Hydrograph Example-6.2: Rainfall of magnitude 3.8 cm and 2.8 cm occurring on two consecutive 4-h durations on a catchment of area 27 $km^2$ produced the following hydrograph of flow at the outlet of the catchment. Estimate the rainfall excess and $\phi$-index

| Time from start of rainfall (hr) | 0 | 6 | 12 | 18 | 24 | 30 | 36 | 42 | 48 | 54 | 60 | 66 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Observed flow ($m^3/s$) | 6 | 5 | 13 | 26 | 21 | 16 | 12 | 9 | 7 | 5 | 5 | 4.5 | 4 |

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Catchment

Let us use simple straight line method for base

$N = 0.83 \times A^{0.2}$

$(27)^{0.2}$

has the peak at

Let us take N = 8-12 =

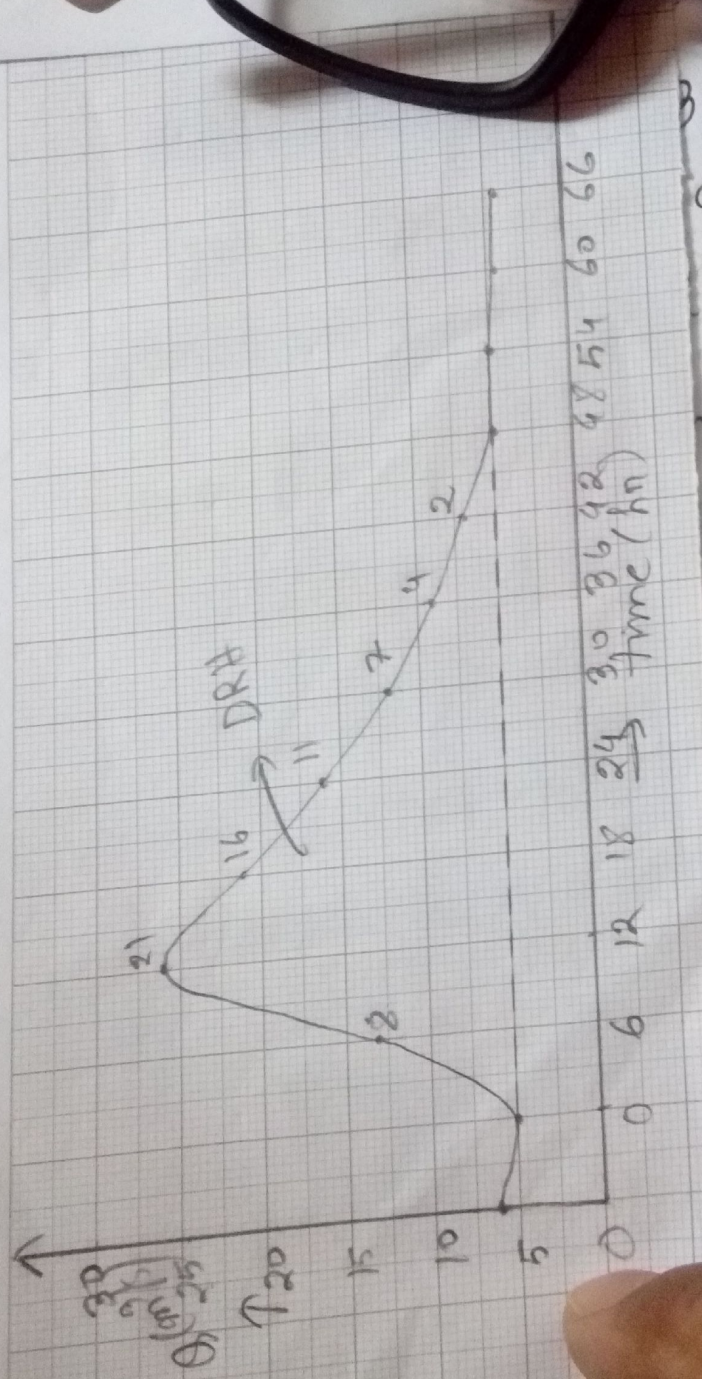
ydnograph (DRH)

