



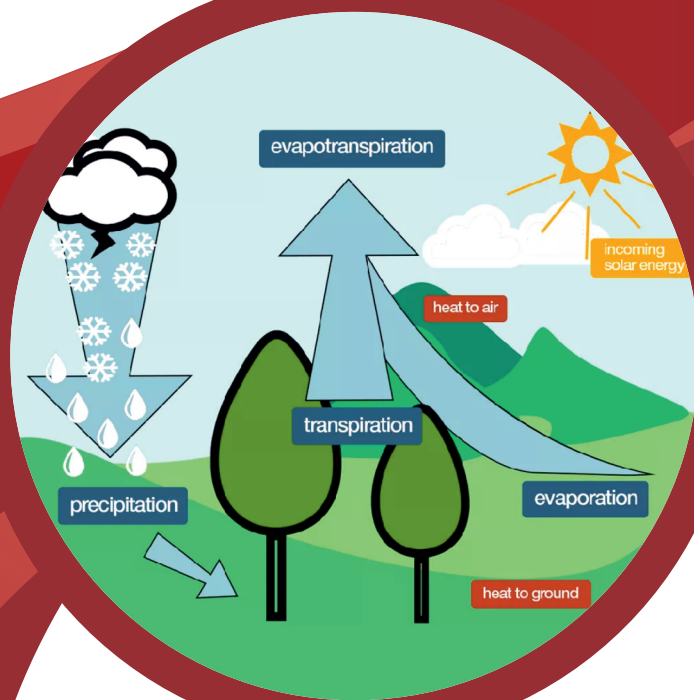
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(**Text Book** : Theory with worked out Examples
and Practice Questions)



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Hydrology

(Solutions for Text Book Practice Questions)

01. 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: (c)

Sol: Missing rain fall @ station $P_{III} = ?$

Missing rainfall

$$P_{III} = \frac{N_{III}}{m} \left[\frac{P_I}{N_I} + \frac{P_{II}}{N_{II}} + \frac{P_{IV}}{N_{IV}} \right]$$

$$P_{III} = \frac{80}{3} \left[\frac{90}{60} + \frac{60}{75} + \frac{70}{100} \right]$$

$$P_{III} = 80 \text{ cm}$$

04. Ans: 1093.43

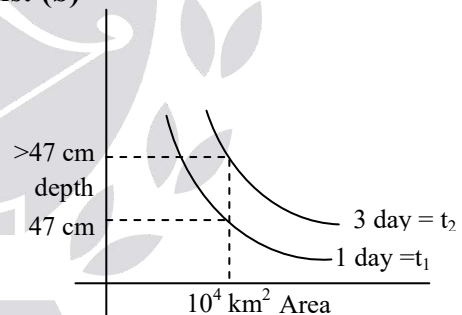
$$\text{Sol: } P_p = \frac{N_p}{m} \left[\frac{P_Q}{N_Q} + \frac{P_R}{N_R} + \frac{P_S}{N_S} \right]$$

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

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

05. Ans: (b)

Sol:



For 3 day storm

Average depth > depth of one day storm

> 47 cm

06. Ans: (c)

07. Ans: (a) & (d)

Sol: Stn	P	Q	R	S
N (cm)	50	48	46	40
P (mm)	$P_p = P_x = ?$	43	42	38

(-) 10% _____ $N_x = N_P = 50$ _____ (+) 10%



$N_s = 40$, is not within 10% of N_x , use normal ratio method

$$\frac{P_x}{N_x} = \frac{1}{m} \left[\frac{P_1}{N_1} + \frac{P_2}{N_2} + \dots + \frac{P_m}{N_m} \right]$$

$$\frac{P_p}{50} = \frac{1}{3} \left[\frac{43}{48} + \frac{42}{46} + \frac{38}{40} \right]$$

$$P_p = 45.98 \text{ mm}$$

08. Ans: (a) & (c)

02. Mean Precipitation Calculation

01. Ans: (a)

Sol:
$$\bar{P} = \frac{P_A A_A + P_B A_B + P_C A_C + P_D A_D}{A_A + A_B + A_C + A_D}$$

$$= \frac{3 \times 75 + 5 \times 125 + 4 \times 150 + 6 \times 150}{75 + 125 + 150 + 150}$$

$$= 4.7 \text{ cm}$$

02. Ans: (b)

Sol:
$$\bar{P} = P_A \times \frac{A_A}{A} + P_B \times \frac{A_B}{A} + P_C \times \frac{A_C}{A} + P_D \times \frac{A_D}{A}$$

$$\frac{A_D}{A} = 1 - \left(\frac{A_A}{A} + \frac{A_B}{A} + \frac{A_C}{A} \right)$$

