



ACE
ESE | GATE | PSUs

CIVIL ENGINEERING

HYDROLOGY

Volume - 1 : Study Material with Classroom Practice Questions



Hydrology

Solutions for Volume : I Classroom Practice Questions

Chapter- 1 Precipitation

01. Ans: (d)

Sol: Existing no. of rain gauge stations $m = 6$

Average depth of rainfall $\bar{P} = 92.8 \text{ cm}$

Standard deviation of rainfall $\sigma = 30.7 \text{ cm}$

Allowable error (E) = 10%

Optimum no. of rain gauge stations,

$$n = \left[\frac{C_v}{E} \right]^2$$

$$C_v = \frac{100\sigma}{\bar{P}} = \frac{100 \times 30.7}{92.8} = 33.08\%$$

$$n = \left[\frac{C_v}{E} \right]^2 = \left[\frac{33.08}{10} \right]^2 = 10.94 \approx 11 \text{ No's}$$

02. Ans: (b)

Sol: $n = 5$; $C_v = 33\%$

$$\therefore n = \left[\frac{C_v}{E} \right]^2 \Rightarrow 5 = \left[\frac{33}{E} \right]^2$$

$$E = 14.758\%$$

$$\% \text{ Accuracy} = 100 - \% \text{ error}$$

$$= 100 - 14.758$$

$$= 85.24\%$$

03. Ans: (d)

Sol: $\therefore N_A = N_C = N_B \pm 10\% N_B$

\therefore Simple mean method is used

$$P_B = \frac{P_A + P_C}{2} = \frac{153.0 + 145.0}{2} = 149 \text{ cm}$$

04. Ans: 1093.43

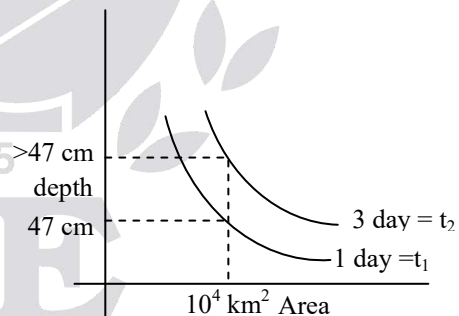
$$\text{Sol: } P_p = \frac{N_p}{m} \left[\frac{P_Q}{N_Q} + \frac{P_R}{N_R} + \frac{P_S}{N_S} \right]$$

$$860 = \frac{780}{3} \left[\frac{930}{850} + \frac{1010}{920} + \frac{P_S}{980} \right]$$

$$P_S = 1093.43 \text{ mm}$$

05. Ans: (b)

Sol:



For 3 day storm

Average depth > depth of one day storm

> 47 cm



06. Ans: (c)

Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-1, 30th Question - pg: 294)

07. Ans: (c)

Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-1, 12th Question - pg: 291)

09. Ans: (d)

Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-1, 10th Question - pg: 291)

10. Ans: (c)

Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-1, 29th Question - pg: 294)

11. Ans: (b)

Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-1, 35th Question - pg: 295)

Chapter- 2 Mean Precipitation Calculation

01. Ans: (a)

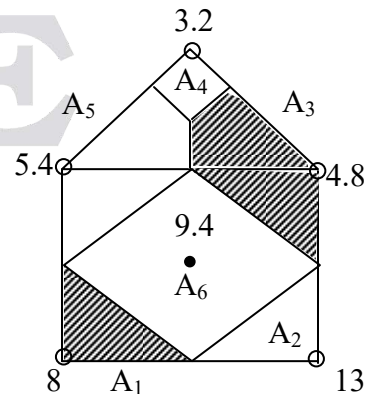
$$\begin{aligned} \text{Sol: } \bar{P} &= \frac{P_A A_A + P_B A_B + P_C A_C + P_D A_D}{A_A + A_B + A_C + A_D} \\ &= \frac{3 \times 75 + 5 \times 125 + 4 \times 150 + 6 \times 150}{75 + 125 + 150 + 150} \\ &= 4.7 \text{ cm} \end{aligned}$$

02. Ans: (b)

$$\begin{aligned} \text{Sol: } \bar{P} &= P_A \times \frac{A_A}{A} + P_B \times \frac{A_B}{A} + P_C \times \frac{A_C}{A} + P_D \times \frac{A_D}{A} \\ \frac{A_D}{A} &= 1 - \left(\frac{A_A}{A} + \frac{A_B}{A} + \frac{A_C}{A} \right) \\ &= 1 - (0.1 + 0.2 + 0.3) = 0.4 \\ \bar{P} &= 10 \times 0.1 + 15 \times 0.2 + 20 \times 0.3 + 25 \times 0.4 \\ &= 20 \text{ cm} \end{aligned}$$

03. Ans: (a)

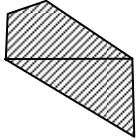
Sol:



$$A = 4 \times 4 + \frac{\sqrt{3}}{4} (4)^2 = 22.928 \text{ km}^2$$



$$A_1 = A_2 = \frac{1}{2} \times 2 \times 2 = 2 \text{ km}^2$$



$$A_3 = A_5 = \frac{1}{2} \times 2 \times 2 + \frac{1}{3} \times \frac{\sqrt{3}}{4} \times (4)^2 = 4.309 \text{ km}^2$$

$$A_4 = \frac{1}{3} \times \frac{\sqrt{3}}{4} (4)^2 = 2.308 \text{ km}^2$$



$$A_6 = \sqrt{8} \times \sqrt{8} = 8 \text{ km}^2$$

$$\bar{P} = \frac{P_1 A_1 + P_2 A_2 + P_3 A_3 + P_4 A_4 + P_5 A_5 + P_6 A_6}{A}$$

$$\bar{P} = \frac{8 \times 2 + 13 \times 2 + 4.8 \times 4.309 + 3.2 \times 2.309 + 5.4 \times 4.309 + 9.4 \times 8}{22.928}$$

$$\bar{P} = 7.35 \text{ cm}$$

04. Ans: (b)

Sol:

$$\bar{P} = \frac{A_1 \left[\frac{P_1 + P_2}{2} \right] + \dots + A_{n-1} \left[\frac{P_{n-1} + P_n}{2} \right]}{A}$$

$$\bar{P} = \frac{92 \left[\frac{15+12}{2} \right] + 128 \left[\frac{12+9}{2} \right] + 120 \left[\frac{9+6}{2} \right] + 175 \left[\frac{6+3}{2} \right] + 85 \left[\frac{3+1}{2} \right]}{600}$$

$$= 7.4 \text{ cm}$$

05. Ans: (b)

Sol:

$$\begin{aligned} & 30 \times 12 + 140 \times \left(\frac{12+10}{2} \right) + 80 \times \left(\frac{10+8}{2} \right) \\ & + 180 \times \left(\frac{8+6}{2} \right) + 20 \left(\frac{6+4}{2} \right) \\ \bar{P} = & \frac{\quad}{30 + 140 + 80 + 180 + 20} \\ & = 8.84 \text{ cm} \end{aligned}$$

Note: Formula same as earlier problem

08. Ans: (c)

Sol: $P_1 = 45 \text{ cm}$,

$P_2 = 55 \text{ cm}$,

$P_3 = 65 \text{ cm}$

$$\bar{P} = \frac{A_1 \left[\frac{P_1 + P_2}{2} \right] + A_2 \left[\frac{P_2 + P_3}{2} \right]}{A}$$

$$= \frac{100 \left[\frac{45 + 55}{2} \right] + 150 \left[\frac{55 + 65}{2} \right]}{100 + 150}$$

$$= 56 \text{ cm}$$

09. Ans: (c)

Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-1, 5th Question - pg: 290)

10. Ans: (100 cm)

Refer previous ESE-Conv-(Vol-2) solutions Book (Cha-2, 6th Question - pg: 213)



Chapter - 3
Frequency of Point
Rainfall & Probability

01. Ans: (i) 2.5, (ii) 2, (iii) 1.25

Sol: Return period (T) for a magnitude listed at a position “m” in a total of ‘n’ entries is

$$T = \frac{n+1}{m}$$

Arrange all flood data in descending order and allot rank to each flood (i.e)

Annual peak flood (m ³ /s)	Rank
130	1
120	2
100	3
80	4
75	5
70	6
60	7
50	8
40	9

(i) Return period of flood 80 m³/sec = $\frac{9+1}{4}$
= $\frac{10}{4} = 2.5$

(ii) Return period of flood 75 m³/sec = $\frac{9+1}{5} = 2$

(iii) Return period of flood 50 m³/sec = $\frac{9+1}{8}$
= $\frac{10}{8} = 1.25$

02. Ans: (d)

Sol: T = 20 years

$$\therefore p = \frac{1}{T} = \frac{1}{20} = 0.05$$

n = 12 years

$$q = 1 - p = 1 - 0.05 = 0.95$$

Probability of occurring at least once

$$= 1 - q^n = 1 - 0.95^{12} = 45.96\% \approx 46\%$$

03. Ans: (c)

Refer previous GATE solutions Book
(Cha-1, 2nd Question-(1M) -pg: 641)

04. Ans: (a)

Sol: n = 50 yrs

T = 100 yrs

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

$$q = 1 - P = 1 - 0.01 = 0.99$$

$$\text{Risk} = 1 - (q)^n = 1 - (0.99)^{50}$$

$$= 0.395 = 39.5\%$$

05. Ans: (c)

Sol: Risk = 20% = 0.2; n = 10yrs, T = ?