(8+21) + (21+16) + (16+

(7+4) + (4+2) + 2

$\text{excess} = \frac{1.4904 \times 10}{27 \times 10^6}$

tion =

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Solve: Total rainfall = 3.8 + 2.8 = 6.6cm

Catchment area = 27 km²

Let us use simple straight line method for baseflow seperation - $N = 0.83 \times A^{0.2}$

$= 0.83 \times (27)^{0.2}$

$= 1.6$ days

$\approx 32.5$ h

from graph, DRH starts at t = 0 has the peak at t = 12h and ends at t = 48hr. Let us take N = 48 - 12 = 36h

Area of direct Runoff Hydrograph (DRH)

$= 6 \times 3600 \times \frac{1}{2} \{8 + (8+21) + (21+16) + (16+11) + (11+12) + (7+4) + (4+2) + 2\}$

$= 1.4904 \times 10^6 m^3$

Runoff depth = Rainfall excess $= \frac{1.4904 \times 10^6}{27 \times 10^6} \times 100$

$= 5.52$cm

Depth of infiltration = 6.6 - 5.52

$= 1.08$cm

Total rainfall duration = 4 + 4 = 8hr

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$$\phi\text{-index} = \frac{1.08}{8}$$

$$= 0.135 \text{ cm/hr}$$

Example 6.3: A storm over a catchment of area 5.0 km$^2$ had a duration of 14 hours. The mass curve of rainfall of the storm is as follows-

| Time from start of storm (hr) | 0 | 2 | 4 | 6 | 8 | 10 | 12 | 14 |
|---|---|---|---|---|---|---|---|---|
| Accumulated rainfall (cm) | 0 | 0.6 | 2.8 | 5.2 | 6.6 | 7.5 | 9.2 | 9.6 |

If the $\phi$-index of the catchment is 0.4 cm/h, determine the effective rainfall hyetograph and the volume of direct run-off from from the catchment due to the storm

Solve:

| Depth of rainfall (cm) | 0 | 0.6 | 2.2 | 2.4 | 1.4 | 0.9 | 1.7 | 0.4 |
|---|---|---|---|---|---|---|---|---|
| Intensity of rainfall (cm/hr) | 0 | 0.3 | 1.1 | 1.2 | 0.7 | 0.45 | 0.85 | 0.2 |

Total rainfall = $(0.3 + 1.1 + 1.2 + 0.7 + 0.45 + 0.85 + 0.2) \times 2$

$= 4.8$ cm

$= 9.6$ cm

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Depth of pre-mnth time of rainfall excess = 14 - 2 - 2
= 10hr

Depth of infiltration = 0.4 × 10
= 4 cm

Effective rainfall depth = 9.6 - 4

or Depth of Direct Runoff = 5.6 cm

Volm of direct runoff = $\frac{5.6}{100} \times 5 \times (10^3)^2$

= 28000 $m^3$ (Ans)

(Confusion → sin G ask Z 9 10 Z 14)

Unit Hydrograph Example 6.4: Given below are the ordinates of a 6-h unit hydrograph for a catchment. Calculate the ordinates of the DRH due to a rainfall excess of 3.5 cm occurring in 6hr.

| Time(h) | 0 | 3 | 6 | 9 | 12 | 15 | 18 | 24 | 30 | 36 | 42 | 48 | 54 | 60 | 6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UH Ordinates ($m^3/s$) | 0 | 25 | 50 | 85 | 125 | 160 | 185 | 160 | 110 | 60 | 36 | 25 | 16 | 8 | 0 |

Solve:

| Time (h) | 0 | 3 | 6 | 9 | 12 | 15 | 18 | 24 | 30 | 36 | 42 | 48 | 54 | 60 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DRH ($m^3/s$) | 0 | 87.5 | 175 | 297.5 | 437.5 | 560 | 647.5 | 560 | 385 | 210 | 126 | 87.5 | 56 | 28 |