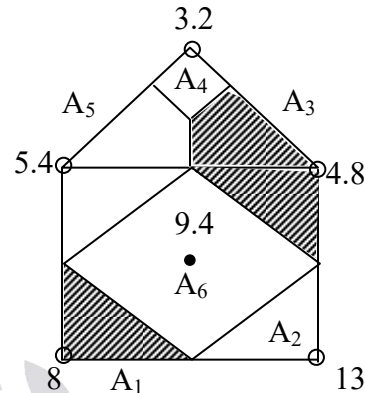
$$= 1 - (0.1 + 0.2 + 0.3) = 0.4$$

$$\bar{P} = 10 \times 0.1 + 15 \times 0.2 + 20 \times 0.3 + 25 \times 0.4$$

$$= 20 \text{ cm}$$

03. Ans: (a)

Sol:



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

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

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

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

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

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

$$= \frac{8 \times 2 + 13 \times 2 + 4.8 \times 4.309 + 3.2 \times 2.308 + 5.4 \times 4.309 + 9.4 \times 8}{22.928}$$

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

04. Ans: (c)

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

$P_2 = 55 \text{ cm}$,

$P_3 = 65 \text{ cm}$

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

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

$$= 56 \text{ cm}$$

05. Ans: (b)

Sol:

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

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

$$= 7.4 \text{ cm}$$

06. Ans: (b)

Sol:

$$30 \times 12 + 140 \times \left(\frac{12+10}{2} \right) + 80 \times \left(\frac{10+8}{2} \right)$$

$$+ 180 \times \left(\frac{8+6}{2} \right) + 20 \left(\frac{6+4}{2} \right)$$

$$\bar{P} = \frac{\quad}{30 + 140 + 80 + 180 + 20}$$

$$= 8.84 \text{ cm}$$

Note: Formula same as earlier problem

07 Ans: (b)

08 Ans: (c)

03. 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: For 6 cm rain fall

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

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

03. 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

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

04. Ans: (a)

Sol: $n = 50$ yrs

$T = 100$ yrs

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

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

$$\begin{aligned} \text{Risk} &= 1 - (q)^n = 1 - (0.99)^{50} \\ &= 0.395 = 39.5\% \end{aligned}$$

05. Ans: (c)

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

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

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

$$P = 1 - q = 0.022$$

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

06. Ans: (d)

Sol: $T = 100$ yr

$n = 2$

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

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

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

07. 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

$$\begin{aligned} \text{Risk} &= (1 - q^n) = 1 - 0.975^{20} \\ &= 0.3973 \end{aligned}$$

$$R = 39.73\%$$

(iii) Probability of occurring of flood

magnitude less than $4000 \text{ m}^3 / \text{sec}$

Probability of not occurring a flood of

magnitude $\geq 4000 \text{ m}^3 / \text{sec}$

$$q = 0.975$$

08. Ans: (c)

04. 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 = $C_p \times \text{pan evaporation}$)

$$= 0.7 \times 11.936$$

$$= 8.35 \text{ mm}$$

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 km^2

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

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

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

$$\begin{matrix} \text{[inflow + Precipitation]} & - & \text{[outflow + Evaporation + seepage]} \\ \text{(Ha.m)} & & \text{(Ha.m)} \quad \text{(Ha.m)} \quad \text{(Ha.m)} \end{matrix}$$

$$= \text{change in storage} \\ \text{(Ha.m)}$$

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

$$\therefore \text{seepage loss} = 4.6 \text{ Ha.m}$$

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

$$= PET = \frac{KPT_m}{100} \times 2.54 \text{ cm/month}$$

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

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

$\therefore$ consumptive use

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

07. Ans: (a)

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

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

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

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

$$\text{January no. of days} = 31$$

Consumptive use

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

08. Ans: (c)

Sol: Indian standard pan

$$\therefore C_p = 0.8$$

$$\text{Pan evaporation} = 4.0 \text{ cm}$$

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)