$$\text{Risk} = 1 - (q)^n$$

$$0.2 = 1 - (q)^{10} \Rightarrow q = 0.9778$$

$$P = 1 - q = 0.022$$

$$T = \frac{1}{P} = \frac{1}{0.022} = 45.45 \approx 45 \text{ yrs}$$



06. Ans: (d)

Sol: For 6 cm rain fall

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

$$n = 10$$

(i) Hazen formula,

$$T = \frac{n}{m - 0.5}$$

$$T = \frac{10}{6 - 0.5} = \frac{10}{5.5} = \frac{20}{11}$$

(ii) By Weibull Formula

$$T = \frac{n+1}{m} = \frac{10+1}{6} = \frac{11}{6}$$

07. Ans: (d)

Sol: $T = 100$ yr

$$n = 2$$

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

$$q = 1 - P = 1 - 0.01 = 0.99$$

$$\text{Risk} = 1 - (q)^n = 1 - (0.99)^2 = 0.0199 = 1.99\%$$

08. Ans: (i) 0.025, (ii) 0.397, (iii) 0.975

Sol $T = 40$ years

$$(i) p = \frac{1}{T} = \frac{1}{40} = 0.025$$

$$q = 1 - p = 1 - 0.025 = 0.975$$

(ii) At least once in next 20 years

$$\text{Risk} = (1 - q^n) = 1 - 0.975^{20}$$

$$= 0.3973$$

$$R = 39.73\%$$

(iii) Probability of occurring of flood magnitude less than $4000 \text{ m}^3 / \text{sec}$

Probability of not occurring a flood of magnitude $\geq 4000 \text{ m}^3 / \text{sec}$

$$q = 0.975$$

09. Ans: (b)

Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-1, 24th Question - pg: 293)

10. Ans: (d)

Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-1, 2nd Question - pg: 290)

11. Ans: (c)

Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-1, 25th Question - pg: 294)

12. Ans: (d)

Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-1, 34th Question - pg: 295)

13. Ans: (c)

Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-1, 42nd Question - pg: 296)



14. Ans: (3574.6 m³/sec)

Refer previous ESE-Conv-(Vol-2) solutions Book (Cha-1, 04th Question - pg: 244)

Chapter - 4
Evaporation & Evapotranspiration

01. Ans: 5.157

Sol: Depth of water removed,

$$Z = \frac{4.2 \times 10^{-3}}{\frac{\pi}{4}(1.22)^2} \times 1000 = 3.592 \text{ mm}$$

Pan evaporation

$$E = P \pm Z = 8.75 - 3.592 = 5.157 \text{ mm}$$

02. Ans: 11.94 mm & 8.35 mm

Sol: Depth of water added

$$(Z) = \frac{8.75 \times 10^{-3}}{\frac{\pi}{4}(1.2)^2} \times 1000 = 7.736 \text{ mm}$$

Pan evaporation, $E = p \pm Z$

$$= 4.2 + 7.736$$

$$= 11.936 \text{ mm (+Z} \rightarrow \text{water added)}$$

$$- Z \rightarrow \text{water removed)}$$

(Actual evaporation = $C_p \times$ pan evaporation)

$$= 0.7 \times 11.936$$

$$= 8.35 \text{ mm}$$

03. Ans: 61.08

Sol: Increase in storage

$$= 103.258 - 103.2 = 0.058 \text{ m}$$

$$\sum I - \sum O = \pm \Delta S = +\Delta S$$

($\therefore + \rightarrow$ increase)

$$[I+P] - [O+E+S] = +\Delta S$$

$$\left[\frac{6 \times 30 \times 24 \times 60 \times 60}{5000 \times 10^4} \times 1000 + 145 \right]$$

$$- \left[\frac{6.5 \times 30 \times 24 \times 60 \times 60}{5000 \times 10^4} \times 1000 - E + 0 \right]$$

$$= 0.058 \times 1000$$

$$[456.04] - [336.96 - E] = 0.058 \times 1000$$

$$E = 61.08 \text{ mm}$$

\therefore Evaporation loss in that month

$$E = 61.08 \text{ mm}$$

04. Ans: (d)

Sol: $\sum I - \sum O = \pm \Delta S$

Plan area of reservoir = 1 km²

$$= 1 \times 100 = 100 \text{ ha}$$

$$= \left[10 + \frac{3}{100} \times 100 \right] - \left[20 + \frac{12 \times 0.7}{100} \times 100 + \text{seepage} \right]$$

$$= \frac{-20}{100} \times 100$$

$$[\text{inflow} + \text{Precipitation}] - [\text{outflow} + \text{Evaporation} + \text{seepage}]$$

$$(\text{Ha.m}) \quad (\text{Ha.m}) \quad (\text{Ha.m}) \quad (\text{Ha.m}) \quad (\text{Ha.m})$$

= change in storage

(Ha.m)

$$[10 + 3] - [20 + 8.4 + \text{seepage}] = -20$$

\therefore seepage loss = 4.6 Ha.m

Note: All values substitute in above equation in Ha.m



05. Ans: (a)

Sol: $R = 200 \text{ watt/m}^2$

$$L = 2441 \text{ kJ/kg} = 2441 \times 10^3 \text{ J/kg};$$

$$\rho_w = 997 \text{ kg/m}^3$$

$$E = \frac{R}{\rho_w L} = \frac{200}{997 \times 2441 \times 10^3}$$

$$= 8.218 \times 10^{-8} \text{ m/sec}$$

$$\approx 7.1 \text{ mm/day}$$

06. Ans: (c)

Sol: $P = 7.2\%$,

$$T_m = 18^\circ\text{C},$$

$$K = 0.7$$

Consumptive use

$$= \text{PET} = \frac{KPT_m}{100} \times 25.4 \text{ cm/month}$$

$$\text{PET} = \frac{0.7 \times 7.2 \times (1.8 \times 18 + 32)}{100} \times 25.4 \frac{\text{mm}}{\text{month}}$$

$$= 82.44 \text{ mm/month}$$

\therefore consumptive use

$$\text{PET} = \frac{82.44}{30} = 2.74 \text{ mm/day}$$

07. Ans: (a)

Sol: $K = \frac{\text{consumptive use}}{\text{pan evaporation}}$

$$0.52 = \frac{\text{consumptive use}}{9.5}$$

$$\text{Consumptive use} = 9.5 \times 0.52$$

$$= 4.94 \text{ cm/month}$$

January no. of days = 31

Consumptive use

$$= 4.94 \times \frac{10}{31} \approx 1.6 \text{ mm/day}$$

08. Ans: (c)

Sol: Indian standard pan

$$\therefore C_p = 0.8$$

Pan evaporation = 4.0 cm

Actual evaporation from reservoir

$$= C_p \times \text{pan evaporation}$$

$$= 0.8 \times 4 = 3.2 \text{ cm}$$

Volume of water evaporated = plan area of reservoir \times actual evaporation loss

$$= 100 \times \frac{3.2}{100} \times 10^4 = 3.2 \times 10^4 \text{ m}^3 / \text{day}$$

09. Ans: (d)

Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-2, 08th Question - pg: 306)

11. Ans: (d)

Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-2, 10th Question - pg: 306)

12. Ans: (d)

Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-2, 04th Question - pg: 305)

13. Ans: (a)

Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-2, 3rd Question - pg: 305)



**Chapter - 5
Infiltration**

01. Ans: (a)

Sol: $f < f_c$ when $i < f_c$

02. Ans: (b)

Sol: Hydraulic conductivity of soil

$$f_c = 0.2 \text{ cm/hr}$$

$$i = 0.5 \text{ cm/hr} \quad [\because i > f_c]$$

$$f_a = f_c = 0.2 \text{ cm/hr}$$

03. Ans: (d)

Sol: $f_t = f_c + (f_0 - f_c) e^{-kt}$

$$f_t = 1.34 + (7.62 - 1.34)e^{-4.182t}$$

$$f_2 = 1.34 + (7.62 - 1.34)e^{-4.182 \times 2} = 1.34$$

$$f_2 = f_c$$

\therefore steady state attained

Total infiltration in 2hrs

$$= f_c \times t + \frac{f_0 - f_c}{K}$$

$$= 1.34 \times 2 + \frac{7.62 - 1.34}{4.182} = 4.18 \text{ cm}$$

04. Ans: 4.375

Sol:

$$f_0 = 2 \text{ cm/hr}; f_c = 0.5 \text{ cm/hr}; K = 4 \text{ hr}^{-1}$$

$$\text{Infiltration in 8hr} = f_c \times t + \frac{f_0 - f_c}{K}$$

$$= 0.5 \times 8 + \frac{1.5}{4} = 4.375 \text{ cm}$$

05. Ans: 40320 m³

Sol: In 24 hrs Rainfall = 10 cm

$$\text{In 24 hrs evaporation} = C_p \times \text{pan}$$

$$\text{evaporation}$$

$$= 0.7 \times 0.6$$

$$\text{In 24 hrs infiltration} = f_c \times t + \frac{f_0 - f_c}{K}$$

$$= 0.3 \times 24 + \frac{1 - 0.3}{5}$$

$$= 7.34 \text{ cm}$$

$$\text{Run off} = P - E - I$$

$$\text{Runoff (R)} = 10 - (0.7 \times 0.6) - 7.34 = 2.24 \text{ cm}$$

$$\text{Depth of runoff} = 2.24 \text{ cm}$$

$$\text{Volume of runoff}$$

$$= \text{Area of catchment} \times \text{depth of Runoff}$$

$$= 1.8 \times (1000)^2 \times \frac{2.24}{100}$$

$$= 40320 \text{ m}^3$$

06. Ans: 10.71 mm /hr & 11.31 mm/hr

Sol: $f_c = 6 \text{ mm/hr}; f_0 = 16 + 6 = 22 \text{ mm/hr};$

$$K = 2 \text{ hr}^{-1}$$

Depth of infiltration in first 45 min

$$\text{i.e., } t = \frac{45}{60} \text{ hr} = 0.75 \text{ hr}$$

$$= \int_0^{0.75} (6 + 16e^{-2t}) dt$$

$$= 6[t]_0^{0.75} + \frac{16}{-2} [e^{-2t}]_0^{0.75}$$

$$= 6 \times 0.75 - 8[e^{-2 \times 0.75} - e^{-2 \times 0}]$$

$$= 10.71 \text{ mm}$$

Avg. Infiltration rate for first 75 min



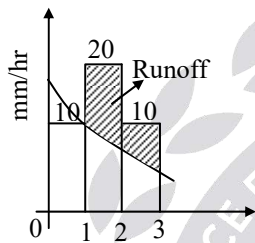
$$\left(t = \frac{75}{60} = 1.25 \text{ hr} \right)$$