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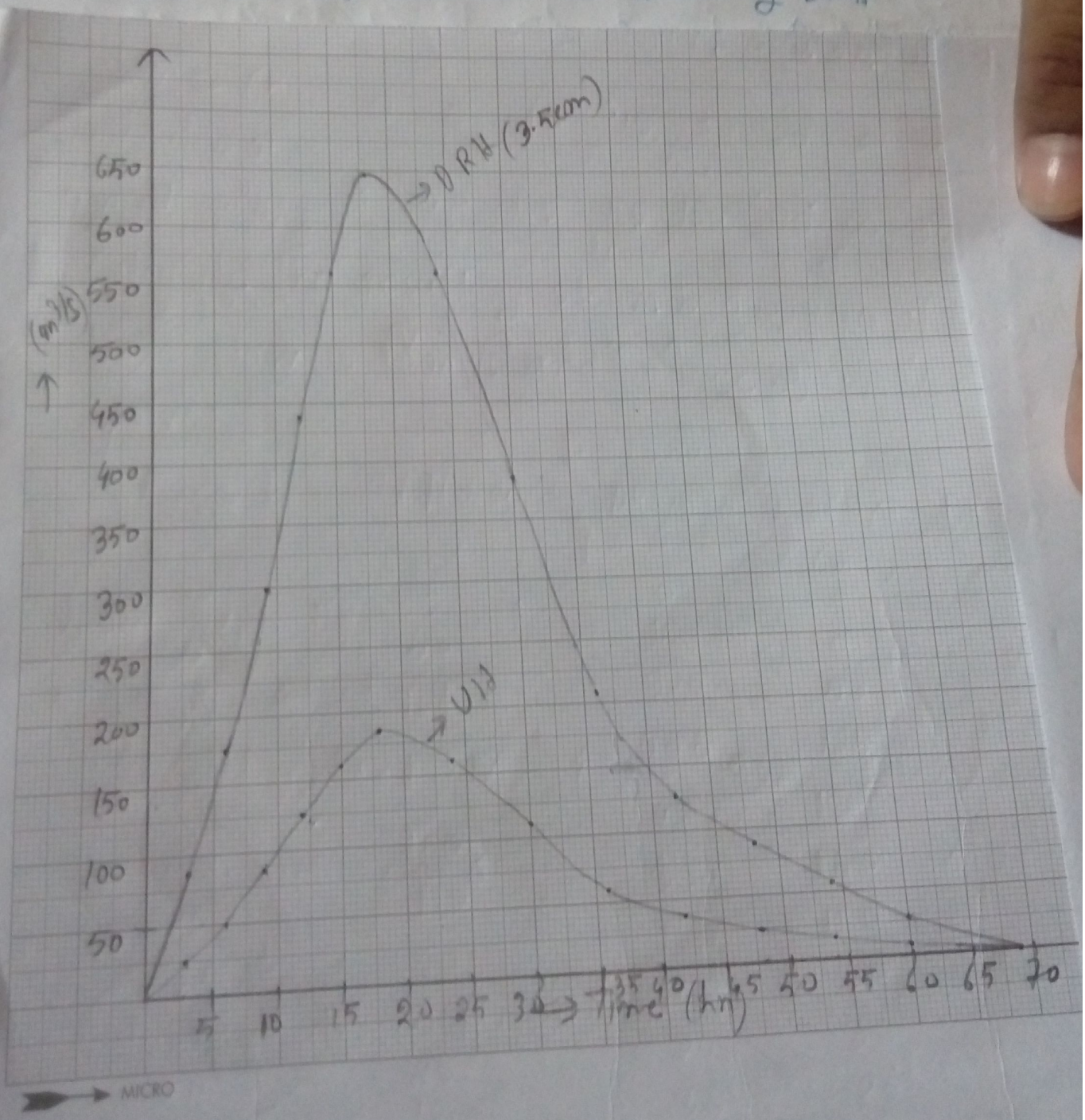
Example-6.5: Two storms each of 6-h duration and having rainfall excess values of 3.0 and 2.0 cm respectively occur successively. The 2cm ER rain follows the 3 cm rain. The 6-h unit hydrograph for the catchment is the same as given in example-6.4. Calculate the resulting DRH