10. Ans: (a)

05. 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

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

evaporation

$$= 0.7 \times 0.6$$

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

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

$$= 7.34 \text{ cm}$$

Run off = $P - E - I$

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

Depth of runoff = 2.24 cm

Volume of runoff

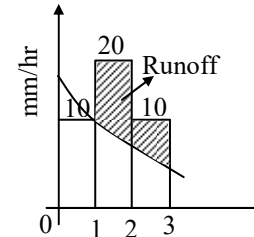
= Area of catchment $\times$ depth of Runoff

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

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

06. Ans: (d)

Sol: Runoff = Area of hyetograph above IC curve



Area of hyetograph above IC curve

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

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

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

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

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

$$= 13.63 \text{ mm}$$

07. Ans: (b)

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

$P = 2 \text{ cm};$

$T = 6 \text{ hour}$

Given, Uniform rate $R = ?$

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

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

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

$$\text{Runoff} = 0 \text{ cm}$$

08. Ans: (d)

Sol: The total observed runoff volume

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

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

$$\text{Rainfall intensity} = 4 \text{ hr}$$

$$\text{Duration of rain} = 4 \text{ hr}$$

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

Runoff depth (R)

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

Average infiltration

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

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

09. Ans: (a)

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 10 & 11

10. Ans: (a)

Sol: Storm – I

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

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

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

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

11. Ans: (d)

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

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

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

12. Ans: (c)

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

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

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

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

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

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

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

13. Ans: (b)

Sol: W_{index} :

$$P = \sum i_i \times t_i$$

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

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

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

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

ϕ_{Index} :

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

$$P_e = [1.6 + 3.6 + 5 + 2.8 + 2.2] \times \frac{30}{60} = 7.6 \text{ cm}$$

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

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

14. Ans: (a)

Sol: W_{index} :

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

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

$$W_{\text{index}} = \frac{P - R - \text{losses}}{t} = \frac{11.1 - 4.7 - 0.6}{24} = 0.241 \text{ cm/hr}$$

ϕ_{index} :

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

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

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

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

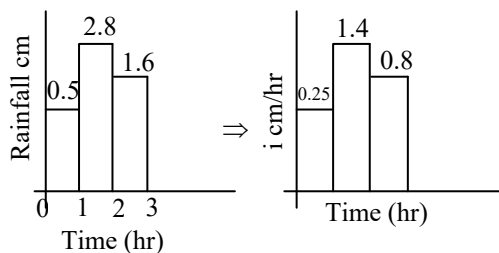
15. Ans: (c)

Sol: W_{index} :

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

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

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



ϕ_{index} :

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

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

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

16. Ans: (c)

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

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

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

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

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

17. Ans: (1.816 cm, 1.616 cm)

$$\text{Sol: } f_t = f_c + (f_o - f_c) e^{-kt}$$

$$= 3 + e^{-2t}$$

(i) Infiltration in 30 minutes (or) 0.5 hr

$$= \int_0^{0.5} (3 + e^{-2t}) dt$$

$$= 3(t)_0^{0.5} + \left[\frac{e^{-2t}}{-2} \right]_0^{0.5}$$

$$= 3 \times 0.5 - 0.5 [e^{-1} - e^{2 \times 0}]$$

$$= 1.816 \text{ cm}$$

(ii) Infiltration in 2nd 30 minutes

First we have to calculate infiltration in 0 hr to 1 hr

$$= \int_0^1 (3 + e^{-2t}) dt$$

$$= [3t]_0^1 + \frac{[e^{-2t}]_0^1}{-2}$$

$$= 3 - 0.5[e^{-2} - e^0]$$

$$= 3.432 \text{ cm}$$

But in question he ask next 30 minutes so we subtract

1st 30 min infiltration

$$= 3.432 \text{ cm} - 1.816 \text{ cm}$$

$$= 1.616 \text{ cm}$$

18. Ans: (a) & (d)

$$\text{Sol: } R = \frac{57.2 \times 10^6}{650 \times 10^6} = 0.088 \text{ m} = 8.8 \text{ cm}$$

