{5000}{2000}} \qquad S_2 = \dfrac{1}{2000}$

$\Rightarrow \quad Q_2 = 284.6 \text{ m}^3/\text{s} \qquad \dfrac{S_2}{S_1} = \dfrac{5000}{2000}$

**13. (b)**

$V_{0.2} = 0.5 \text{ m/s}$

$V_{0.8} = 0.3 \text{ m/s}$

$\therefore \quad V = \dfrac{V_{0.2} + V_{0.8}}{2} = \dfrac{0.5 + 0.3}{2} = 0.4 \text{ m/s}$

$\therefore \quad Q = AV = \dfrac{1}{2} \times 9 \times 3 \times 0.4 \text{ m}^3/\text{s} = 5.4 \text{ m}^3/\text{s}$

**14. (b)**

$f_0 = 25 \text{ mm/hr}, \quad k = 0.5/\text{hr}$

$f_c = 9 \text{ mm/hr}$

$\because \quad f_t = f_c + (f_0 - f_c)e^{-kt}$

$\Rightarrow \quad f_t = 9 + (25 - 9)\, e^{-0.5t}$

$\Rightarrow \quad f_t = 9 + 16\, e^{-0.5\, t}$

$\therefore \quad \text{Total infiltration} = \int_0^t f_t dt = \int_0^{10} (9 + 16e^{-0.5t})dt = 90 + 32\left(1 - e^{-5}\right)$

$= 90 + 31.78 = 121.78 \simeq 122 \text{ mm}$

**15. (b)**

The probability corresponding to 100 years return period

$$P = \frac{1}{100} = 0.01$$

The probability of the flood exceeding at least once in 50 years

$R = 1 - (1 - P)^{50} = 1 - 0.99^{50}$

$= 39.49\% \simeq 40\%$

**16. (d)**

For confidence probability $C$, the confidence interval (if variate $x_T$ is bounded by values $x_1$ and $x_2$) is given by

$$x_1 = x_T - f(c) \cdot S_e$$

$$x_2 = x_T + f(c) \cdot S_e$$

Given $x_T = 19000 \text{ m}^3/\text{s}$

$$S_e = 2200 \text{ m}^3/\text{s}$$

For 95% confidence probability $f(c) = 1.96$

$\therefore$ $x_1 = 19000 - 1.96 \times 2200 = 14688 \text{ m}^3/\text{s}$

$$x_2 = 19000 + 1.96 \times 2200 = 23312 \text{ m}^3/\text{s}$$

**17. (c)**

$$p = \frac{1}{50} = 0.02, \qquad q = 1 - 0.02 = 0.98$$

$$\text{For} = n = 15, r = 2, \quad P = n_{c_r} P^r q^{n-r}$$

$$\text{Probability} = {}^{15}C_2 (0.02)^2 (0.98)^{13}$$

**18. (a)**

In the second 30 minutes

$$t_1 = 30 \text{ mins} = 0.5 \text{ hr}$$

$$t_2 = 60 \text{ ins} = 1\text{hr}$$

$$F_p = \int_{\frac{30}{60}}^{\frac{60}{60}} \left(4 + e^{-2t}\right) dt$$

$$= \int_{0.5}^{1} 4t\, dt + \int_{0.5}^{1} e^{-2t}\, dt$$

$$F_p = 4(1 - 0.5) - \left.\frac{e^{-2t}}{2}\right|_{0.5}^{1}$$

$$= 4 \times 0.5 + \frac{1}{2}\left[e^{-2\times 0.5} - e^{-2\times 1}\right]$$

$$= 2 + \frac{1}{2}\left[e^{-1} - e^{-2}\right]$$

$$= 2 + \frac{1}{2}\left[\frac{1}{e} - \frac{1}{e^2}\right] = 2 + \frac{1}{2} \times 0.231$$

$$= 2 + 0.115 = 2.115 \text{ cm} \approx 2.11 \text{ cm}$$

**19. (a)**

| Time (h) (Col. 1) | Ordinate of 3h-UH ($m^3/s$) (Col. 2) | Ordinate of 3h-UH lagged by 3hr ($m^3/s$) (Col. 3) | Ordinate of 6h-DRH ($m^3/s$) (Col. 2 + Col. 3) | Ordinate of 6 hour UH = $\frac{\text{Ordinate of 6h-DRH}}{2\text{ cm}}$ ($m^3/s$) |
|---|---|---|---|---|
| 0 | 0 | | 0 | 0 |
| 1 | 5 | | 5 | 2.5 |
| 2 | 12 | | 12 | 6 |
| 3 | 25 | 0 | 25 | 12.5 |
| 4 | 41 | 5 | 46 | 23.0 |
| 5 | | 12 | 12 | 6 |
| 6 | | 25 | 25 | 12.5 |
| 7 | | 41 | 41 | 20.5 |