MICRO

60 24 (16) 24

(2.2) (8.7)

Example-6.5: Two storms each of 6-h duration and having rainfall excess values of 3.0 and 2.0 cm respectively occur successively. The 2cm ER rain follows the 3 cm rain. The 6-h unit hydrograph for the catchment is the same as given in example-6.4. Calculate the resulting DRH

Solve:

~~0 3 6 9 12 15 18 24 30 36 42 48 54 60~~

~~DRH1 (cm³/s)~~

| Time | DRH1 ordinates | DRH2 ordinates | Resulting DRH ordinates |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 3 | 75 | 0 | 75 |
| 6 | 150 | 0 | 150 |
| 9 | 255 | 50 | 305 |
| 12 | 375 | 100 | 475 |
| 15 | 480 | 170 | 650 |
| 18 | 555 | 250 | 805 |
| (21) | (517.5) | (320) | 837.5 |
| 24 | 480 | 370 | 850 |
| 30 | 330 | 320 | 650 |
| 36 | 180 | 220 | 400 |
| 42 | 108 | 120 | 228 |
| 48 | 75 | 72 | 147 |
| 54 | 48 | 50 | 98 |
| 60 | 24 | 32 | 56 |
| (66) | (2.7) | (8.2) | 24 |
| | | (16) | |

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| | | | |
|---|---|---|---|
| 63 | 10 | 10-7 | 10-7 |
| 25 | 0 | 0 | 0 |

2012-13 1(b) The rainfall values over a catchment in three successive 5-hr intervals are known to be 3, 1 and 7 cm. The $\phi$ index for the catchment to be 0.2 cm/hr. Given below are the ordinates of a 5hr unit hydrograph

| Time (hr) | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ordinates of 5-hr UH ($m^3/s$) | 0 | 50 | 125 | 185 | 160 | 110 | 60 | 36 | 25 | 12 | 0 |

Calculate the resulting storm hydrograph if the initial base flow is $10 m^3/s$ and increase by $2 m^3/s$ every 5 hours

Solve:

| Time (hr) | U H ordinates ($m^3/s$) | DRH(3) ($m^3/s$) | DRH(1) ($m^3/s$) | DRH(2) ($m^3/s$) | Base flow ($m^3/s$) |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | | |
| 5 | 50 | 150 | 0 | | |
| 10 | 125 | 375 | 50 | | |
| 15 | 185 | 555 | 125 | | |
| 20 | 160 | 480 | 185 | | |
| 25 | 110 | 330 | 160 | | |
| 30 | 60 | 180 | 110 | | |
| 35 | 36 | 108 | 60 | | |
| 40 | 25 | 75 | 36 | | |
| 45 | 12 | 36 | 25 | | |
| 50 | 0 | 0 | 12 | | |

