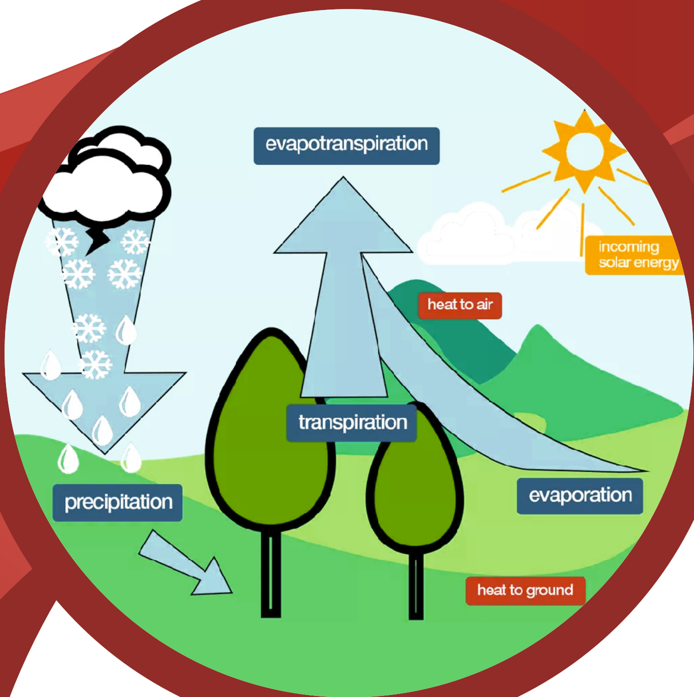
GATE | PSUs

CIVIL ENGINEERING

Hydrology

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



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 $\overline{P} = 92.8\,cm$

Standard deviation of rainfall $\sigma = 30.7$ cm

Allowable error (E) = 10%

Optimum no. of rain gauge stations,

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

$$C_V = \frac{100\sigma}{\overline{P}} = \frac{100 \times 30.7}{92.8} = 33.08\%$$

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

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%

% Accuracy = 100–% 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 cm

04. Ans: 1093.43

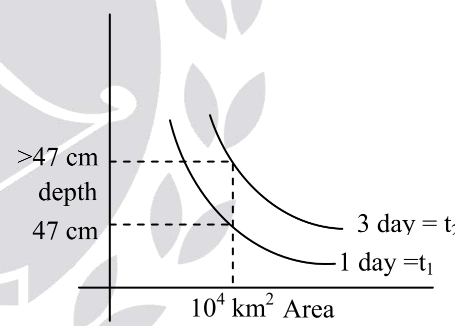
Sol: $$P_P = \frac{N_P}{m}\left[\frac{P_Q}{N_Q} + \frac{P_R}{N_R} + \frac{P_S}{N_S}\right]$$

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

P_s = 1093.43 mm

05. Ans: (b)

Sol:



For 3day storm

Average depth > depth of one day storm > 47 cm

06. Ans: (c)

Sol : Double mass curve: Used to check inconsistency of rainfall record and to check arithmetical errors in transferring rainfall data from one record to another.

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

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

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

$P_P = 45.98$ mm

08. Ans: (a) & (c)

Sol: Precipitation is measured using a rain gauge (also called pluviometer, ombrometer).

Lysimeter: is a device used to measure evapotranspiration which is released by plants. (Usually crops or trees).

Phytometer: is generally used to measure transpiration, of plants.

02. Mean Precipitation Calculation

01. Ans: (a)

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

$$= \frac{3\times75 + 5\times125 + 4\times150 + 6\times150}{75+125+150+150}$$

$= 4.7$ cm

02. Ans: (b)

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

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

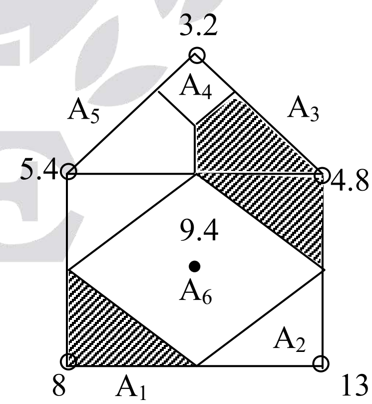
$= 1-(0.1+0.2+0.3) = 0.4$

$$\overline{P} = 10\times0.1 + 15\times0.2 + 20\times0.3 + 25\times0.4$$

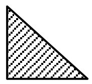
$= 20$ cm

03. Ans: (a)

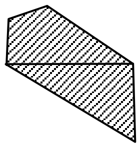
Sol:



$$A = 4\times4 + \frac{\sqrt{3}}{4}(4)^2 = 22.928\,\text{km}^2$$

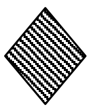


$$A_1 = A_2 = \frac{1}{2}\times 2\times 2 = 2\,km^2$$



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

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



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

$$\overline{P} = \frac{P_1A_1 + P_2A_2 + P_3A_3 + P_4A_4 + P_5A_5 + P_6A_6}{A}$$

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

$\overline{P} = 7.35$ cm

04. Ans: (c)

Sol: $P_1 = 45$ cm,

$P_2 = 55$ cm,

$P_3 = 65$ cm

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

$$= \frac{100\left[\frac{45+55}{2}\right] + 150\left[\frac{55+65}{2}\right]}{100+150} = 56\text{ cm}$$