**20. (a)**

$$P_{avg} = \frac{P_1A_0 + \left(\frac{P_1+P_2}{2}\right)A_1 + \left(\frac{P_2+P_3}{2}\right)A_2 + \left(\frac{P_3+P_4}{2}\right)A_3 + \left(\frac{P_4+P_3}{2}\right)A_4 + P_5A_5}{A_0 + A_1 + A_2 + A_3 + A_4 + A_5}$$

$$= \frac{70\times 60 + \left(\frac{70+90}{2}\right)275 + \left(\frac{90+100}{2}\right)260 + \left(\frac{100+125}{2}\right)380 + \left(\frac{125+140}{2}\right)215 + 140\times 40}{60+275+260+380+215+40}$$

$= 103.85$ mm

**21. (c)**

$e_s$ = 17.54 mm of Hg

Actual vapour pressure = Relative humidity × 17.54 = 0.5 × 17.54

$e_a$ = 8.77 mm Hg

Let $U_9$ = Wind velocity at a height of 9 m above ground surface

$\therefore$ $U_9 = U_1(9)^{1/7} = 16(9)^{1/7} = 21.9$ kmph

From Meyer's method,

$$\text{Evaporation loss, } E_L = k_m(e_s - e_a)\left(1 + \frac{U_9}{16}\right)$$

$$= 0.36(17.54 - 8.77)\left(1 + \frac{21.9}{16}\right) = 7.48 \text{ mm/day}$$

Daily evaporation as per pan evaporimeter

$$= \frac{70}{7} \times 0.8 = 8 \text{ mm/day}$$

So, $$\%\ \text{error} = \frac{8 - 7.48}{8} \times 100 = 6.5\%$$

**22.** **(d)**

$$\text{Peak of 2H-DRH} = 135 - 10 = 125 \text{ m}^3/\text{s}$$

$$\text{Effective rainfall} = 54 - 4 \times 2 = 46 \text{ mm} = 4.6 \text{ cm}$$

$$\text{Peak of 2 hr UH} = \frac{125}{4.6} = 27.17 \text{ m}^3/\text{s}$$

**23.** **(b)**

$$P = \frac{1}{T} = \frac{1}{60}$$

$$P_{\text{2 times in 15 years}} = {}^{15}C_2 \left(\frac{1}{60}\right)^2 \left(1 - \frac{1}{60}\right)^{13}$$

$$= 0.02344 = 2.344\%$$

**24.** **(d)**

$$P = (10 + 30 + 40 + 50 + 25 + 8) \times \frac{30}{60} = 81.5 \text{ mm}$$

$$R = 38 \text{ mm}$$

$$\therefore \quad W_{\text{index}} = \frac{P - R}{k} = \frac{81.5 - 38}{(180/60)} = 14.5 \text{ mm/hr}$$

$$\therefore \quad \phi_{\text{index}} = \frac{81.5 - 38 - (10 + 8)0.5}{(180 - 30 - 30)/60} = 17.25 \text{ mm/hr}$$

**Check:**

$$\text{Runoff} = \left[(30 - 17.25) + (40 - 17.25) + (50 - 17.25) + (25 - 17.25)\right]\frac{30}{60}$$

$$= 38 \text{ mm which is same as given in question}$$

**25.** **(b)**

Horton's equation of I.C. curve,

$$f = f_c + (f_0 - f_c)e^{-kt}$$

$$\Rightarrow \quad (f - f_c) = (f_0 - f_c)e^{-kt}$$

$$\Rightarrow \quad \log(f - f_c) = \log(f_0 - f_c) - kt \log e$$

$$\Rightarrow \quad \log(f - f_c) - \log(f_0 - f_c) = -kt \log e$$

$$\Rightarrow \quad t = \frac{-1}{k \log e}\left[\log(f - f_c) - \log(f_0 - f_c)\right]$$

$$= \frac{-1}{k \log e}\log(f - f_c) + \frac{1}{k \log e}\log(f_0 - f_c)$$

$$\therefore \quad \text{Slope} = \frac{-1}{k \log e} = -0.4605$$

$$\Rightarrow \quad k = 5.0 \text{ time}^{-1}$$

**26. (c)**

$$h = 3 \text{ cm}$$

$$\therefore \quad A = \frac{0.36 \times \sum \text{Ordinates} \times \Delta t}{h}$$