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~~55~~ 0

Effective rainfall depth in 1st 5hr = 3 − 5×0.2 = 2cm

" " " " 2nd 5hr = 1 − 5×0.2 = 0

" " " " 3rd 5h = 7 − 5×0.2 = 6cm

| Time | VH ordinates ($m^3/s$) | DRH(2) ($m^3/s$) | DRH(6) $m^3/s$ | Base flow ($m^3/s$) | Storm Hydrograph |
|---|---|---|---|---|---|
| 0 | ~~40~~ | 0 | 0 | 10 | 10 |
| 5 | ~~250~~ | 100 | 0 | 12 | 112 |
| 10 | ~~185~~ 125 | 250 | 0 | 14 | 264 |
| 15 | 185 | 370 | 300 | 16 | 686 |
| 20 | 160 | 320 | 750 | 18 | 1088 |
| 25 | 110 | 220 | 1110 | 20 | 1350 |
| 30 | 60 | 120 | 960 | 22 | 1102 |
| 35 | 36 | 72 | 660 | 24 | 756 |
| 40 | 25 | 50 | 360 | 26 | 434 |
| 45 | 12 | 24 | 216 | 28 | 268 |
| 50 | 0 | 0 | 150 | 30 | 180 |
| 53 | 0 | 0 | 60 | ~~32~~ 31.2 | 91.2 |
| 55 | 0 | 0 | 0 | ~~32~~ 32 | 32 |

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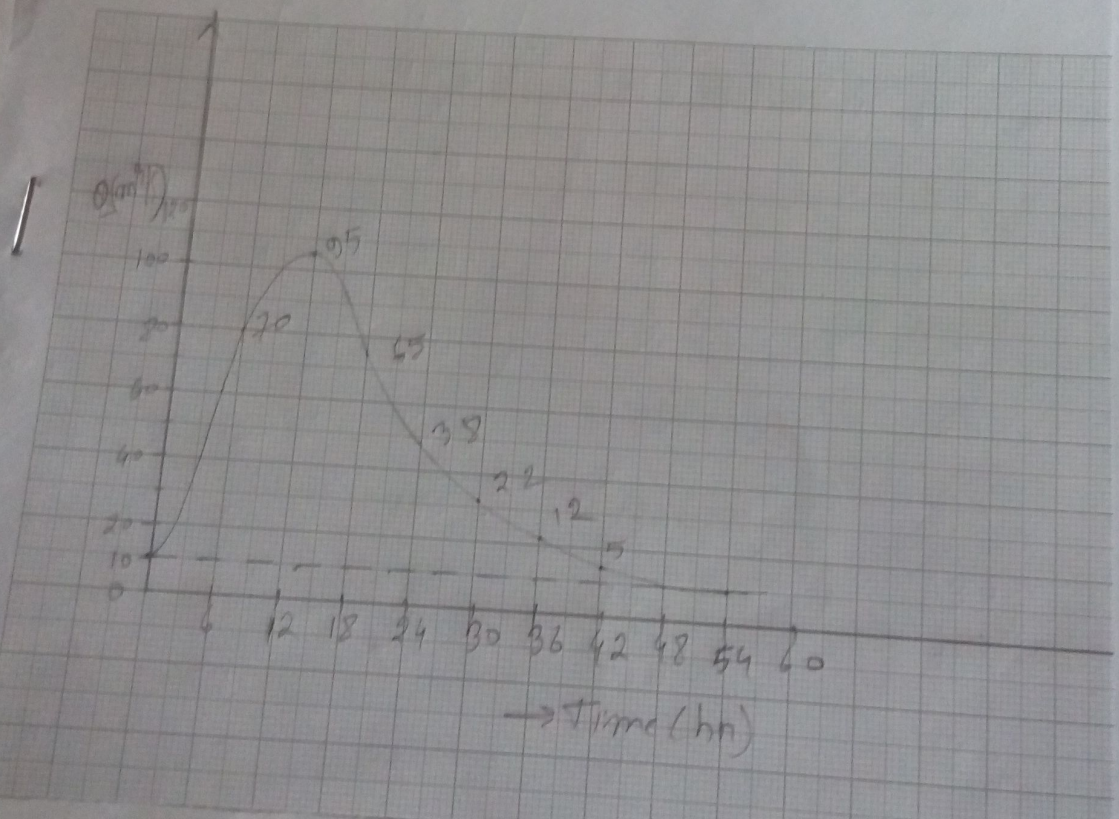
2012-13 1(c) Following are the ordinates of a storm hydrograph of a river draining a catchment area of 50 km$^2$ due to a 6 hr isolated storm. Derive the ordinates of a 6 hr unit hydrograph for the catchment

| Time from start of storm (hr) | 0 | 6 | 12 | 18 | 24 | 30 | 36 | 42 | 48 | 54 |
|---|---|---|---|---|---|---|---|---|---|---|




volume ordinates of direct runoff are, 0, 70, 95, 65, 38, 22, 12, 5, 0

volume of direct runoff $= (6 \times 3600) \times \frac{1}{2} \{70 + (70+95) + (95+65) + (65+38) + (38+22) + (22+12) + (12+5) + 5\}$