05. Ans: (b)

Sol: $$\overline{P} = \frac{A_1\left[\frac{P_1+P_2}{2}\right] + ...+ A_{n-1}\left[\frac{P_{n-1}+P_n}{2}\right]}{A}$$

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

= 7.4 cm

06. Ans: (b)

Sol

$$\overline{P} = \frac{30\times 12 + 140\times\left(\frac{12+10}{2}\right) + 80\times\left(\frac{10+8}{2}\right) + 180\times\left(\frac{8+6}{2}\right) + 20\left(\frac{6+4}{2}\right)}{30+140+80+180+20}$$

= 8.84 cm

Note: Formula same as earlier problem

07 Ans: (b)

Sol: Hyetograph: It is a graph between time in hour (x-axis) and rainfall intensity (mm/hr) on y-axis.

Direct runoff hydrograph: From rainfall excess we can draw direct runoff hydrograph with time on x-axis and discharge on y-axis.

Isohyets: is defined as a lime joining points of equal rainfall (Rainfall averaging)

Mass curve: It is a plot of cumulative rainfall and time.

08. Ans: (c)

Sol: Thiessen - Polygon method: Rainfall recorded at each station is given a Weightage on the basis of an area closest to the station.

$$P_a = \frac{P_1A_1 + P_2A_2 + ...P_mA_m}{A_1 + A_2 + ...A_m} = \frac{\Sigma P_1A_1}{\Sigma A_1}$$

The ratio $\frac{A_1}{\Sigma A_1}$ = Weightage factor where P_1 P_2…. Are rainfalls and A_1, A_2 …. Are respective theissen polygon areas.

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 m^3/sec $= \frac{9+1}{4}$

$$= \frac{10}{4} = 2.5$$

(ii) Return period of flood 75 m^3/sec $= \frac{9+1}{5} = 2$

(iii) Return period of flood 50 m^3/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

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

= 0.395 = 39.5%

05. Ans: (c)

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

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

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

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

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

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

$= 0.3973$

R = 39.73%

(iii) Probability of occurring of flood magnitude less than 4000 m^3/sec

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

$q = 0.975$

08. Ans: (c)

Sol: The probability of a event whose magnitude equal to or in excess of a specified magnitude(x) and having a recurrence interval 'T' , occurring in a given year, is given by

$P = \frac{1}{T}$ where P is called exceedence probability

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

04. Evaporation & Evapotranspiration

01. Ans: 5.157

Sol: Depth of water removed,

$$Z = \frac{4.2\times10^{-3}}{\frac{\pi}{4}(1.22)^2}\times1000 = 3.592\,\text{mm}$$

Pan evaporation

E = P ± Z = 8.75 – 3.592 = 5.157 mm

02. Ans:11.94 mm & 8.35 mm

Sol: Depth of water added

$$(Z) = \frac{8.75\times10^{-3}}{\frac{\pi}{4}(1.2)^2}\times1000 = 7.736\,\text{mm}$$

Pan evaporation, E = p±Z

= 4.2+7.736

= 11.936 mm (+Z → water added

– Z → water removed)

(Actual evaporation = C_P × pan evaporation)

= 0.7×11.936

= 8.35 mm

03. Ans: 61.08

Sol: Increase in storage

= 103.258–103.2=0.058 m

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

(∵ +→ increase)

[I+P]–[O+E+S] = +ΔS

$$\left[\frac{6\times30\times24\times60\times60}{5000\times10^4}\times1000+145\right]$$

$$-\left[\frac{6.5\times30\times24\times60\times60}{5000\times10^4}\times1000-E+0\right]$$

= 0.058×1000

[456.04]–[336.96–E] = 0.058×1000

E = 61.08 mm

∴ Evaporation loss in that month

E = 61.08 mm

04. Ans: (d)

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

Plan area of reservoir = 1 km^2

= 1×100 = 100 ha

$$=\left[10+\frac{3}{100}\times100\right]-\left[20+\frac{12\times0.7}{100}\times100+\text{seepage}\right]$$

$$=\frac{-20}{100}\times100$$

$$\underset{(\text{Ha.m})}{[\text{inflow}} + \underset{(\text{Ha.m})}{\text{Precipitation}]} - \underset{(\text{Ha.m})}{[\text{outflow}} + \underset{(\text{Ha.m})}{\text{Evaporation}} + \underset{(\text{Ha.m})}{\text{seepage}]}$$