$$= \int_0^{1.25} \frac{f_t \cdot dt}{\text{time}} = \frac{1}{1.25} \left[6 \times (t)_0^{1.25} + \frac{16}{-2} [e^{-2t}]_0^{1.25} \right]$$

$$= 11.31 \text{ mm/hr}$$

07. Ans: (d)

Sol: Runoff = Area of hietograph above IC curve



Area of hietograph above IC curve

$$= \left[\text{Total area of hietograph between 1hr to 3hr} \right] - \left[\text{Area below IC curve between 1hr to 3hr} \right]$$

$$= [20 \times 1 + 10 \times 1] - \int_1^3 f_t \cdot dt$$

$$= 30 - \left[\int_1^3 (6.8 + 8.7e^{-t}) dt \right]$$

$$= 30 - \left[6.8 \times (t)_1^3 + \frac{8.7}{-1} [e^{-t}]_1^3 \right]$$

$$= 30 - [6.8 \times [3 - 1] - 8.7 [e^{-3} - e^{-1}]]$$

$$= 13.63 \text{ mm}$$

08. Ans: 0.42 hr^{-1}

Sol: $f_0 = 10 \text{ mm/hr}$

$$f_c = 1.2 \text{ mm/hr}$$

Total infiltration = 33 mm

$$\text{Total infiltration} = f_c \times t + \frac{f_0 - f_c}{K}$$

$$33 = 1.2 \times 10 + \frac{10 - 1.2}{K}$$

$$K = 0.419 \text{ hr}^{-1}$$

09. Ans: (b)

Sol: $\phi_{\text{index}} = 0.5 \text{ cm/h}$

$$P = 2 \text{ cm}; \quad T = 6 \text{ hour}$$

Given, Uniform rate $R = ?$

$$W_{\text{index}} = \frac{P - R - \text{losses}}{t}$$

$$0.50 = \frac{2 - R - 0}{6}$$

$$R = -1 \text{ cm}$$

Runoff = 0 cm

10. Ans: (d)

Sol: The total observed runoff volume

$$= 25.2 \times 10^6 \text{ m}^3$$

$$\text{Area of basin} = 280 \text{ km}^2$$

Rainfall intensity = 4hr

Duration of rain = 4 hr

$$\text{Total rainfall in 4hr, } P = 2.8 \times 4 = 11.2 \text{ cm}$$

Runoff depth (R)

$$= \frac{25.2 \times 10^6}{280 \times (1000)^2} \times 100 = 9 \text{ cm}$$

Average infiltration

$$= \frac{P - R}{t} = \frac{11.2 - 9}{4} = 0.55 \text{ cm/hr}$$

$$= 5.5 \text{ mm/hr}$$



11. Ans: (a)

$$\text{Sol: } \phi_{\text{index}} = \frac{P_{e_1} - R_1}{t_{e_1}} = \frac{P_{e_2} - R_2}{t_{e_2}}$$

$$\Rightarrow \frac{4-2}{4} = \frac{10-R_2}{8} \Rightarrow R_2 = 6 \text{ cm}$$

Linked answer questions for 12 & 13

12. Ans: (a)

Sol: Storm - I

$$i_e = 2 \text{ cm/hr}$$

$$t_e = 5 \text{ hr, } R = 4 \text{ cm}$$

$$P_e = i_e t_e = 2 \times 5 = 10 \text{ cm}$$

$$\phi_{\text{index}} = \frac{P_e - R}{t_e} = \frac{10-4}{5} = 1.2 \text{ cm/hr}$$

13. Ans: (d)

Sol: $R_2 = 8.4 \text{ cm}$; $\phi = 1.2 \text{ cm/hr}$; $t_e = 8 \text{ hr}$

$$\phi = \frac{P_{e_2} - R_2}{t_{e_2}} = \frac{P_{e_2} - 8.4}{8} \Rightarrow P_{e_2} = 18 \text{ cm}$$

$$\text{Intensity} = \frac{P}{t} = \frac{18}{8} = 2.25 \text{ cm/hr}$$

14. Ans: (c)

Sol: $P = 7 + 18 + 25 + 17 + 11 + 3$

$$P = 81 \text{ cm}$$

$$W_{\text{index}} = \frac{P - R - \text{losses}}{t}$$

$$= \frac{81 - 39}{6} = 7 \text{ mm/hr}$$

$$\phi_{\text{index}} > W_{\text{index}}$$

$$\therefore 8 \text{ mm/h} > 7 \text{ mm/h}$$

$$\phi_{\text{index}} = 8 \text{ mm/h}$$

15. Ans: (b)

Sol: W_{index} :

$$P = \sum i_1 \times t_1$$

$$P = [1.6 + 3.6 + 5 + 2.8 + 2.2 + 1] \times \frac{30}{60} = 8.1 \text{ cm}$$

$$t = 3 \text{ hr; } R = 3.6 \text{ cm}$$

$$W_{\text{index}} = \frac{P - R - \text{losses}}{t} = \frac{8.1 - 3.6 - 0}{3}$$

$$= 1.5 \text{ cm/hr}$$

ϕ_{index} :

$$\phi_{\text{index}} > W_{\text{index}}$$

$$P_e = [1.6 + 3.6 + 5 + 2.8 + 2.2] \times \frac{30}{60}$$

$$= 7.6 \text{ cm}$$

$$t_e = 2.5 \text{ hr; } R = 3.6 \text{ cm}$$

$$\phi_{\text{index}} = \frac{P_e - R}{t_e} = \frac{7.6 - 3.6}{2.5} = 1.6 \text{ cm/hr}$$

16. Ans: (a)

Sol: W_{index} :

$$P = 1.6 + 5.4 + 4.1 = 11.1 \text{ cm}$$

$$R = 4.7 \text{ cm, } t = 24 \text{ hr, losses} = 0.6 \text{ cm}$$

$$W_{\text{index}} = \frac{P - R - \text{losses}}{t} = \frac{11.1 - 4.7 - 0.6}{24}$$

$$= 0.241 \text{ cm/h}$$

ϕ_{index} :

$$\phi_{\text{index}} > W_{\text{index}}$$

$$P_e = [5.4 + 4.1] = 9.5 \text{ cm}$$

$$t_e = 16 \text{ hr}$$

$$\phi_{\text{index}} = \frac{P_e - R}{t_e} = \frac{9.5 - 4.7}{16} = 0.3 \text{ cm/hr}$$



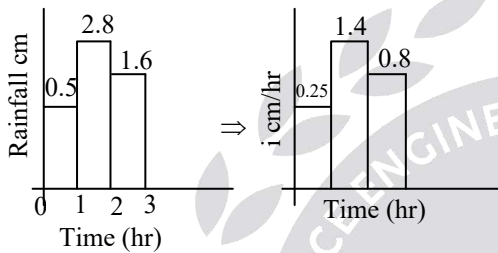
17. Ans: (c)

Sol: W_{index} :

$$P = \sum i_i t_i = 0.5 + 2.8 + 1.6 = 4.9 \text{ cm}$$

$$R = 3.2 \text{ cm}$$

$$W_{index} = \frac{P - R - \text{losses}}{t} = \frac{4.9 - 3.2 - 0}{6} = 0.283 \text{ cm/hr}$$



ϕ_{index} :

$$P_e = 1.4 \times 2 + 0.8 \times 2 = 4.4 \text{ cm}$$

$$t_e = 4 \text{ hr}, R = 3.2 \text{ cm}$$

$$\phi_{index} = \frac{P_e - R}{t_e} = \frac{4.4 - 3.2}{4} = 0.3 \text{ cm/hr}$$

18. Ans: (c)

Sol: $\phi_{index} = 10 \text{ mm/hr}$

$$P_e = i_e \times t_e \quad (i_e \rightarrow i > \phi_{index})$$

$$= 28 \times 1 + 12 \times 1 = 40 \text{ mm}$$

$$t_e = 2 \text{ hr}$$

$$\phi_{index} = \frac{P_e - R}{t_e} \Rightarrow 10 = \frac{40 - R}{2} = 20 \text{ mm}$$

19. Ans: (c)

Refer previous GATE - solutions Book
(Cha-4, (2M) 3rd Question -pg: 657)

20. Ans: (d)

Refer previous ESE-Obj-(Vol-2)
solutions Book (Cha-3, 11th Question
-pg: 310)

