CLASS TEST

Sl. : 01_IG_CE_A+C_31052023

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# HYDROLOGY

## CIVIL ENGINEERING

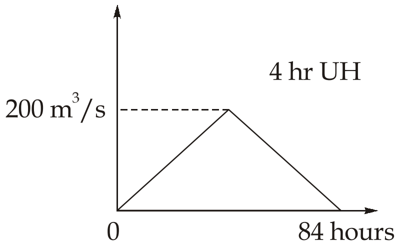
**Date of Test : 31/05/2023**

## ANSWER KEY

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

# DETAILED EXPLANATIONS

**3. (d)**




$$\text{Area of UH} = \text{C.A.} \times 0.01 \qquad \text{(where C.A. is catchment area)}$$

$$\Rightarrow \frac{1}{2} \times 84 \times 3600 \times 200 = \text{C.A.} \times 0.01$$

$$\Rightarrow \text{C.A.} = 3024 \times 10^6 \text{ m}^2$$

$$\Rightarrow \text{C.A.} = 3024 \text{ km}^2$$

**4. (a)**

$$T = 200 \text{ years}$$

$$y_T = \text{Reduced variate} = -\ln.\ln.\left(\frac{T}{T-1}\right) = -\ln.\ln.\left(\frac{200}{200-1}\right)$$

$$\Rightarrow y_T = 5.296 \simeq 5.3$$

**5. (b)**

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

$$P = 54 \text{ mm}, \qquad \phi = 4 \text{ mm/hr}$$

$$\therefore R = P - \phi \times t = 54 - 4 \times 1 = 50 \text{ mm} = 5 \text{ cm}$$

$$\therefore \text{Peak of 1 hr UH} = \frac{125}{5} = 25 \text{ m}^3/\text{s}$$

**6. (c)**

For a given catchment IUH, being independent of rainfall characteristics, is indicative of the catchment storage characteristics.

**7. (d)**

State is defined as the water surface elevation measured above a datum:

Manual stage measurements are done using.

(i) Staff gauge

(ii) Wire gauge

Automatic stage measurements are done using

(i) Float gauge recorder

(ii) Bubble gauge

Stage data is presented in the form of plot of stage against chronological time known as stage hydrograph.

**8. (b)**

Drizzle is a fine sprinkle of numerous water droplets of size less than 0.5 mm and intensity less then 1 mm/hr.

**9. (c)**

Symon's raingauge is non-recording type raingauge.

**10. (a)**

The rising limb of a hydrograph is also known as concentration curve and it represents the increase in discharge due to the gradual building up of storage in channels and over the catchment surface.

**11. (d)**

Total rainfall = 0.6 + 3.0 + 1.8 = 5.4 cm

Excess rainfall = 5.4 – 3.5 = 1.9 cm

Excess rainfall duration, $t_e$ = 2 × 3 = 6 hrs

$\phi$-index = 1.9/6 = 0.317 cm/hr

This value being more than $\frac{0.6}{2} = 0.3$ cm/hr, the excess rainfall duration will reduce by 2 hours.

$\therefore$ $t_e$ = 4 hours

Excess rainfall = 3 + 1.8 – 3.5 = 1.3 cm

$\therefore$ $\phi$-index = 1.3/4 = 0.325 cm/hr

**13. (a)**

$$P(\text{at least once}) \text{ in 20 years} = 1-\left(1-\frac{1}{T}\right)^n = 1-\left(1-\frac{1}{40}\right)^{20} = 0.397 \simeq 40\%$$

**15. (a)**

On comparison with the Horton's equation in the standard form, $f_c$ = 6 mm/hr, $f_o$ = 22 mm/hr and $k$ = 2/h.

Since the rainfall intensity is more than $f_o$, the infiltration takes place at the capacity rate throughout the storm. Hence the commutative depth of infiltration for the first 45 minutes is given by,

$$f = \int_0^{3/4} f\,dt = \int_0^{0.75}\left(6+16e^{-2t}\right)dt = \left[6t-8e^{-2t}\right]_0^{0.75} = \left[6\times 0.75-8\times e^{-1.5}\right]-[0-8]$$

$$= 10.715 \text{ mm}$$

**16. (a)**

$$\text{Direct runoff} = \frac{1}{2}\times 64\times 3600\times 36 = 4147200 \text{ m}^3 = 4.1472\times 10^6 \text{ m}^3$$

Effective rainfall = 1 cm

$$\therefore \quad \text{Catchment area} = \frac{4.147\times 10^6}{1}\times 10^2 \text{ m}^2 = 414.72 \text{ km}^2$$

$$\therefore \quad \text{Equilibrium discharge} = 2.778\times\frac{A}{D} = 2.778\times\frac{414.72}{6} = 192.02 \text{ m}^3/\text{sec}$$