= change in storage (Ha.m)

[10 + 3]–[20 + 8.4 + seepage] = –20

∴ seepage loss = 4.6 Ha.m

Note: All values substitute in above equation in ha-m

05. Ans: (a)

Sol: R = 200 watt/m^2

L = 2441 kJ/kg

= 2441×10^{3}J/kg;

ρ_w = 997 kg/m^3

$$E = \frac{R}{\rho_w L} = \frac{200}{997\times2441\times10^3}$$

= 8.218×10^{-8} m/sec

≃ 7.1 mm/day

06. Ans: (c)

Sol: P = 7.2%,

T_m = 18°C,

K = 0.7

Consumptive use

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

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

= 82.44 mm/month

∴ consumptive use

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

07. Ans: (a)

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

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

Consumptive use= 9.5×0.52

= 4.94 cm/month

January no.of days} = 31

Consumptive use

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

08. Ans: (c)

Sol: Indian standard pan

∴ C_P = 0.8

Pan evaporation = 4.0 cm

Actual evaporation from reservoir

= C_p×pan evaporation

= 0.8× 4=3.2 cm

Volume of water evaporated = plan area of reservoir× 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)

Sol: Cetyl alcohol and stearyl alchol are used to minimize the loss of water through the process of evaporation.

10. Ans: (a)

Sol: $\text{Aridity Index (AI)} = \frac{\text{PET} - \text{AET}}{\text{PET}} \times 100$

Where AET = Actual Evapotranpiration

PET = Potential Evapotranpiration

Potential Evapotranpiration (PET): Evapotransipration which occurs when sufficient moisture is always available to completely meet the needs of vegetation, fully covering the area.

Acutal Evapotranpiration (AET) : The actual Evapotranpiration occurring in a specific situation.

05. Infiltration

01. Ans: (a)

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

02. Ans: (b)

Sol: Hydraulic conductivity of soil

$f_c = 0.2$ cm/hr

$i = 0.5$ cm/hr [$\because i>f_c$]

$f_a = f_c = 0.2$ cm/hr

03. Ans: (d)

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

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

$f_2 = 1.34+(7.62-1.34)e^{-4.182\times2} = 1.34$

$f_2 = f_c$

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

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

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

05. Ans: 40320 m^3

Sol: In 24 hrs Rainfall = 10 cm

In 24 hrs evaporation = $C_P\times$pan evaporation

$= 0.7\times0.6$

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

Runoff (R) = 10−(0.7×0.6)−7.34=2.24 cm

Depth of runoff = 2.24 cm

Volume of runoff

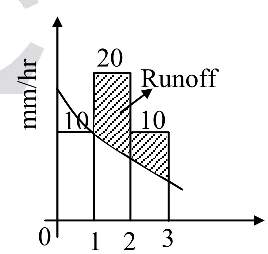
= Area of catchment × depth of Runoff

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

$= 40320$ m^3

06. Ans: (d)

Sol: Runoff = Area of hyetograph above IC curve



Area of hyetograph above IC curve

$$= \begin{bmatrix}\text{Total area of hyetograph}\\ \text{between 1hr to 3hr}\end{bmatrix} - \begin{bmatrix}\text{Area below IC}\\ \text{curve between 1hr to 3hr}\end{bmatrix}$$

$$= [20\times1+10\times1] - \int_1^3 f_t.dt$$

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

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

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

= 13.63 mm

07. Ans: (b)

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

P = 2 cm; T = 6 hour

Given, Uniform rate R = ?

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

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

R = -1 cm

Runoff = 0 cm

08. Ans: (d)

Sol: The total observed runoff volume

$= 25.2 \times 10^6 m^3$

Area of basin $= 280\ km^2$

Rainfall intensity = 4hr

Duration of rain = 4 hr

Total rainfall in 4hr, P = 2.8×4 = 11.2 cm

Runoff depth (R)

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

Average infiltration

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

= 5.5 mm/hr

09. Ans: (a)

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

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

Linked answer questions for 10 & 11

10. Ans: (a)

Sol: Storm – I

i_e = 2 cm/hr

t_e = 5 hr, R = 4 cm

$P_e = i_e t_e = 2 \times 5 = 10$ cm

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

11. **Ans: (d)**

Sol: R_2 = 8.4 cm ; ϕ = 1.2 cm/hr; t_e = 8hr

$$\phi = \frac{P_{e_2} - R_2}{t_{e2}} = \frac{P_{e_2} - 8.4}{8} \Rightarrow P_{e_2} = 18 cm$$