Chapter - 7 Hydrographs

01. Ans: (d)

Sol: Volume of runoff = Area of DRH

$$= \frac{1}{2} \times 80 \times 200 \times 60 \times 60$$

$$= 28.8 \times 10^6 \text{ m}^3$$

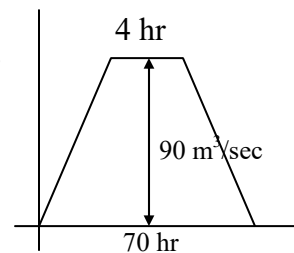
$$\text{Runoff depth} = \frac{\text{Volume of runoff}}{\text{Area of catchment}}$$

$$= \frac{28.8 \times 10^6}{1440 \times 10^6} \times 100$$

$$= 2 \text{ cm}$$

02. Ans: (b)

Sol: Area of catchment = $\frac{\text{Volume of Runoff}}{\text{depth of Runoff}}$

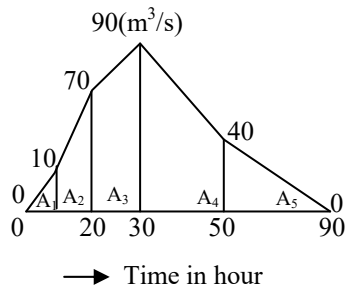


$$\frac{\left[\frac{70 + 4}{2} \right] \times 60 \times 60 \times 90}{\frac{2}{100} \times (1000)^2} = 599.4 \text{ km}^2$$



03. Ans: (d)

Sol:



$$A_1 = \frac{1}{2} \times 10 \times 10 \times 60 \times 60 = 50 \times 60 \times 60$$

$$A_2 = \left[\frac{10 + 70}{2} \right] \times 10 \times 60 \times 60 = 400 \times 60 \times 60$$

$$A_3 = \left[\frac{70 + 90}{2} \right] \times 10 \times 60 \times 60 = 800 \times 60 \times 60$$

$$A_4 = \left[\frac{90 + 40}{2} \right] \times 20 \times 60 \times 60 = 1300 \times 60 \times 60$$

$$A_5 = \left[\frac{1}{2} \times 40 \times 40 \times 60 \times 60 \right] = 800 \times 60 \times 60$$

$$A = A_1 + A_2 + A_3 + A_4 + A_5 = 3350 \times 60 \times 60$$

Rainfall excess = Runoff

$$= \frac{3350 \times 60 \times 60}{300 \times (1000)^2} \times 100 = 4.02 \text{ cm}$$

04. Ans: 2.67cm

Sol: Area of catchment = 50 km²

Time	4hr FHG ordinate (m ³ /sec)	Base flow (m ³ /sec)	4hr DRH ordinate (m ³ /sec)
0	6	6	0
6	18	6	12
12	30	6	24
18	24	6	18
24	12	6	6
30	8	6	2
36	6	6	0

Rainfall excess = Runoff depth

Depth of runoff = $\frac{\text{volume of run off}}{\text{area of catchment}}$

Volume of runoff = Area of DRH

$$= 6 \times 60 \times 60 \left[\frac{0+0}{2} + (12 + 24 + 18 + 6 + 2) \right] = 1339200 \text{ m}^3$$

$$\text{Depth of runoff} = \frac{1339200}{50 \times (1000)^2} \times 100 = 2.67 \text{ cm}$$

05. Ans: (c)

Sol: Volume of runoff = Area of DRH

$$= \frac{1}{2} \times 48 \times 300 \times 60 \times 60$$

$$= 25.92 \times 10^6 \text{ m}^3$$

$$\text{Runoff depth} = \frac{\text{Volume of runoff}}{\text{Area of catchment}}$$



$$\begin{aligned} \text{Area of catchment} &= \frac{25.92 \times 10^6}{\frac{1}{100}} \\ &= 2592 \text{ km}^2 \end{aligned}$$

06. Ans: (c)

Sol: Volume of runoff = Area of catchment

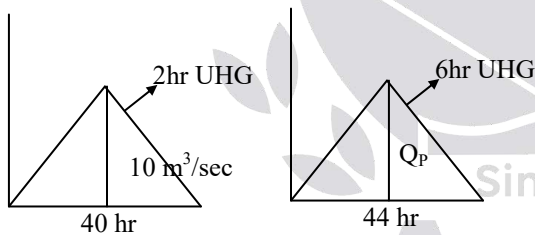
$$\begin{aligned} &= \frac{1}{2} \times Q \times 20 \\ &= 10 \times Q \end{aligned}$$

Runoff depth = $\frac{\text{Volume of runoff}}{\text{Area of catchment}}$

$$\begin{aligned} \frac{1}{100} &= \frac{10 \times Q}{500 \times 10^4} \\ Q &= 5000 \text{ m}^3/\text{h} \end{aligned}$$

07. Ans: 9.09 m³/sec

Sol:



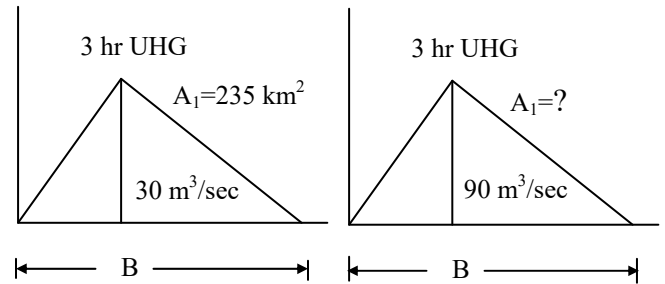
$$\frac{\frac{1}{2} \times 10 \times 40 \times 60 \times 60}{\frac{1}{100}} = \frac{\frac{1}{2} \times Q_p \times 44 \times 60 \times 60}{\frac{1}{100}}$$

$$10 \times 40 = 44 Q_p$$

$$Q_p = \frac{10 \times 40}{44} = 9.09 \text{ m}^3/\text{sec}$$

08. Ans: (d)

Sol:



Same base but peak has increased to 90 m³/sec
i.e., 3 times increase

∴ Area also increase to 3 times
 $A_2 = 3A_1 = 3 \times 235 = 705 \text{ km}^2$

09. Ans: (i) 39 m³/sec; (ii) 46 m³/sec

Sol:

Time	2hr UHG ordinate
0	0
1	5
2	15
3	12
4	10
5	6
6	0

Base flow = 7 m³/sec

$P_e = 4.2 \text{ cm}; t_e = 2 \text{ hr}$

$\phi_{\text{index}} = 0.8 \text{ cm/hr}$

$$\phi_{\text{index}} = \frac{P_e - R}{t_e} \Rightarrow 0.8 = \frac{4.2 - R}{2}$$

$R = 2.6 \text{ cm}$

Max. discharge of 2hr UHG = 15 m³/sec



(i) Max. discharge of 2hr DRH = UHG × R
= 15 × 2.6 = 39 m³/sec

(ii) Max. flood discharge = Max. DRH +
Base flow
= 39 + 7
= 46 m³/sec

10. Ans: a) 7.6 cm b) 40 m³/sec

Sol: Peak flood resulting for 6hr storm

$$= 150 \text{ m}^3/\text{sec}$$

$$\text{Base flow} = 6 \text{ m}^3/\text{sec}$$

$$\text{Peak flood of 6hr DRH} = 150 - 6 \\ = 144 \text{ m}^3/\text{sec}$$

$$\text{Peak ordinate of 6hr UHG} = 36 \text{ m}^3/\text{sec}$$

$$\text{Peak ordinate of 6hr DRH}$$

$$= \text{Peak ordinate of 6 hr UHG} \times R$$

a) $144 = 36 \times R$

$$R = \frac{144}{36} = 4 \text{ cm}; \phi = 6 \text{ mm/hr}$$

$$\phi = \frac{P_e - R}{t_e} \Rightarrow 6 = \frac{P_e - 40}{6}$$

$$\Rightarrow P_e = 76 \text{ mm}$$

$$P_e = 7.6 \text{ cm} = \text{depth of storm rainfall}$$

b) 15th hr

Time interval	6hr UHG
0	0
3	15
6	36
9	30
12	17.5
15	8.5

$$6\text{hr UHG ordinate at } 15^{\text{th}} \text{ hr} = 8.5 \text{ m}^3/\text{sec}$$

$$6\text{hr DRH ordinate at } 15^{\text{th}} \text{ hr}$$

$$= 6 \text{ hr UHG} \times R$$

$$= 8.5 \times 4 = 34 \text{ m}^3/\text{sec}$$

$$6\text{hr storm flow at } 15^{\text{th}} \text{ hr} = 34 + 6 = 40 \text{ m}^3/\text{sec}$$