$$P = i \times t = 1.6 \times 8 = 12.8 \text{ cm}$$

$$\phi - \text{Index} = \frac{12.8 - 8.8}{8} = 0.5 \text{ cm/hr}$$

$$= 5 \text{ mm/hr}$$

06. Runoff

01. Ans: (d)

02. Ans: (a)

03. Ans: (a)

04. Ans: (a)

07. Hydrographs

01. Ans: (d)

Sol: Volume of runoff = Area of DRH

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

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

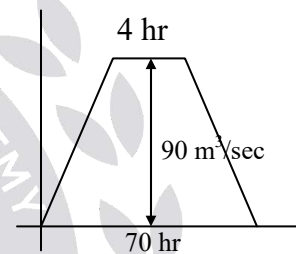
$$\text{Runoff depth} = \frac{\text{Volume of runoff}}{\text{Area of catchment}}$$

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

$$= 2 \text{ cm}$$

02. Ans: (b)

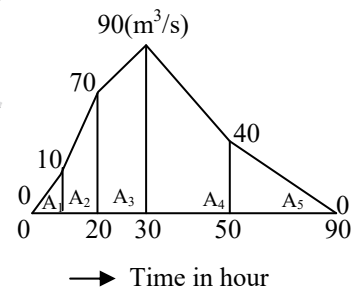
$$\text{Sol: Area of catchment} = \frac{\text{Volume of Runoff}}{\text{depth of Runoff}}$$



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

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: (c)

Sol: Volume of runoff = Area of DRH

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

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

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

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

05. Ans: (c)

Sol: Volume of runoff = Area of catchment

$$= \frac{1}{2} \times Q \times 20$$

$$= 10 \times Q$$

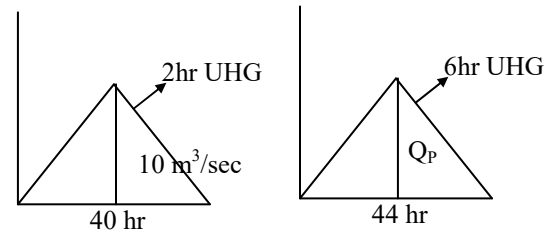
$$\text{Runoff depth} = \frac{\text{Volume of runoff}}{\text{Area of catchment}}$$

$$\frac{1}{100} = \frac{10 \times Q}{500 \times 10^4}$$

$$Q = 5000 \text{ m}^3/\text{h}$$

06. Ans: 9.09 m³/sec

Sol:



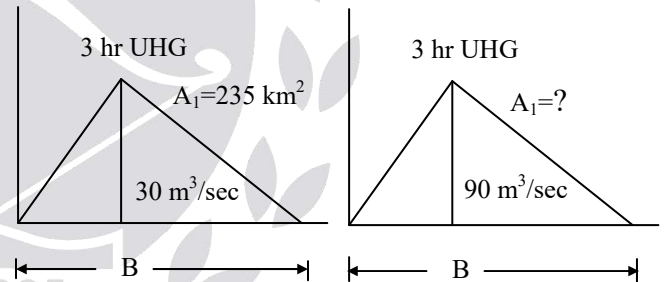
$$\frac{\frac{1}{2} \times 10 \times 40 \times 60 \times 60}{\frac{1}{100}} = \frac{\frac{1}{2} \times Q_p \times 44 \times 60 \times 60}{\frac{1}{100}}$$

$$10 \times 40 = 44 Q_p$$

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

07. Ans: (d)

Sol:



Same base but peak has increased to 90 m³/sec

i.e., 3 times increase

∴ Area also increase to 3 times

$$A_2 = 3A_1 = 3 \times 235 = 705 \text{ km}^2$$

08. Ans: a) 7.6 cm b) 40 m³/sec

Sol: Peak flood resulting for 6hr storm

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

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

$$\text{Peak flood of 6hr DRH} = 150 - 6$$

$$= 144 \text{ m}^3/\text{sec}$$

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

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) 15^{th} hr

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

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

6hr DRH ordinate at 15^{th} hr

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

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

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

09. Ans: (b)

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

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

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

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

Peak of 3hr DRH = Peak of 3hr FHG

Base flow = $210 - 20$

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

Peak of 3hr

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

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

Linked answers (10 & 11)