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

12. Ans: (c)

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

P = 81cm

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

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

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

$\therefore$ 8 mm/h > 7mm/h

ϕ_{index} = 8 mm/h

13. Ans: (b)

Sol: W_{index} :

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

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

t = 3hr; R = 3.6cm

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

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

ϕ_{Index}:

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

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

t_e = 2.5 hr; R = 3.6 cm

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

14. Ans: (a)

Sol: W_{index} :

P = 1.6 + 5.4 + 4.1 = 11.1 cm

R = 4.7cm, t = 24hr, losses = 0.6 cm

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

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

ϕ_{index}:

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

$$P_e = [5.4 + 4.1] = 9.5\,cm$$

t_e = 16 hr

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

15. Ans: (c)

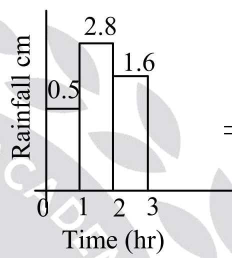
Sol: W_{index} :

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

R = 3.2 cm

$$W_{index} = \frac{P - R - losses}{t} = \frac{4.9 - 3.2 - 0}{6}$$

$$= 0.283 \text{ cm/hr}$$



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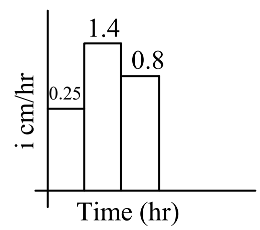


ϕ_{index} :

$P_e = 1.4\times2+0.8\times2=4.4$ cm

t_e= 4 hr, R = 3.2 cm

$$\phi_{index} = \frac{P_e - R}{t_e} = \frac{4.4 - 3.2}{4}$$

$$= 0.3 \text{ cm/hr}$$

16. Ans: (c)

Sol: ϕ_{index} = 10 mm/hr

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

$= 28\times1+12\times1 = 40$ mm

t_e = 2 hr

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

17. Ans:(1.816 cm, 1.616 cm)

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

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

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

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

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

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

$= 1.816$ cm

(ii) Infiltration in 2nd 30 minutes

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

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

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

$= 3 - 0.5[e^{-2} - e^{o}] = 3.432$ cm

But in question he ask next 30 minutes so we subtract 1st 30 min infiltration

$= 3.432$ cm $- 1.816$ cm

$= 1.616$ cm

18. Ans: (a) & (d)

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

$P = i \times t = 1.6 \times 8 = 12.8$ cm

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

$= 5$ mm/hr

06. Runoff

01. Ans: (d)

Sol: Runoff can also be known as

i. Effective rainfall

ii. Rainfall excess

iii. Net rain

iv. direct runoff

02. Ans: (a)

Sol: Methods to estimate runoff are

1. Regression analysis (Runoff – Rainfall relationship).
2. Binnie's percentages
3. Barlow's Tables
4. Stranges Tables
5. Water shed simulations
6. Hortone's infiltration capacity
7. Infiltration indices
8. SCN –CN method.

03. Ans: (a)

Sol: The ratio between runoff to rainfall is know as runoff factor.

04. Ans: (a)

Sol: A conventional flow duration curve is a plot between flow rate and percentage time flow is exceeded (Percentage probability).

07. Hydrographs

01. Ans: (d)

Sol: Volume of runoff = Area of DRH

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

$$= 28.8\times 10^6\ m^3$$

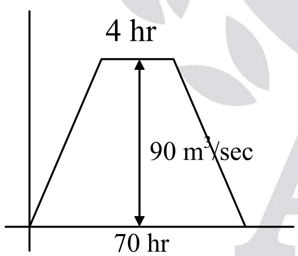
$$\text{Runoff depth} = \frac{\text{Volume of runoff}}{\text{Area of catchment}}$$

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

$$= 2\ cm$$

02. Ans: (b)

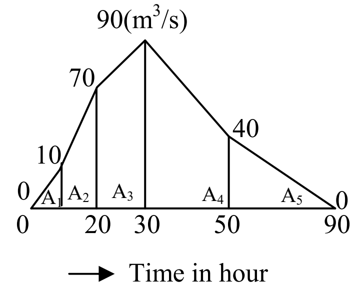
Sol: $\text{Area of catchment} = \dfrac{\text{Volume of Runoff}}{\text{depth of Runoff}}$