11. Ans: (b)

Sol: $P_e = 2.7 \text{ cm}, t_e = 3\text{hr}, \phi = 0.3 \text{ cm/hr}$

$$\phi = \frac{P_e - R}{t_e} \Rightarrow 0.3 = \frac{2.7 - R}{3} \Rightarrow R = 1.8 \text{ cm}$$

$$\text{Peak of 3hr FHG} = 210 \text{ m}^3/\text{sec}$$

$$\text{Base flow} = 20 \text{ m}^3/\text{sec}$$

$$\text{Peak of 3hr DRH} = \text{Peak of 3hr FHG}$$

$$\text{Base flow} = 210 - 20$$

$$= 190 \text{ m}^3/\text{sec}$$

$$\text{Peak of 3hr}$$

$$\text{UHG} = \frac{\text{Peak of 3hr DRH}}{R} = \frac{190}{1.8}$$

$$= 105.55 \text{ m}^3/\text{sec}$$

12. Ans: 70 m³/sec

Sol: Peak of 6hr FHG = 470 m³/sec

$$P_e = 8 \text{ cm}$$

$$\phi = 0.25 \text{ cm/hr}; t_e = 6\text{hr}$$

$$\text{Base flow} = 15 \text{ m}^3/\text{sec}$$

$$\phi = \frac{P_e - R}{t_e} \Rightarrow \frac{8 - R}{6} = 0.25 \Rightarrow R = 6.5 \text{ cm}$$

$$\text{Peak of DRH} = \text{peak of FHG} - \text{Base flow}$$

$$= 470 - 15 = 455 \text{ m}^3/\text{sec}$$



$$\begin{aligned} \text{Peak of UHG} &= \text{Peak of } \frac{\text{DRH}}{R} \\ &= \frac{455}{6.5} = 70 \text{ m}^3/\text{sec} \end{aligned}$$

Linked answers (13 & 14)

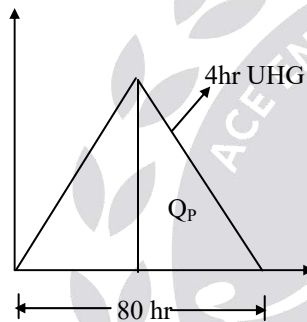
13. Ans: (b)

Sol: Area of catchment = 720 km²

Base flow = 30 m³/sec

$\phi_{\text{index}} = 1 \text{ mm/hr}$

$P_e = 4 \text{ cm}, t_e = 4 \text{ hr} = 40 \text{ mm}$



\therefore UHG runoff depth = 1 cm

Volume of runoff = Area of catchment \times
Depth of runoff

$$\frac{1}{2} \times Q_p \times 80 \times 60 \times 60 = 720 \times (1000)^2 \times \frac{1}{100}$$

$$Q_p = 50 \text{ m}^3/\text{sec}$$

14. Ans: (a)

$$\text{Sol: } \phi_{\text{index}} = \frac{P_e - R}{t_e} \Rightarrow 1 = \frac{40 - R}{4}$$

$$R = 36 \text{ mm} = 3.6 \text{ cm}$$

Peak ordinate of 4hr DRH = Peak ordinate
of 4hr UHG $\times R$

$$= 50 \times 3.6 = 180 \text{ m}^3/\text{sec}$$

Peak flood discharge = Peak DRH + Base flow

$$= 180 + 30 = 210 \text{ m}^3/\text{sec}$$

Common data for Q 15 & 16

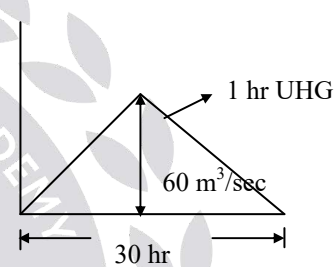
15. Ans: (c)

Sol: $\phi_{\text{index}} = 0.4 \text{ cm/hr}$

Base flow = 15 m³/sec

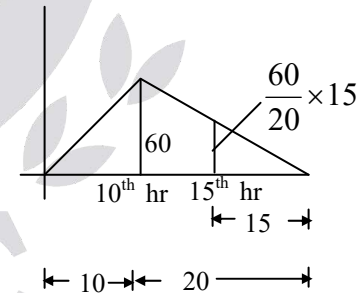
Area of catchment = $\frac{\text{Volume of Runoff}}{\text{depth of Runoff}}$

$$\begin{aligned} &= \frac{\frac{1}{2} \times 60 \times 30 \times 60 \times 60}{\frac{1}{100} \times (1000)^2} = 324 \text{ km}^2 \end{aligned}$$



16. Ans: (b)

Sol: $\phi_{\text{index}} = 0.4 \text{ cm/hr}$



At 15th hr time interval ordinate of 1 hr

$$\text{UHG} = \frac{60}{20} \times 15 = 4.5 \text{ m}^3/\text{sec}$$

$$\phi = \frac{P_e - R}{t_e} \Rightarrow 0.4 = \frac{5.4 - R}{1}$$

Ordinate of 1hr DRH

= ordinate of UHG $\times R$

$$= 4.5 \times 5 = 22.5 \text{ m}^3/\text{sec}$$



FHG ordinate at 15th hr
 = DRH + Base flow
 = 225 + 15 = 240 m³/sec

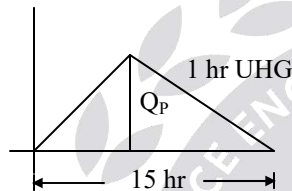
Common data for Q 17 & 18

17. Ans: (b)

Sol: Area watershed = 50 km²

Base flow = 10 m³/sec

φ Index = 0.5 cm/hr



Volume of Runoff = Area of water shed ×
 Runoff depth

$$\frac{1}{2} \times Q_p \times 15 \times 60 \times 60 = 50 \times (1000)^2 \times \frac{1}{100}$$

$$Q_p = 18.52 \text{ m}^3/\text{sec}$$

18. Ans: (d)

Sol: P_e = 5.5 cm

t_e = 1 hr

φ_{index} = 0.5 cm/hr

Peak ordinate of 1hr UHG = 18.52 m³/sec

Peak ordinate of 1hr DRH

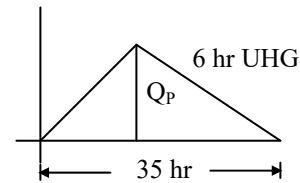
$$\begin{aligned} &= \text{Peak ordinate 1hr UHG} \times R \\ &= 18.52 \times 5 = 92.60 \text{ m}^3/\text{sec} \end{aligned}$$

Peak ordinate of 1hr SHG

$$\begin{aligned} &= \text{DRH} + \text{Base flow} \\ &= 92.60 + 10 \\ &= 102.6 \text{ m}^3/\text{sec} \end{aligned}$$

19. Ans: (c)

Sol: Area of catchment = 252 km²



$$\frac{1}{2} \times Q_p \times 35 \times 60 \times 60 = \text{Area} \times \text{depth of Runoff}$$

$$= 252 \times (1000)^2 \times \frac{1}{100}$$

$$Q_p = 40 \text{ m}^3/\text{sec}$$

Peak ordinate of 6hr UHG = 40 m³/sec

Peak ordinate of 6 hr DRH = Peak ordinate

$$\begin{aligned} &\text{of 6 hr UHG} \times R \\ &= 40 \times 5 = 200 \text{ m}^3/\text{sec} \\ &= 200 \text{ cumec} \end{aligned}$$

Common data for Q 21 & 22

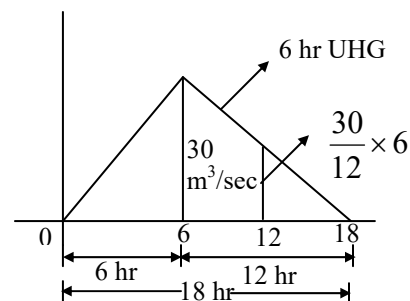
21. Ans: (b)

Sol: P_e = 16 cm, t_e = 12 hr

φ_{index} = 0.5 cm/hr

$$\phi_{\text{index}} = \frac{P_e - R}{t_e} \Rightarrow 0.5 = \frac{16 - R}{12}$$

$$R = 10 \text{ cm}$$





Time	6hr UHG ordinate	6hr lagged 6hr UHG	12hr DRH R=2 cm	12 hr UHG ordinate
0	0	-	0	0
6	30	0	30	15
12	15	30	45	22.5
18	0	15	15	7.5
		0	0	0

Peak discharge of 12hr UHG = 22.5 m³/sec

Peak discharge 12hr DRH

$$= \text{Peak discharge of 12 hr UHG} \times R$$

$$= 22.5 \times 10 = 225 \text{ m}^3/\text{sec}$$

22. Ans: (c)

Sol: Area of catchment

$$= \frac{\text{Volume of Runoff}}{\text{depth of runoff}}$$

$$= \frac{\frac{1}{2} \times 30 \times 18 \times 60 \times 60}{\frac{1}{100} \times 10^4} = 9720 \text{ ha}$$

Common data for Q 23 & 24

23. Ans: (d)

Sol: Catchment area = $\frac{\text{Volume of Runoff}}{\text{depth of Runoff}}$

$$= \frac{1 \times 60 \times 60 \left[\frac{0+0}{2} + (2+6+4+2+1) \right]}{\frac{1}{100} \times (1000)^2}$$

$$= 5.4 \text{ km}^2$$

24. Ans: (c)

Sol:

Time (hr)	1hr UHG ordinate (m ³ /sec)	1hr delayed 1 hr UHG ordinate (m ³ /sec)	2hr delay 1hr UHG (m ³ /sec)	3 hr DRH R = 3 cm (m ³ /sec)
0	0	-	-	0
1	2	0	-	2
2	6	2	0	8
3	4	6	2	12
4	2	4	6	12
5	1	2	4	7
6	0	1	2	3
		0	1	1

At time interval (t) = 3 hr

3hr DRH ordinate = 12m³/sec ; R = 3 cm

$$\begin{aligned} \text{3hr UHG ordinate} &= \frac{\text{3hr DRH ordinate}}{R} \\ &= \frac{12}{3} = 4 \text{ m}^3/\text{sec} \end{aligned}$$