$$= \frac{0.36 \times 105 \times 1}{3} = 12.60 \text{ km}^2$$

$$= 1260 \text{ ha}$$

**Alternate solution,**

$$V = Qt$$

$$\Rightarrow \quad Ah = Qt$$

$$\Rightarrow \quad A = \frac{(0 + 7 + 24 + 35 + 26 + 13) \times 3600}{0.03}$$

$$= 12.6 \times 10^6 \text{ m}^2 = 1260 \text{ ha}$$

**27. (d)**

$$\text{Area of DRH} = ER \times \text{Area of catchment}$$

$$\text{Area of DRH} = \left[\begin{aligned} &\frac{1}{2} \times 10 \times 10 + \frac{1}{2}(10 + 70) \times 10 + \frac{1}{2}(70 + 90) \times 10 \\ &+ \frac{1}{2}(90 + 40) \times 20 + \frac{1}{2} \times 40 \times 40 \end{aligned}\right] \times 3600 \text{ m}^3$$

$$= ER \text{ (in cm)} \times 10^{-2} \text{ m} \times 300 \times 10^6 \text{ m}^2$$

$$ER = 4.02 \text{ cm}$$

**28. (a)**

From water budget equation,

$$P + R - G - E - T = \Delta S$$

Total rainfall, $P$ = 10 mm

Antecedent moisture at root in the soil = 5 mm

Loss of water due to seepage = 2.5 mm

Loss of water due to percolation = 2 mm

Surface runoff = 3 mm

Moisture retained in the soil = 1 mm

So, $10 + 5 - 2.5 - 2 - 3 - T = 1$

$\Rightarrow \quad 7.5 - T = 1$

$\Rightarrow \quad T = 6.5 \text{ mm}$

$\therefore$ Amount of evapotranspiration = 6.5 mm

**29. (b)**

Assuming $\phi$-index to be less than 9 mm/hr

Surface runoff = $[(17-\phi)+(35-\phi)+(51-\phi)+(27-\phi)+(23-\phi)+(9-\phi)]\times\frac{30}{60}=36$

$\Rightarrow$ $\phi = 15$ mm/hr (∴ Our assumption is wrong)

Assuming $\phi > 15$ mm/hr end < 17 mm/h

$$\Rightarrow [(17-\phi)+(35-\phi)+(51-\phi)+(27-\phi)+(23-\phi)]\times\frac{30}{60}=36$$

$\Rightarrow$ $\phi = 16.2$ mm/hr (OK)

Total rainfall $P = [17+35+51+27+23+9]\times\frac{30}{60} = 81$ mm

$$\text{W-index} = \frac{P-R}{t_f} = \frac{(81-36)}{3} = 15\ mm/hr$$

$$\text{Required ratio} = \frac{16.2}{15} = 1.08$$

**30. (d)**

Since K = 12 h and 2 Kx = 2 × 12 × 0.2 = 4.8 h, $\Delta$ t should be such that 12 h > $\Delta$ t > 4.8 h. In the present case $\Delta$ t = 6 h is selected to suit the given inflow hydrograph ordinate interval.

$$C_0 = \frac{-kx+0.5\Delta t}{k-kx+0.5\Delta t} = \frac{-12\times 0.20+0.5\times 6}{12-12\times 0.2+0.5\times 6} = \frac{0.6}{12.6} = 0.048$$

$$C_1 = \frac{kx+0.5\Delta t}{k-kx+0.5\Delta t} = \frac{12\times 0.2+0.5\times 6}{12.6} = 0.429$$

$$C_2 = \frac{k-kx-0.5\Delta t}{k-kx+0.5\Delta t} = \frac{12-12\times 0.2-0.5\times 6}{12.6} = 0.524$$

Now $Q_n = C_0I_n + C_1I_{n-1} + C_2Q_{n-1}$

∴ $Q_2 = C_0I_2 + C_1I_1 + C_2Q_1$

$I_1 = 10.0$, $I_2 = 20.0$ and $Q_1 = 10.0$

∴ $Q_2 = 10.49\ m^3/s$

Similarly, $Q_3 = C_0I_3 + C_1I_2 + C_2Q_2 = 16.48\ m^3/s$

| Time$(m)$ | $I(m^3/s)$ | $0.048I_n$ | $0.429I_{n-1}$ | $0.524Q_{n-1}$ | $Q(m^3/s)$ |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
| 0 | 10 | | | | 10.00 |
| 6 | 20 | 0.96 | 4.29 | 5.24 | 10.49 |
| 12 | 50 | 2.40 | 8.58 | 5.49 | 16.48 |

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