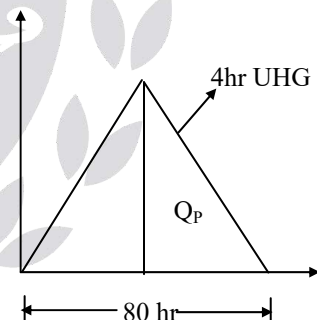
10. Ans: (b)

Sol: Area of catchment = 720 km^2

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

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

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



$\therefore$ UHG runoff depth = 1 cm

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

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

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

11. 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 $\times R$

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

$$\begin{aligned} \text{Peak flood discharge} &= \text{Peak DRH} + \text{Base flow} \\ &= 180 + 30 = 210 \text{ m}^3/\text{sec} \end{aligned}$$

Common data for Q 12 & 13

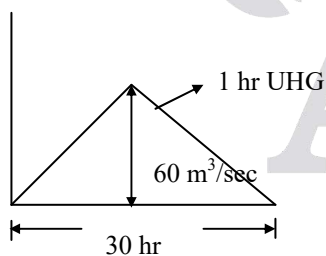
12. Ans: (c)

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

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

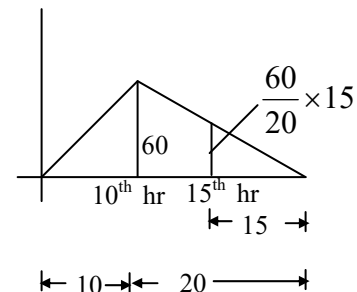
$$\text{Area of catchment} = \frac{\text{Volume of Runoff}}{\text{depth of Runoff}}$$

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



13. Ans: (b)

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



At 15th hr time interval ordinate of 1 hr

$$\text{UHG} = \frac{60}{20} \times 15 = 45 \text{ m}^3/\text{sec}$$

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

Ordinate of 1hr DRH

$$= \text{ordinate of UHG} \times R$$

$$= 45 \times 5 = 225 \text{ m}^3/\text{sec}$$

FHG ordinate at 15th hr

$$= \text{DRH} + \text{Base flow}$$

$$= 225 + 15 = 240 \text{ m}^3/\text{sec}$$

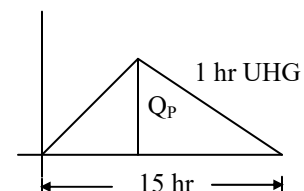
Common data for Q 14 & 15

14. Ans: (b)

$$\text{Sol: Area watershed} = 50 \text{ km}^2$$

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

$$\phi \text{ Index} = 0.5 \text{ cm/hr}$$



Volume of Runoff = Area of water shed $\times$
Runoff depth

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

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

15. Ans: (d)

Sol: $P_e = 5.5 \text{ cm}$

$$t_e = 1 \text{ hr}$$

$$\phi_{\text{index}} = 0.5 \text{ cm/hr}$$

$$\text{Peak ordinate of 1hr UHG} = 18.52 \text{ m}^3/\text{sec}$$

Peak ordinate of 1hr DRH

$$= \text{Peak ordinate 1hr UHG} \times R$$

$$= 18.52 \times 5 = 92.60 \text{ m}^3/\text{sec}$$

Peak ordinate of 1hr SHG

$$= \text{DRH} + \text{Base flow}$$

$$= 92.60 + 10$$

$$= 102.6 \text{ m}^3/\text{sec}$$

Common data for Q 16 & 17

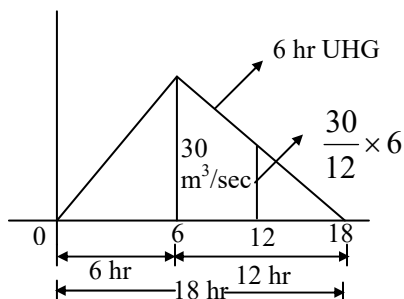
16. Ans: (b)

Sol: $P_e = 16 \text{ cm}$, $t_e = 12 \text{ hr}$

$$\phi_{\text{index}} = 0.5 \text{ cm/hr}$$

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

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



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

$$\text{Peak discharge of 12hr UHG} = 22.5 \text{ m}^3/\text{sec}$$

Peak discharge 12hr DRH

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

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

17. Ans: (c)

Sol: Area of catchment

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

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

18. Ans: (d)

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

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

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

19. 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

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

20. Ans: (c)

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

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

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

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

21. Ans: 160 m³/sec

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

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

Volume of runoff = Area of DRH

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

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

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

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

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

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

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

22. 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 23 & 24

23. Ans: (c)

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

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

$$= 7.92 \text{ km}^2$$

24. 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 25 & 26

25. Ans: (b)

Sol:

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

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

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

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

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

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

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

26. Ans: (c)

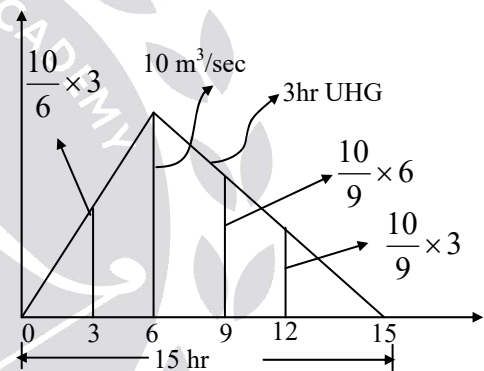
Time	S_A S-curve ordinates $Q = 1 - (1+t)e^{-t}$	S_B 2 hr delayed S-curve ordinate	2hr DRH ($S_A - S_B$)
0	0	—	
1	0.264	—	
2	0.593	0	
3	0.8	0.264	$0.8 - 0.264$ $= 0.536$

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

27. Ans: 43.33 m³/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 UH m³/sec	I st storm =UH×R ₁ m³/sec	II nd storm =UH×R ₂ m³/sec	6hr H Ordinate m³/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

$$\text{DRH} = 43.33 \text{ m}^3/\text{sec}$$

28. Ans: 715 m³/sec

Sol: Ist storm

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

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

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

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

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

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

IInd storm

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

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

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

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

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

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

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

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

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

$$\text{Storm discharge} = \text{DRH} + \text{Base flow}$$

$$= 705 + 10$$

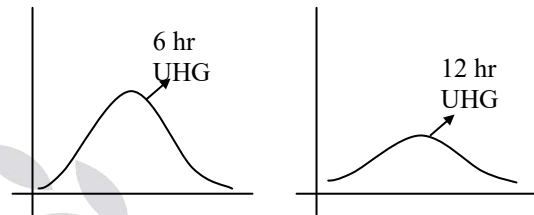
$$= 715 \text{ m}^3/\text{sec}$$

29. Ans: (d)

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

$$\text{Peak ordinate of 12hr UHG} = ?$$

Explanation:



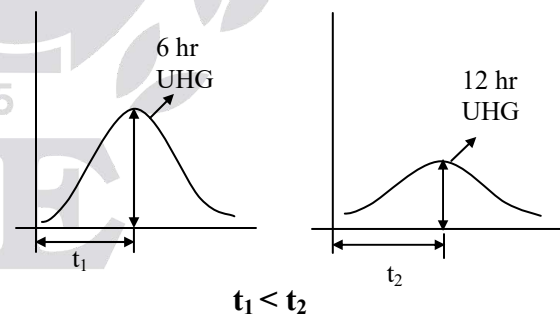
Storms of shorter duration produce more peak than storms of longer duration storm.

$$\text{Peak of 12hr UHG} < \text{peak of 6hr UHG}$$

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

30. Ans: (c)

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



31. Ans: (d)

32. Ans: (c)

33. Ans: (b) & (c)

Sol: Area of UH = C.A × 0.01

$$\Delta t \Sigma o'' = C.A \times 0.01$$

$$3 \times 3600 \times (20 + 80 + \dots + 15 + 5)$$

$$= C.A \times 0.01$$

$$3 \times 3600 \times 699 = C.A \times 0.01$$

$$C.A = 754920000 \text{ m}^2$$

$$C.A = 75492 \text{ ha}$$

$$C.A = 754.92 \text{ km}^2$$

08. Maximum Flood Estimation

01. Ans: (d)

Sol: A = 90 ha

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

$$R = 0.40$$

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

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

02. Ans: (b)

Sol: 30% → 0.40

$$70\% \rightarrow 0.60$$

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

$$I = 0.54$$

03. Ans: (d)

Sol: A = 1.5 km² = 150 Ha, I = 0.42

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

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

$$= \frac{150 \times 0.42 \times (48/28) \times 60}{360} = 18 \text{ m}^3/\text{sec}$$