**17. (b)**

$h$ = 3 cm

$$\therefore \quad A = \frac{0.36\times\sum \text{Ordinates}\times\Delta t}{h} = \frac{0.36\times 105\times 1}{3} = 12.60 \text{ km}^2 = 1260 \text{ ha}$$

**18. (c)**

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

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

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

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

**Check:**

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

$= 38$ mm which is same as given in question

**19. (d)**

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

$\Rightarrow \quad 7.5 - T = 1$

$\Rightarrow \quad T = 6.5$ mm

$\therefore$ Amount of evapotranspiration = 6.5 mm

**20. (c)**

By Inglis formula, $$Q_p = \frac{124A}{\sqrt{A + 10.4}} = \frac{124 \times 38.6}{\sqrt{38.6 + 10.4}} = 683.77 \text{ m}^3/\text{sec}$$

**21. (a)**

$$Q = \frac{Q_t(C_1 - C_2)}{C_2 - C_0}$$

$Q_t = 10 \text{ cm}^3/\text{sec} = 10 \times 10^{-6} \text{ m}^3/\text{s}$

$C_1 = 20 \text{ mg}/l = 20 \text{ ppm} = 20 \times 10^3$ ppb,

$C_2 = 5$ ppb,

$C_0 = 0$

$$\therefore \quad Q = 10 \times 10^{-6} \times \left(\frac{20 \times 10^3 - 5}{5 - 0}\right) \text{m}^3/\text{s} = 0.040 \text{ m}^3/\text{s}$$

**22. (d)**

The risk involved is 0.20 and $n = 2$ years

$$\therefore \quad 0.20 = 1 - \left(1 - \frac{1}{T}\right)^2$$

$\Rightarrow \quad T = 9.47$ years

$\Rightarrow \quad T \simeq 9.5$ years

**23. (a)**

Total rainfall, $P = (3.5 + 6.5 + 8.5 + 7.8 + 6.4 + 4.0 + 4.0 + 6.0) \times \frac{30}{60}$

$= 23.35$ cm

Total rainfall excess $= [(6.5 - 4.5) + (8.5 - 4.5) + (7.8 - 4.5) + (6.4 - 4.5) + (6.0 - 4.5)] \times \frac{30}{60}$

$= 6.35$ cm

$\therefore$ $W\text{-index} = \frac{23.35 - 6.35}{4} = 4.25$ cm/hour

**24. (d)**

$$\mu = P_{av.} = \frac{800 + 520 + 440 + 420}{4} = 545 \text{ mm}$$

$$\sigma_{n-1}^2 = \frac{\Sigma(P_i - P_{av})^2}{n-1}$$

$$\Rightarrow \quad \sigma_{n-1}^2 = \frac{(800-545)^2 + (520-545)^2 + (440-545)^2 + (420-545)^2}{4-1}$$

$$\Rightarrow \quad \sigma_{n-1} = 175.404 \text{ mm}$$

$$c_v = \frac{\sigma_{n-1}}{\mu} \times 100 = \frac{175.404}{545} \times 100 = 32.18\%$$

Now, No. of rainguages, $N = \left(\frac{c_v}{\varepsilon}\right)^2 = \left(\frac{32.18}{10}\right)^2 = 10.355$

i.e. $N = 11$

$\therefore$ Additional raingauge stations required = 11 – 4 = 7

**25. (b)**

Muskingam routing equation:

$$Q_2 = C_0 I_2 + C_1 I_1 + C_2 Q_1$$

Here $C_0 = \frac{0.5\Delta t - kx}{k - kx + 0.5\Delta t} = \frac{0.5 \times 6 - 10(0.25)}{10 - 10(0.25) + 0.5(6)} = .0476$

$$C_1 = \frac{0.5\Delta t + kx}{k - kx + 0.5\Delta t} = \frac{0.5(6) + 10(0.25)}{10 - 10(0.25) + 0.5(6)} = 0.5238$$