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2012-13 1(c) Following are the ordinates of a storm hydrograph of a river draining a catchment area of 50 km² due to a 6 hr isolated storm. Derive the ordinates of a 6 hr unit hydrograph for the catchment

| Time from start of storm (hr) | 0 | 6 | 12 | 18 | 24 | 30 | 36 | 42 | 48 | 54 |
|---|---|---|---|---|---|---|---|---|---|---|
| Discharge ($m^3/s$) | 10 | 80 | 105 | 75 | 48 | 32 | 22 | 15 | 10 | 10 |

Solve: Catchment area $A = 50 km^2$

Let us use simple straight line method for base flow seperation.

$$N = 0.83 \times A^{0.2} = 0.83 \times (50)^{0.2}$$

$$= 1.815 \text{ days}$$

$$= 43.6 hr$$

from graph DRH strant at $t = 0$, has the peak at $t = 12 hr$ and ends at $t = 48 hr$

let us take $N = 48 - 12 = 36 hr$ instead of 43.6 hr

volume ordinates of direct runoff are, 0, 70, 95, 65, 38, 22, 12, 5, 0

volume of direct runoff $= (6 \times 3600) \times \frac{1}{2} \{70 + (70+95) + (95+65) + (65+38) + (38+22) + (22+12) + (12+5) + 5\}$

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$= 6.6312 \times 10^6 m^3$

depth of direct runoff on effective rainfall

$$= \frac{6.6312 \times 10^6}{50 \times 10^6} \times 100$$

$= 13.2624 cm$

| ~~so ordinates~~ | DRH ordinates | UH ordinates |
|---|---|---|
| | 0 | 0 |
| | 70 | 5.28 |
| | 95 | 7.16 |
| | 65 | 4.9 |
| | 38 | 2.87 |
| | 22 | 1.66 |
| | 12 | 0.9 |
| | 5 | 0.15 |
| | 0 | 0 |

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Method of Superposition:

Example-6.9: Given the ordinates of a 4-h unit hydrograph as below. Derive the ordinates of a 12-hr unit Hydrograph for the same catchment

| Time (h) | 0 | 4 | 8 | 12 | 16 | 20 | 24 | 28 | 32 | 36 | 40 | 44 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ordinate of UH (4-h) | 0 | 20 | 80 | 130 | 150 | 130 | 90 | 52 | 27 | 15 | 5 | 0 |

Solve:

| Time | Ordinates of 4-h UH | Ordinates of 4-h UH (lagged by 4h) | Ordinates of 4-h UH (lagged by 8h) | DRH of 3 consecutive 12 hr |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |
| 4 | 20 | 0 | 0 | 20 |
| 8 | 80 | 20 | 0 | 100 |
| 12 | 130 | 80 | 20 | 230 |
| 16 | 150 | 130 | 80 | 360 |
| 20 | 130 | 150 | 130 | 410 |
| 24 | 90 | 130 | 150 | 370 |
| 28 | 52 | 90 | 130 | 272 |
| 32 | 27 | 52 | 90 | 169 |
| 36 | 15 | 27 | 52 | 94 |
| 40 | 5 | 15 | 27 | 47 |
| 44 | 0 | 5 | 15 | 20 |
| 48 | 0 | 0 | 5 | 5 |
| 52 | 0 | 0 | 0 | 0 |

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now.