04. 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

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

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

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

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

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

05. Ans: (c) 06. Ans: (c) 07. Ans: (a)

09. Flood Routing

01. Ans: 17.748 m³/sec

Sol: t₁ = 3 hr, t₂ = 4 hr, I₃ = 18 m³/s,

$$I_4 = 42 \text{ m}^3/\text{s}, C_o = 0.042, C_1 = 0.538,$$

$$Q_3 = 15 \text{ m}^3/\text{s}, Q_4 = ?,$$

$$C_2 = 1 - C_o - C_1 = 1 - 0.042 - 0.538 = 0.42$$

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

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

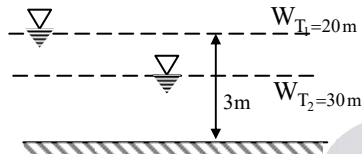
$$= 17.748 \text{ m}^3/\text{s}$$

02. Ans: (a)

10. Well Hydraulics

01. Ans: (b)

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



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

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

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

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

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

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

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

Volume of GW extracted = ?

Volume of aquifer

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

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

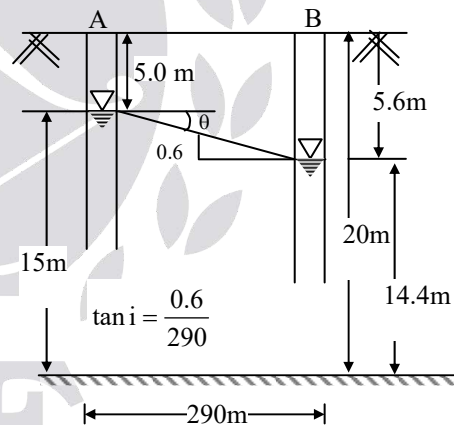
04. Ans: 0.105

Sol: Darcy's equation:

$$Q = KiA$$

$$V = Ki$$

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



(V = apparent or seepage velocity)

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

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

$$Q = KiA$$

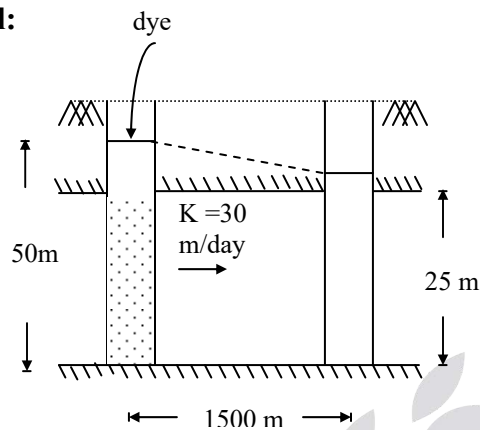
$$= \frac{4 \times 10^{-3} \times 10^{-2}}{1} \times \left(\frac{5.6 - 5}{290} \right) \times 1 \times \left(\frac{14.4 + 15}{2} \right)_{\text{avg.ht}}$$

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

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

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: 12.2 m/day

$$\text{Sol: } H = 14.5\text{m}, r_1 = 16\text{m}, r_2 = 34\text{m}, s_1 = 2.2\text{m},$$

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

$$= 1332\text{ m}^3/\text{day}$$

$$S_1 = 2.45$$

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

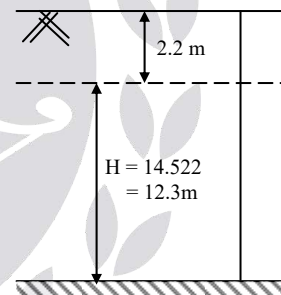
$$K = ?$$

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

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

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

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



07. Ans : (b)

Sol: Radius of well,

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

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

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

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

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

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

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

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

08. Ans: (a) & (c)

Sol: $Q = \frac{\pi k[H^2 - h_w^2]}{\ln[R/\gamma_w]}$

$$Q = \frac{\pi \times 5[60^2 - 50^2]}{\ln[150/0.15]}$$

$$Q = 2501.36 \text{ m}^3/\text{day}$$

$$Q = 1737.05 \text{ l/min}$$

11. River Gauging

01. Ans: (b)

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

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

$$C_{\text{mix}} = 4 \text{ ppm}$$

$$= 1 \text{ mg/lit}$$

$$Q_s = ?$$

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

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

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