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

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

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

04. Ans: (c)

Sol: Volume of runoff = Area of DRH

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

$$= 25.92\times 10^6\ m^3$$

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

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

05. Ans: (c)

Sol: Volume of runoff = Area of catchment

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

$$= 10 \times Q$$

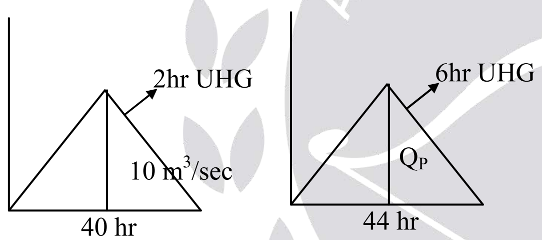
$$\text{Runoff depth} = \frac{\text{Volume of runoff}}{\text{Area of catchment}}$$

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

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

06. Ans: 9.09 m^3/sec

Sol:



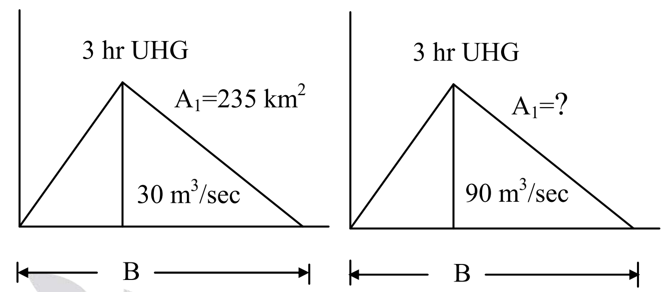
$$\frac{\frac{1}{2} \times 10 \times 40 \times 60 \times 60}{\frac{1}{100}} = \frac{\frac{1}{2} \times Q_P \times 44 \times 60 \times 60}{\frac{1}{100}}$$

$$10 \times 40 = 44\ Q_p$$

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

07. Ans: (d)

Sol:



Same base but peak has increased to 90 m^3/sec

i.e., 3 times increase

$\therefore$ 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 m^3/sec

Sol: Peak flood resulting for 6hr storm

= 150 m^3/sec

Base flow = 6 m^3/sec

Peak flood of 6hr DRH = 150–6

= 144 m^3/sec

Peak ordinate of 6hr UHG = 36m^3/sec

Peak ordinate of 6hr DRH

= Peak ordinate of 6 hr UHG × R

a) 144 = 36 ×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 =7.6cm = 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 m^3/sec

6hr DRH ordinate at 15^{th} hr

= 6 hr UHG ×R

= 8.5×4 = 34 m^3/sec

6hr storm flow at 15^{th} hr = 34 + 6

= 40 m^3/sec

09. Ans: (b)

Sol: P_e = 2.7 cm, t_e = 3hr, ϕ = 0.3 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 m^3/sec

Base flow = 20 m^3/sec

Peak of 3hr DRH = Peak of 3hr FHG

Base flow = 210 −20

= 190 m^3/sec

Peak of 3hr

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

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

Linked answers (10 & 11)

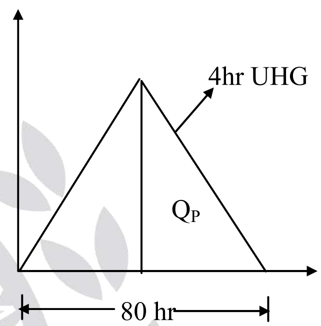
10. Ans: (b)

Sol: Area of catchment = 720 km^2

Base flow = 30m^3/sec

ϕ_{index} = 1mm/hr

P_e = 4 cm, t_e = 4hr = 40 mm



∵ UHG runoff depth = 1 cm

Volume of runoff = Area of catchment × 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 m^3/sec

11. Ans: (a)

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

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

Peak ordinate of 4hr DRH = Peak ordinate of 4hr UHG × R

= 50×3.6 = 180 m^3/sec

Peak flood discharge = Peak DRH+ Base flow

= 180+30 = 210 m^3/sec

Common data for Q 12 & 13

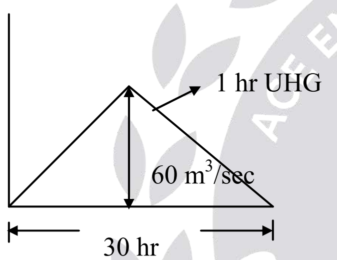
12. Ans: (c)

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

Base flow = 15 m^3/sec

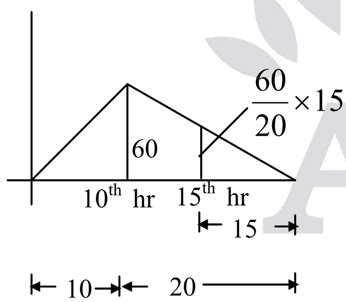
$$\text{Area of catchment} = \frac{\text{Volume of Runoff}}{\text{depth of Runoff}}$$

$$= \frac{\frac{1}{2}\times 60\times 30\times 60\times 60}{\frac{1}{100}\times(1000)^2} = 324\,km^2$$