Since $C_0 + C_1 + C_2 = 1$

$\Rightarrow$ $C_2 = 1 - 0.0476 - 0.5238$

$\Rightarrow$ $C_2 = 0.4286$

$\therefore$ $Q_2 = 0.0476 \times 25 + 0.5238 \times 10 + 0.4286 \times 10$

$\Rightarrow$ $Q_2 = 10.714 \text{ m}^3/\text{s}$

$\therefore$ $Q_3 = 0.0476 \times 50 + 0.5238 \times 25 + 0.4286 \times 10.714$

$= 20.067 \text{ m}^3/\text{s} \simeq 20.07 \text{ m}^3/\text{s}$

**26. (c)**

$$f_{40} = \int_0^{2/3} f(t)\,dt = \int_0^{2/3} \left(10 + 15e^{-1.5t}\right) dt$$

$$= \left[10t + 15\left[\frac{e^{-1.5t}}{-1.5}\right]\right]_0^{2/3} = 10\left[\frac{2}{3} - 0\right] - \frac{15}{1.5}\left[e^{-1.5 \times \frac{2}{3}} - e^{-1.5 \times 0}\right]$$

$$= \frac{20}{3} - 10[0.368 - 1] = 12.99 \text{ mm}$$

$\therefore$ The average infiltration rate for the first 40 minutes will be

$$f_{avg} = \frac{12.99}{\left(\frac{2}{3}\right)} = 19.485 \text{ mm/hr}$$

**27. (c)**

For the 1st 6 hr

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

$$\text{Effective rainfall} = 3 - 0.325 \times 6 = 1.05 \text{ cm}$$

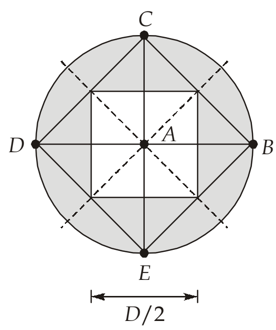
For the 2nd 6 hr

$$\text{Rainfall} = 4 \text{ cm}$$

$$\text{Effective rainfall} = 4 - 0.325 \times 6 = 2.05 \text{ cm}$$

| *I* Time | *II* Ordinate of UH | *III* DRH due to first 6 hr storm | *IV* DRH due to second 6 hr storm | *III+IV* Final DRH | *VI = V + 10* Final flood hydrograph |
|---|---|---|---|---|---|
| 0 | 0 | 0 | – | 0 | 10 |
| 3 | 20 | 21 | – | 21 | 31 |
| 6 | 45 | 47.25 | 0 | 47.25 | 57.25 |
| 9 | 65 | 68.25 | 41 | 109.25 | 119.25 |
| 12 | 120 | 126 | 92.25 | 218.25 | 228.25 |
| 15 | 165 | 173.25 | 133.25 | 306.5 | 316.5 |

**28. (b)**




Basin diameter, $D = 15$ km

$$\text{Side of square around station } A = \frac{15}{2} = 7.5 \text{ km}$$

$$\text{Area of station } A = 7.5 \times 7.5 = 56.25 \text{ km}^2$$

$$\text{Total area of circular basin} = \frac{\pi}{4}(15)^2 = 176.7 \text{ km}^2$$

Area of station $B$ = Area of station $C$ = Area of station $D$ = Area of station $E$

$$= \left(\frac{176.7 - 56.25}{4}\right) = 30.11 \text{ km}^2$$

$$\therefore \quad \text{Mean rainfall} = \frac{9 \times 56.25 + 30.11(7 + 10 + 11 + 8)}{176.7}$$

$$= 9 \text{ cm}$$

**29. (a)**

| Storms | Duration (hr) | Intesnsity (cm/hr) | Total runoff depth (cm) |
|---|---|---|---|
| 1 | 4 | $\frac{3}{4}=0.75$ | $3-4\times1=0$ |
| 2 | 4 | $\frac{7}{4}=1.75$ | $7-4\times1=3$ |
| 3 | 4 | $\frac{11}{4}=2.75$ | $11-4\times1=7$ |
| 4 | 6 | $\frac{7}{6}=1.167$ | $7-6\times1=1$ |
| 5 | 6 | $\frac{8}{6}=1.33$ | $8-6\times1=2$ |

$$\begin{aligned}\text{Total runoff depth} &= 3+7+1+2 = 13 \text{ cm} = 0.13 \text{ m}\\ \text{Total runoff volume} &= 0.13\times195\times10^6 \text{ m}^3\\ &= 0.13\times195 \text{ Mm}^3\\ &= 25.35 \text{ Mm}^3\end{aligned}$$

**30. (b)**

$$\text{Average depth of rainfall} = \frac{15\times30+\left(\frac{30+40}{2}\right)\times250+\left(\frac{40+50}{2}\right)\times150+\left(\frac{50+35}{2}\right)\times180+\left(\frac{35+60}{2}\right)\times215+60\times60}{15+250+150+180+215+60}$$

$$= \frac{450+8750+6750+7650+10212.5+3600}{870}$$

$$= 43 \text{ mm}$$

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