25. Ans: (c)

Sol: $Q_{\text{equi}} = 2.778 \frac{A}{D}$

$$A = 270 \text{ km}^2$$

$$D = 3 \text{ hr}$$

$$Q = 2.778 \times \frac{270}{3} = 250 \text{ m}^3/\text{sec}$$

26. Ans: 160 m³/sec

Sol: $t_p = 64 \text{ hours}$

$$Q_p = 30 \text{ m}^3/\text{sec}$$

Volume of runoff = Area of DRH

$$= \frac{1}{2} \times 64 \times 30 \times 3600 = 3.456 \times 10^6 \text{ m}^3$$



$$\text{Runoff depth} = 1 \text{ cm} = 0.01 \text{ m}$$

$$\text{Runoff depth} = \frac{\text{Volume of runoff}}{\text{Area of catchment}}$$

$$\begin{aligned} \text{Area of catchment} &= \frac{3.456 \times 10^6}{0.01} \\ &= 345.6 \text{ km}^2 \end{aligned}$$

$$\text{Equilibrium discharge} = 2.778 \frac{\text{A}}{\text{D}}$$

$$Q_{\text{eq}} = 2.778 \times \frac{345.6}{6}$$

$$Q_{\text{eq}} = 160 \text{ m}^3/\text{sec}$$

27. Ans: 256 m³/sec

Sol:

Time	4H UHG ordinate	S-curve addition	S-curve ordinate (S _A)
0	0		0
2	6		6
4	33	0	33
6	90	6	96
8	119	33	152
10	103	96	199
12	79	152	231
14	50	199	249
16	25	231	256
18	7	249	256
20	0		

Common data for 29 & 30

29. Ans: (c)

$$\text{Sol: Area of catchment} = \frac{\text{Volume of Runoff}}{\text{depth of Runoff}} = \frac{\text{Area of UHG}}{\text{depth of Runoff}}$$

$$= \frac{1 \times 60 \times 60 \left[\frac{0+0}{2} + (3+8+6+3+2) \right]}{\frac{1}{100} \times (1000)^2} = 7.92 \text{ km}^2$$



30. Ans: (a)

Sol:

Time (hr)	2hr UHG Ordinate (m ³ /sec)	S-curve Additions (m ³ /sec)	S-curve Ordinates (m ³ /sec)	3hr lagged S-curve ordinate (m ³ /sec)	3hr DRH S _A -S _B (m ³ /sec)	3hr UHG $\frac{(S_A - S_B)^2}{3}$ (m ³ /sec)
0	0	→	0	-	0	0
1	3	→	3	-	3	2
2	8	→	8	-	8	16/3
3	6	3	9	0	9	6
4	3	8	11	3	8	16/3
5	2	9	11	8	3	2
6	0	11	11	9	2	4/3
		11	11	11	0	0

$$P_e = 6.6 \text{ cm} = 66 \text{ mm}$$

$$\phi_{\text{index}} = 2 \text{ mm/hr}$$

$$t_e = 3 \text{ hr}$$

$$\phi_{\text{index}} = \frac{P_e - R}{t_e}$$

$$\text{base flow} = 5 \text{ m}^3/\text{sec} \quad 2 = \frac{66 - R}{3}$$

$$\Rightarrow R = 60 \text{ mm} = 6 \text{ cm}$$

$$\text{Peak ordinate of 3hr UHG} = 6 \text{ m}^3/\text{sec}$$

$$\text{Peak ordinate of 3hr DRH} = \text{Peak ordinate 3hr UHG} \times R$$

$$= 6 \times 6$$

$$= 36 \text{ m}^3/\text{sec}$$

$$\text{Peak ordinate of 3hr SHG} = \text{Peak of 3hr DRH} + \text{Base flow}$$

$$= 36 + 5$$

$$= 41 \text{ m}^3/\text{sec}$$



Common Data for 31 & 32

31. Ans: (b)

Sol:

$$Q = 1 - (1+t)e^{-t}$$

$$\frac{1}{D} = 1 \text{ cm/hr} \Rightarrow D = 1 \text{ hr}$$

At $t = \infty$, $Q = E_{\text{equilibrium}}$

$$Q_{\text{equi}} = 1 - (1+\infty)e^{-\infty} = 1 \text{ m}^3/\text{sec}$$

$$\text{But } Q_{\text{equi}} = 2.778 \frac{A}{D}$$

$$1 = 2.778 \frac{A}{1}$$

$$\Rightarrow A = \frac{1}{2.778} = 0.36 \text{ km}^2$$

32. Ans: (c)

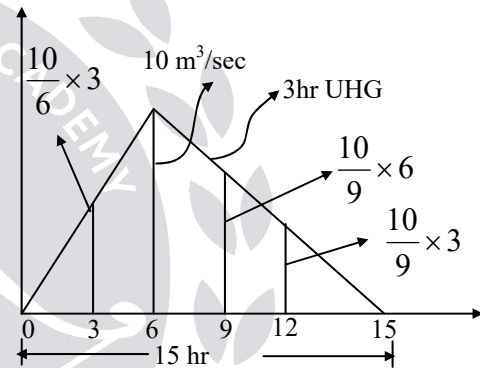
Time	S_A S-curve ordinates $Q = 1 - (1+t)e^{-t}$	S_B 2 hr delayed S-curve ordinate	2hr DRH ($S_A - S_B$)
0	0	-	
1	0.264	-	
2	0.593	0	
3	0.8	0.264	$0.8 - 0.264$ $= 0.536$

$$\begin{aligned} \text{2hr UHG ordinate} &= \frac{(S_A - S_B)D}{T} = \frac{0.536 \times 1}{2} \\ &= 0.27 \text{ m}^3/\text{sec} \end{aligned}$$

33. Ans: $43.33 \text{ m}^3/\text{sec}$

Sol:

Storm I	Storm II
$P_{e1} = 3.8 \text{ cm}$	$P_{e2} = 4.8 \text{ cm}$
$t_{e1} = 3 \text{ hr}$	$t_{e2} = 3 \text{ hr}$
$\phi = 0.6$	$\phi = 0.6$
$0.6 = \frac{3.8 - R_1}{3}$	$0.6 = \frac{4.8 - R_2}{3}$
$R_1 = 2 \text{ cm}$	$R_2 = 3 \text{ cm}$



Time	3hr UHG m^3/sec	I st storm $= \text{UHG} \times R_1$ m^3/sec	II nd storm $= \text{UHG} \times R_2$ m^3/sec	6hr H Ordinate m^3/sec
0	0	0	-	0
3	5	10	0	10
6	10	20	15	35
9	6.66	13.33	30	43.33
12	3.33	6.66	20	26.66
15	0	0	10	10
-	-	-	0	0

Peak discharge of resulting
DRH = $43.33 \text{ m}^3/\text{sec}$



34. Ans: 715 m³/sec

Sol: Ist storm

$$t_c = 6\text{hr}$$

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

$$\phi_{\text{index}} = 0.25\text{ cm/hr}$$

$$\phi = \frac{P_e - R_1}{t_c}$$

$$0.25 = \frac{3 - R_1}{6}$$

$$R_1 = 1.5\text{ cm}$$

IInd storm

$$t_c = 6\text{hr}$$

$$P_e = 5\text{ cm}$$

$$\phi_{\text{index}} = 0.25\text{ cm/hr}$$

$$\phi = \frac{P_e - R_2}{t_c}$$

$$0.25 = \frac{5 - R_2}{6}$$

$$R_2 = 3.5\text{ cm}$$

Time	6hr UHG	I st storm UHG×R ₁	II nd storm UHG×R ₂	12 hr DRH
0	0	0	-	0
6	20	30	0	30
12	60	90	70	160
18	150	225	210	435
24	120	180	525	705
30	90	135	420	
36	66	99	315	
42	50	75	231	
48	32	48	175	
54	20	30	112	
60	10	15	70	
66	0	0	35	
			0	



24th hr

DRH ordinate = $705 \text{ m}^3/\text{sec}$

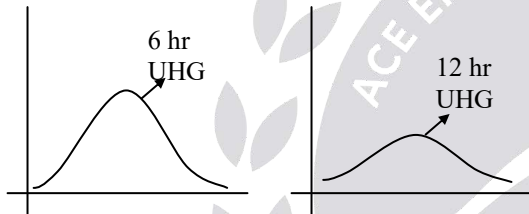
Base flow = $10 \text{ m}^3/\text{sec}$

Storm discharge = DRH + Base flow
 $= 705 + 10$
 $= 715 \text{ m}^3/\text{sec}$

35. Ans: (d)

Sol: 6 hr UHG peak ordinate = $30 \text{ m}^3/\text{sec}$
 Peak ordinate of 12hr UHG = ?

Explanation:



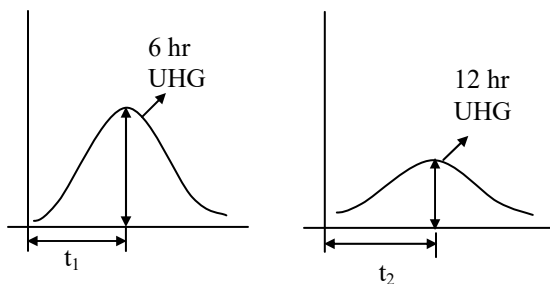
Storms of shorter duration produce more peak than storms of longer duration storm.

Peak of 12hr UHG < peak of 6hr UHG

\therefore Peak ordinate of 12hr UHG < $30 \text{ m}^3/\text{s}$

36. Ans: (c)

Sol: Time to peak for shorter duration storms occur much faster than time to peak for longer duration storm.