13. Ans: (b)

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



At 15^{th} hr time interval ordinate of 1 hr

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

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

Ordinate of 1hr DRH

= ordinate of UHG×R

= 45 × 5 = 225 m^3/sec

FHG ordinate at 15^{th} hr

= DRH + Base flow

= 225+15=240 m^3/sec

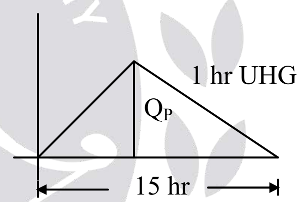
Common data for Q 14 & 15

14. Ans: (b)

Sol: Area watershed = 50 km^2

Base flow = 10 m^3/sec

ϕ Index = 0.5 cm/hr



Volume of Runoff = Area of water shed × Runoff depth

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

$Q_p = 18.52$ m^3/sec

15. Ans: (d)

Sol: $P_e = 5.5$ cm

$t_e = 1$ hr

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

Peak ordinate of 1hr UHG = 18.52 m^3/sec

Peak ordinate of 1hr DRH

= Peak ordinate 1hr UHG × R

= 18.52×5 = 92.60 m^3/sec

Peak ordinate of 1hr SHG

= DRH+ Base flow

= 92.60 + 10

= 102.6 m^3/sec

Common data for Q 16 & 17

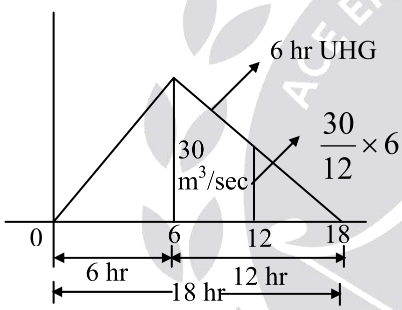
16. Ans: (b)

Sol: $P_e = 16$ cm, $t_e = 12$ hr

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

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

R = 10 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 m^3/sec

Peak discharge 12hr DRH

= Peak discharge of 12 hr UHG× R

= 22.5×10 = 225 m^3/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 $= \frac{\text{Volume of Runoff}}{\text{depth of Runoff}}$

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

$= 5.4$ 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 = $12 m^3/sec$; R = 3 cm

$$3\text{hr UHG ordinate} = \frac{3\text{hr DRH ordinate}}{R}$$

$$= \frac{12}{3} = 4\,m^3/sec$$

20. Ans: (c)

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

A = $270\ km^2$

D = 3 hr

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

21. Ans: 160 m^3/sec

Sol: t_p = 64 hours

$Q_P = 30\ m^3/sec$

Volume of runoff = Area of DRH

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

Runoff depth = 1 cm = 0.01 m

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

$$\text{Area of catchment} = \frac{3.456\times 10^6}{0.01}$$

$= 345.6\ km^2$

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

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

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

22. Ans: 256 m^3/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 $= \dfrac{\text{Volume of Runoff}}{\text{depth of Runoff}} = \dfrac{\text{Area of UHG}}{\text{depth of Runoff}}$

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

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

$P_e = 6.6$ cm $= 66$ mm

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

$t_e = 3$ hr $\qquad \phi_{index} = \dfrac{P_e - R}{t_e}$

base flow $= 5\ m^3$/sec $\qquad 2 = \dfrac{66 - R}{3}$

$\Rightarrow R = 60$ mm $= 6$ cm

Peak ordinate of 3hr UHG = 6 m^3/sec

Peak ordinate of 3hr DRH = Peak ordinate 3hr UHG × R= 6×6 = 36 m^3/sec

Peak ordinate of 3hr SHG = Peak of 3hr DRH + Base flow = 36 + 5 = 41m^3/sec

Common Data for 25 & 26

25. Ans: (b)

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

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

At $t = \infty$, $Q = E_{quilibrium}$

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

But $Q_{equi} = 2.778\dfrac{A}{D}$

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

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

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

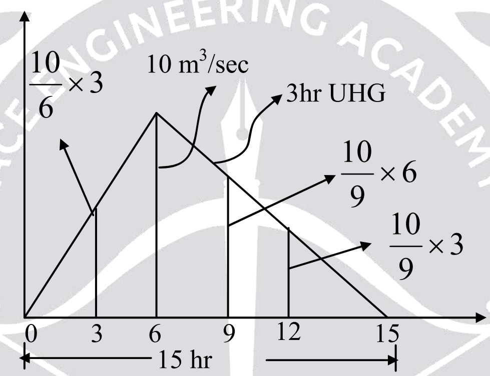
$$\text{2hr UHG ordinate} = \frac{(S_A - S_B)D}{T} = \frac{0.536\times 1}{2}$$

$$= 0.27\ m^3/sec$$

27. Ans: 43.33m^3/sec

Sol:

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



Time	**3hr UHG m^3/sec**	**Ist storm =UHG×R_1 m^3/sec**	**IIndstorm =UHG×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 m^3/sec

28. Ans: 715 m^3/sec

Sol: I^{st} storm

$t_e = 6hr$

$P_e = 3$ cm

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

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

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

$R_1 = 1.5$ cm

II^{nd} storm

$t_e = 6hr$

$P_e = 5$ cm

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

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

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

$R_2 = 3.5$ 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 m^3/sec

Base flow = 10 m^3/sec

Storm discharge = DRH + Base flow

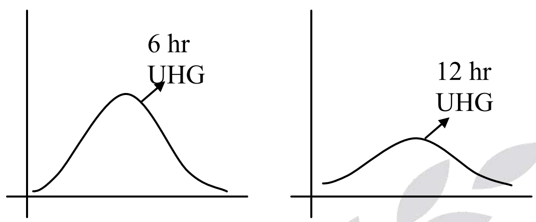
= 705+10 = 715 m^3/sec

29. Ans: (d)

Sol: 6 hr UHG peak ordinate = 30 m^3/sec

Peak ordinate of 12hr UHG =?

Explanation:



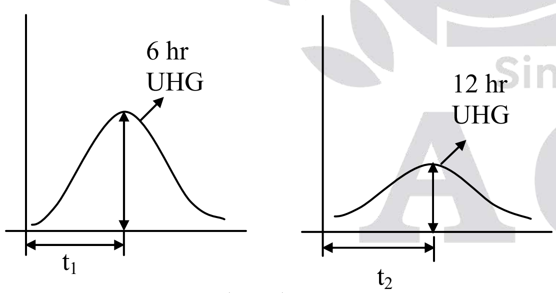
Storms of shorter duration produce more peak than storms of longer duration storm.

Peak of 12hr UHG<peak of 6hr UHG

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

30. Ans: (c)

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



$t_1 < t_2$

31. Ans: (d)

Sol: The ordinate of the instantaneous unit Hydrograph (IUH) of a catchments at time t is the slope $\left(\frac{ds}{dt}\right)$ of the S-curve with effective rainfall intensity of 1 cm/hr.

32. Ans: (c)

Sol: A watershed got transformed from rural to urban over a period of time. The effect of urbanization on storm runoff hydrograph from the watershed is to decrease the time base. Due to urbanization

1. Increase the volume of runoff
2. Decrease the time to peak discharge.
3. Increase the peak discharge.

33. Ans: (b) & (c)

Sol: Area of UH = C.A × 0.01

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

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

$= C.A \times 0.01$

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

C.A = 754920000 m^2

C.A = 75492 ha

C.A = 754.92 km^2

08. Maximum Flood Estimation

01. Ans: (d)

Sol: A = 90 ha

I = 4.5 cm/h = 45 mm/h

R = 0.40

$$Q = \frac{AIR}{360} = \frac{90\times45\times0.40}{360}$$

Q = 4.5 m^3/sec

02. Ans: (b)

Sol: 30% $\rightarrow$ 0.40

70% $\rightarrow$ 0.60

$$I = \frac{\frac{30}{100}\times A\times0.40+\frac{70}{100}\times0.60\times A}{A}$$

I = 0.54

03. Ans: (d)

Sol: A = 1.5 km^2 = 150 Ha, I = 0.42

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

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

$$= \frac{150\times0.42\times(48/28)\times60}{360} = 18 \text{ m}^3\text{/sec}$$

04. Ans: 7.08 m^3/s

Sol: I = 0.30

A = 0.85km^2= 85 ha

25 frequency $\rightarrow$ Culvert design for a rain of 25 year frequency

Duration of storm = time of concentration

= 30 mins

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

R = 100 mm/h

$$Q = \frac{AIR}{360} = \frac{85\times0.30\times100}{360}$$

Q = 7.083 m^3/sec.

05. Ans: (c)

Sol : An isochrone is a line on the basis map joining points having equal time of travel of surface runoff to the catchments outlet.

06. Ans: (c)

Sol: Rational method: Applicable for small size catchments (< 50 km^2) for urban drainage design, small culverts and bridges.

07. Ans: (a)

Sol : Peak flood discharge

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

There is no term of duration in the formula, so the peak discharge remains same.

09. Flood Routing

01. Ans: 17.748 m^3/sec

Sol: $t_1 = 3$ hr, $t_2 = 4$ hr, $I_3 = 18\ m^3/s$,

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

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

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

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

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

$= 17.748\ m^3/s$

02. Ans: (a)

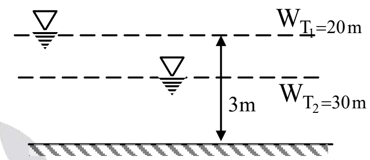
Sol: When outflow from a storage reservoir is uncontrolled as in freely operating spillway, then the peak of outflow hydrograph will occur at the point of intersection of the inflow if outflow curves, whereas if outflow from a reservoir is controlled, the peak will occur after the intersection of the curve.

10. Well Hydraulics

01. Ans: (b)

Sol: $A = 150$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 × drop in level of W.T.

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

$\Delta GW = 112.5$ Ha.m

= volume of water extracted.

02. Ans: (a)

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

area = $5km^2$

Drop in water table level = 102 – 99 = 3m

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

$= 100\times10^6 \times 0.25 = 25\times10^6\ \text{m}^3$

Volume of GW extracted = $S_y \times$ Volume of aquifer = $0.2\times25\times10^6 = 5\times10^6\text{m}^3 = 5\text{Mm}^3$

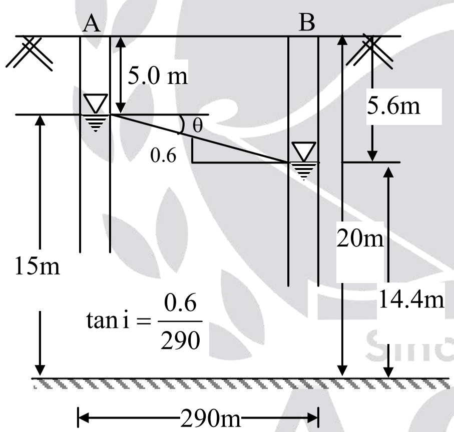
04. Ans: 0.105

Sol: Darcy's equation:

$Q = KiA$

$V = Ki$

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



(V = apparent or seepage velocity)

$K = 4\times10^{-3}\text{cm/sec.}$

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

$Q = KiA$

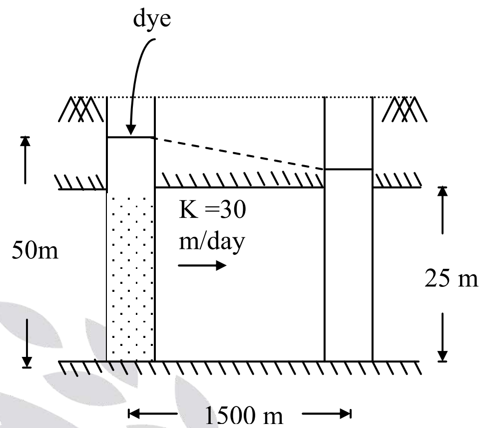
$$= \frac{4\times10^{-3}\times10^{-2}}{1}\times\left(\frac{5.6-5}{290}\right)\times1\times\left(\frac{14.4+15}{2}\right)_{\text{avg.ht}}$$

$Q = 1.216\times10^{-6}\ \text{m}^3\text{/s}$

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

05. Ans: (b)

Sol:



1500 m =Distance between wells.

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

$K = 30$ m/day

$n = 0.25$

Time of travel =?

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

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

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

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

$K = 30\times0.0167 = 0.5$ 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

Sol: H = 14.5m, r_1 = 16m, r_2 = 34m, s_1 = 2.2m,

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

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

$S_1 = 2.45$

$S_2 = 1.20$m

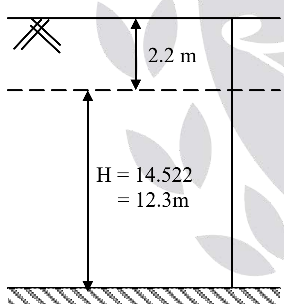
K = ?

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

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

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

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



07. Ans :(b)

Sol: Radius of well,

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

Discharge, Q = 2720 lit/ min

= 3916.8 m^3/day

At r_1 = 10 m, draw down, S_1 = 3 m

At r_2 = 100 m, draw down S_2 = 0.5 m

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

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

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

Transmissivity, T = 574.4 m^2/day

08. Ans: (a) & (c)

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

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

Q = 2501.36 m^3/day

Q = 1737.05 *l*/min

11. River Gauging

01. Ans: (b)

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

$C_T = 500\times10^3$ mg/lit

$C_{mix} = 4$ ppm

$= 1$ mg/lit

$Q_s = ?$

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

$$4 = \frac{0 + 4\times500\times10^3\times10^{-3}}{Q_S + 4\times10^{-3}}$$

$Q_S = 500$ m^3/sec