$t_1 < t_2$

37. Ans: (d)

Refer previous GATE - solutions Book
 (Cha-4, (1M) 1st Question -pg: 655)

38. Ans: (c)

Refer previous GATE - solutions Book
 (Cha-4, (1M) 4th Question -pg: 655)

39. Ans: (c)

Refer previous ESE-Obj-(Vol-2)
 solutions Book (Cha-4, 2nd Question -
 pg: 317)

40. Ans: (c)

Refer previous ESE-Obj-(Vol-2)
 solutions Book (Cha-4, 3rd Question
 -pg: 317)

41. Ans: (a)

Refer previous ESE-Obj-(Vol-2)
 solutions Book (Cha-4, 18th Question
 -pg: 320)

42. Ans: (d)

Refer previous ESE-Obj-(Vol-2)
 solutions Book (Cha-4, 20th Question
 -pg: 321)



43. Ans: (d)

Refer previous ESE-Obj-(Vol-2)
solutions Book (Cha-4, 22nd)
Question -pg: 321)

Chapter- 8
Maximum Flood Estimation

01. Ans: (d)

Sol: A = 90 ha

$$I = 4.5 \text{ cm/h} = 45 \text{ mm/h}$$

$$R = 0.40$$

$$Q = \frac{\text{AIR}}{360} = \frac{90 \times 45 \times 0.40}{360}$$

$$Q = 4.5 \text{ m}^3/\text{sec}$$

02. Ans: (a)

Refer previous ESE-Obj-(Vol-2)
solutions Book (Cha-5, 14th) Question
-pg: 340)

03. Ans: (b)

Sol: 30% → 0.40

$$70\% \rightarrow 0.60$$

$$I = \frac{\frac{30}{100} \times A \times 0.40 + \frac{70}{100} \times 0.60 \times A}{A}$$

$$I = 0.54$$

04. Ans: (d)

Sol: A = 1.5 km² = 150 Ha, I = 0.42

$$R = \frac{48}{28} \times 60 = 102.86 \text{ mm/h}$$

$$Q_p = \frac{\text{AIR}}{360}$$

$$= \frac{150 \times 0.42 \times (48/28) \times 60}{360}$$

$$= 18 \text{ m}^3/\text{sec}$$

05. Ans: (c)

Refer previous ESE-Obj-(Vol-2)
solutions Book (Cha-5, 13th) Question
-pg: 340)

06. Ans: 7.08 m³/s

Sol: I = 0.30

$$A = 0.85 \text{ km}^2 = 85 \text{ ha}$$

25 frequency → Culvert design for a rain
of 25 year frequency

$$\text{Duration of storm} = \text{time of concentration} \\ = 30 \text{ mins}$$

$$R = \frac{\text{depth of rainfall}}{\text{duration of rain}} = \frac{50}{30} \text{ mm/min}$$

$$R = 100 \text{ mm/h}$$

$$Q = \frac{\text{AIR}}{360} = \frac{85 \times 0.30 \times 100}{360}$$

$$Q = 7.083 \text{ m}^3/\text{sec.}$$

07. Ans: (c)

Refer previous GATE - solutions Book
(Cha-5, (2M) 1st) Question -pg: 670)



08. Ans: (b)
Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-5, 1st Question -pg: 338)

09. Ans: (a)
Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-5, 3rd Question -pg: 338)

10. Ans: (c)
Refer previous GATE - solutions Book (Cha-4, (1M) 2nd Question -pg: 655)

11. Ans: (c)
Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-5, 5th Question -pg: 338)

Chapter- 9
Flood Routing

02. Ans: (a)
Refer previous GATE - solutions Book (Cha-6, (1M) 3rd Question -pg: 671)

03. Ans: 17.748 m³/sec

Sol: $t_1 = 3$ hr, $t_2 = 4$ hr, $I_3 = 18$ m³/s,
 $I_4 = 42$ m³/s, $C_0 = 0.042$, $C_1 = 0.538$,
 $Q_3 = 15$ m³/s, $Q_4 = ?$,
 $C_2 = 1 - C_0 - C_1 = 1 - 0.042 - 0.538 = 0.42$

$$Q_4 = C_0 I_4 + C_1 I_3 + C_2 Q_3$$

$$= 0.042 \times 42 + 0.538 \times 18 + 0.42 \times 15$$

$$= 17.748 \text{ m}^3/\text{s}$$

04. Ans: 45.84 m³/sec

Sol: $C_0 = 0.048$, $C_1 = 0.429$, $C_2 = 0.523$

$$Q_1 = 0.048 \times 20 + 0.429 \times 10 + 0.523 \times 10$$

$$= 10.48 \text{ m}^3/\text{s}$$

$$Q_2 = 0.048 \times 40 + 0.429 \times 20 + 0.523 \times 10.48$$

$$= 15.98 \text{ m}^3/\text{s}$$

$$Q_3 = 0.048 \times 60 + 0.429 \times 40 + 0.523 \times 15.98$$

$$= 28.39 \text{ m}^3/\text{s}$$

$$Q_4 = 0.048 \times 50 + 0.429 \times 60 + 0.523 \times 28.39$$

$$= 42.98 \text{ m}^3/\text{s}$$

$$Q_5 = 0.048 \times 40 + 0.429 \times 50 + 0.523 \times 42.98$$

$$= 45.84 \text{ m}^3/\text{s}$$

$$Q_6 = 0.048 \times 30 + 0.429 \times 40 + 0.523 \times 45.84$$

$$= 42.57 \text{ m}^3/\text{s}$$

$$\text{Peak value} = 45.84 \text{ m}^3/\text{s}$$

05. Ans: (c)

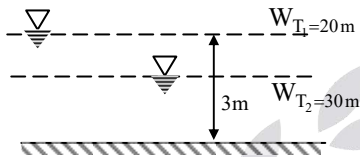
Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-6, 4th Question -pg: 344)



Chapter- 10
Well Hydraulics

01. Ans: (b)

Sol: $A = 150\text{Ha}$, $n = 0.4$, $S_r = 0.15$,
 $\Delta\text{GW} = ?$



$$\Delta\text{GW} = s_y \times \text{volume of aquifer}$$

$$S_y = n - S_r = 0.4 - 0.15 = 0.25$$

volume of aquifer = area of aquifer \times drop
in level of W.T.

$$\Delta\text{GW} = 0.25 \times 150 \times (23 - 20)$$

$$\Delta\text{GW} = 112.5 \text{ Ha.m}$$

= volume of water extracted.

02. Ans: (a)

Sol: Volume of GW extracted = $3 \times 10^6 \text{ m}^3$

$$\text{area} = 5\text{km}^2$$

$$\text{Drop in water table level} = 102 - 99 = 3\text{m}$$

Specific yield, $S_y = ?$

$$S_y = \frac{\text{volume of G.W extracted}}{\text{volume of aquifer}}$$

$$= \frac{3 \times 10^6}{5 \times 10^6 \times 3} = 0.2$$

03. Ans: (b)

Sol: $n = 0.3$, $S_y = 0.2$,

$$A = 100\text{km}^2, \Delta\text{WT} = 0.25\text{m}$$

Volume of GW extracted = ?

Volume of aquifer

$$= 100 \times 10^6 \times 0.25 = 25 \times 10^6 \text{ m}^3$$

$$\text{Volume of GW extracted} = S_y \times \text{Volume of aquifer} = 0.2 \times 25 \times 10^6 = 5 \times 10^6 \text{ m}^3 = 5\text{Mm}^3$$

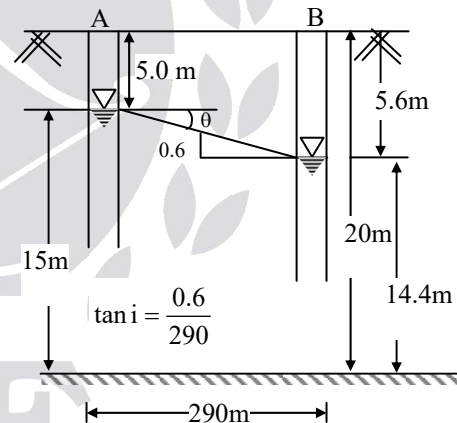
04. Ans: 0.105

Sol: Darcy's equation:

$$Q = KiA$$

$$V = Ki$$

$$V_d = \frac{V}{n}$$



(V = apparent or seepage velocity)

$$K = 4 \times 10^{-3} \text{ cm/sec.}$$

Q ($\text{m}^3/\text{day}/\text{m}$) width of aquifer = ?

$$Q = KiA$$

$$= \frac{4 \times 10^{-3} \times 10^{-2}}{1} \times \left(\frac{5.6 - 5}{290} \right) \times 1 \times \left(\frac{14.4 + 15}{2} \right)_{\text{avg.ht}}$$

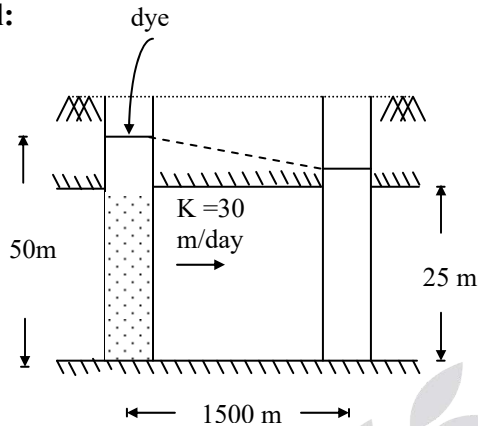
$$Q = 1.216 \times 10^{-6} \text{ m}^3/\text{s}$$

$$Q = 0.105 \text{ m}^3/\text{day}/\text{m}$$



05. Ans: (b)

Sol:



1500 m = Distance between wells.

$$h_1 = 50\text{m}, \quad h_2 = 25\text{m}$$

$$K = 30\text{ m/day}$$

$$n = 0.25$$

Time of travel = ?

Tracer = Will not loose power & never reacts with soil or water & it flows with water.

$$\text{Time} = \frac{\text{Distance traveled by tracer}}{\text{seepage velocity}}$$

$$V_a = \frac{V}{n}, \quad V = Ki,$$

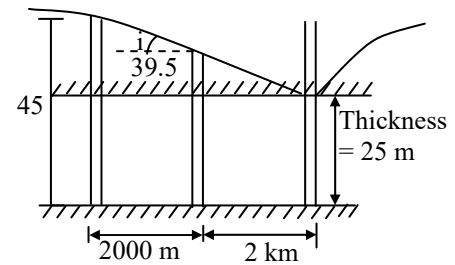
$$i = \frac{50 - 25}{1500} = 0.0167$$

$$K = 30 \times 0.0167 = 0.5\text{ m/day}$$

$$V_a = \frac{0.5}{0.25} = 2\text{ m/day}$$

$$\therefore \text{Time} = \frac{1500}{2} = 750\text{ days}$$

06. Ans: (i) 4125m³/day, (ii) 44.175 m



Width is taken perpendicular to the plane of paper area is taken as perpendicular to the direction of flow.

$$K = 30\text{ m/day}$$

$$i = \frac{5.5}{2000} = 2.75 \times 10^{-3}$$

$$Q = K \cdot i \cdot A$$

$$Q = 30 \times 2.75 \times 10^{-3} \times 2000 \times 25$$

$$Q = 4125\text{ m}^3/\text{day}$$

$$\frac{5.5}{2000} = \frac{x}{300}$$

$$x = 0.825\text{ m}$$

$$H = 45 - 0.825$$

$$H = 44.175\text{ m}$$

07. Ans: 270 m³/day

Sol: H = 40m, D_{well} = 30cm = 0.3m

$$Q = 1500\text{ lit/min}$$

$$= 1500 \times 10^{-3} \times 24 \times 60\text{ m}^3/\text{day}$$

$$= 2160\text{ m}^3/\text{day}$$

$$r_1 = 25\text{m}, r_2 = 75\text{m},$$

$$h_1 = 3.5\text{m}, h_2 = 2\text{m}, T = ?$$

draw down = ?

$$h_1 = 40 - 3.5 = 36.5\text{m}$$

$$h_2 = 40 - 2 = 38\text{m}$$



$$Q = \frac{\pi k [h_2^2 - h_1^2]}{\ln\left(\frac{r_2}{r_1}\right)}$$

$$\therefore k = \frac{Q \cdot \ln\left(\frac{r_2}{r_1}\right)}{\pi(h_2^2 - h_1^2)}$$

$$k = \frac{2160 \times \ln(75/25)}{\pi(38^2 - 36.5^2)} = 6.75 \text{ m/day}$$

\therefore Transmissibility, $T = K.H$

$$T = 6.75 \times 40 = 270 \text{ m}^2/\text{day}$$

08. Ans: 12.2 m/day

Sol: $H = 14.5\text{m}$, $r_1 = 16\text{m}$,

$$r_2 = 34\text{m},$$

$$s_1 = 2.2\text{m},$$

$$Q = 925 \text{ lit/min} = 925 \times 24 \times 60 \times 10^{-3} \\ = 1332 \text{ m}^3/\text{day}$$

$$S_1 = 2.45$$

$$S_2 = 1.20\text{m}$$

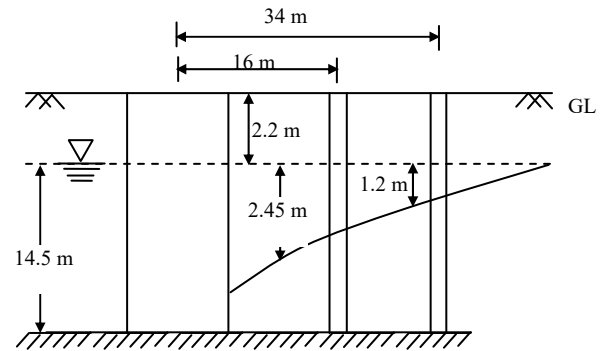
$$K = ?$$

$$h_1 = 14.5 - 2.45 \\ = 12.05\text{m} - 2.2 = 9.85\text{m}.$$

$$h_2 = 14.5 - 1.20 \\ = 13.3\text{m} - 2.2 = 11.1\text{m}.$$

$$Q = \frac{\pi k [h_2^2 - h_1^2]}{\ln[r_2/r_1]}$$

$$K = \frac{\ln[34/16] \times 1332}{\pi \times [11.1^2 - 9.85^2]} = 12.2 \text{ m/day}$$



09. Ans : (b)

Sol: Radius of well,

$$r = \frac{20}{2} = 10 \text{ cm} = 0.10 \text{ m}$$

$$\text{Discharge, } Q = 2720 \text{ lit/min} \\ = 3916.8 \text{ m}^3/\text{day}$$

$$\text{At } r_1 = 10 \text{ m, draw down, } S_1 = 3 \text{ m}$$

$$\text{At } r_2 = 100 \text{ m, draw down } S_2 = 0.5 \text{ m}$$

$$Q = \frac{2\pi K b (S_1 - S_2)}{\log_e\left(\frac{r_2}{r_1}\right)}$$

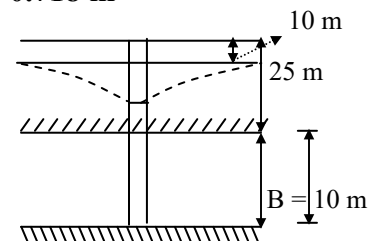
$$Q = \frac{2\pi T (S_1 - S_2)}{\log_e\left(\frac{r_2}{r_1}\right)} ; T = K.b$$

$$3916.8 = \frac{2\pi T (3 - 0.5)}{\log_e\left(\frac{100}{10}\right)}$$

$$\text{Transmissivity, } T = 574.4 \text{ m}^2/\text{day}$$

10. Ans: 0.718 m

Sol:





$$H = 10 + 25 - 10 = 25 \text{ m}$$

$$r_1 = r_w ; S_1 \rightarrow S$$

$$r_2 = R ; S_2 \rightarrow 0$$

$$\therefore Q = \frac{2\pi KB(S-0)}{\ln\left(\frac{R}{r_w}\right)}$$

$$\therefore \ln\left(\frac{500}{r_w}\right) = \frac{2\pi \times 48 \times 10 \times 12}{5000} = 7.238$$

$$\therefore r_w = 0.718 \text{ m}$$

11. Ans: (i) 10 lit/sec

Sol: $H_1 = 2.5 \text{ m}$, $H_1 - H_2 = 1.8 \text{ m}$, $t = 80 \text{ min}$,
 $d = 4 \text{ m}$

$$\therefore H_2 = 0.7 \text{ m}$$

(i) When, $H = 3 \text{ m}$, $C = 2.65 \times 10^{-4} \text{ 1/sec}$

$$Q = CAH = \frac{1}{t} \ln \frac{H_1}{H_2} \cdot A \cdot H$$

$$= \frac{1}{80 \times 60} \ln\left(\frac{2.5}{0.7}\right) \times \frac{\pi}{4} \times 4^2 \times 3$$

$$Q = 10 \text{ lit/sec}$$

12. Ans: (d)

Sol: $K = 1.96 \text{ cm/s} = 0.0196 \text{ m/s}$

$$v = 1 \times 10^{-6} \text{ m}^2/\text{s}$$

Intrinsic permeability, K_0 in darcy = ?

$$K_0 = \frac{Kv}{g} = \frac{0.0196 \times 1 \times 10^{-6}}{9.81 \times 9.87 \times 10^{-13}}$$

$$K_0 = 2024.27 \text{ m}^2 \approx 2026 \text{ m}^2$$

13. Ans: (d)

Refer previous ESE-Obj-(Vol-2)
solutions Book (Cha-7, 6th Question
-pg: 350)

14. Ans: (d)

Refer previous ESE-Obj-(Vol-2)
solutions Book (Cha-7, 11th
Question -pg: 359)

Chapter- 11 River Gauging

01. Ans: (a)

Sol: $V = aN_s + b$

$$\frac{12}{48} a + b = 0.125 \quad \text{--- (i)}$$

$$\frac{41}{60} a + b = 0.255 \quad \text{--- (ii)}$$

$$a = 0.3 \quad b = 0.05$$

$$\therefore V = 0.3 \times \frac{24}{50} + 0.05 = 0.194 \text{ m/s}$$

02. Ans: (b)

Sol: $Q_T = 4 \text{ lit/sec} = 4 \times 10^{-3} \text{ m}^3/\text{sec}$

$$C_T = 500 \times 10^3 \text{ mg/lit}$$

$$C_{\text{mix}} = 4 \text{ ppm} = 1 \text{ mg/lit}$$

$$Q_s = ?$$

$$C_{\text{mix}} = \frac{Q_s C_s + Q_T C_T}{Q_s + Q_T}$$

$$4 = \frac{0 + 4 \times 500 \times 10^3 \times 10^{-3}}{Q_s + 4 \times 10^{-3}}$$

$$Q_s = 500 \text{ m}^3/\text{sec}$$