DRH of 3 cm/1m 12hr

UH of 12-h

Ordinates of 12-

UH

0

6.67

33.33

76.67

120

136.67

123.33

90.67

56.33

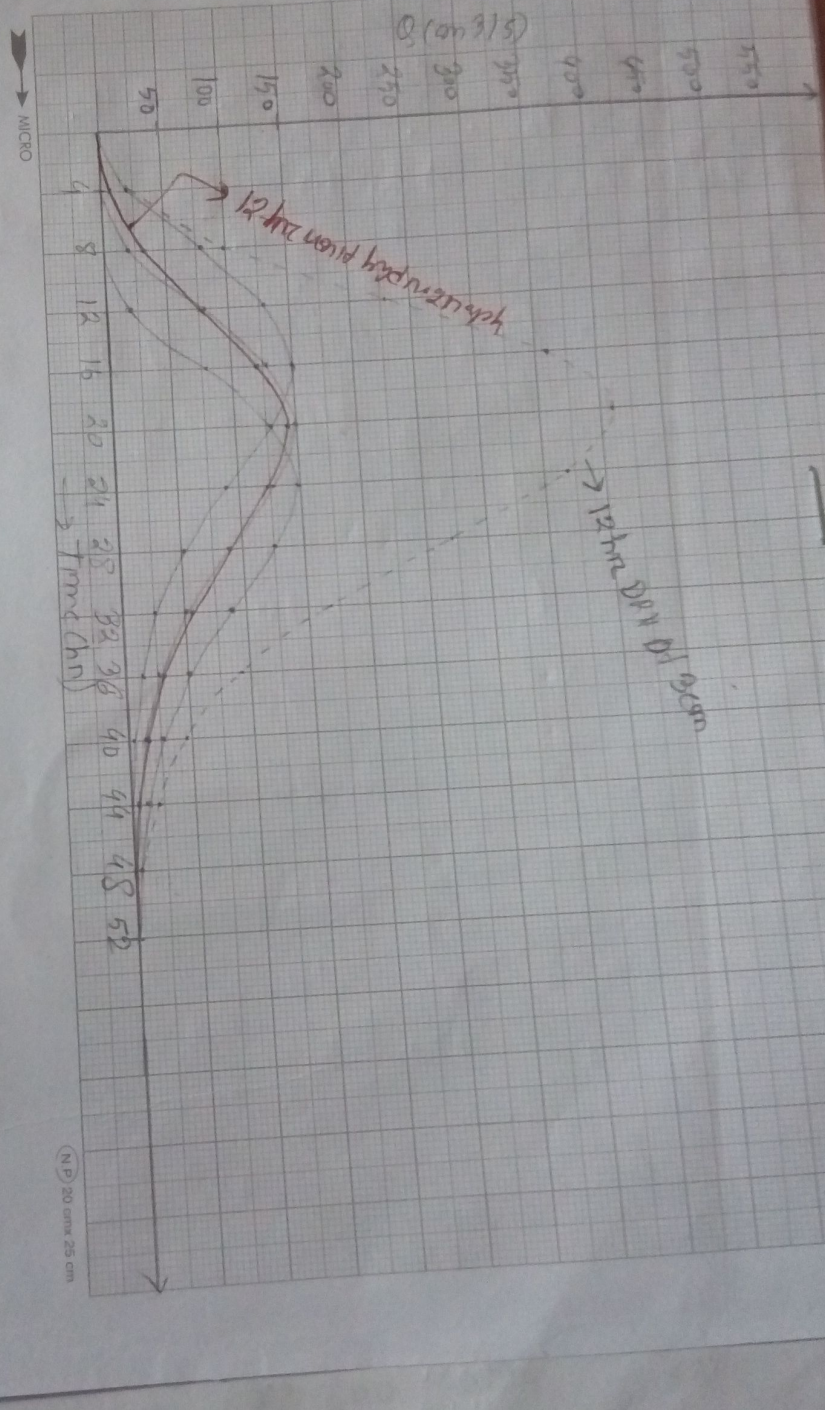
31.33

15.67

6.67

1.67

0

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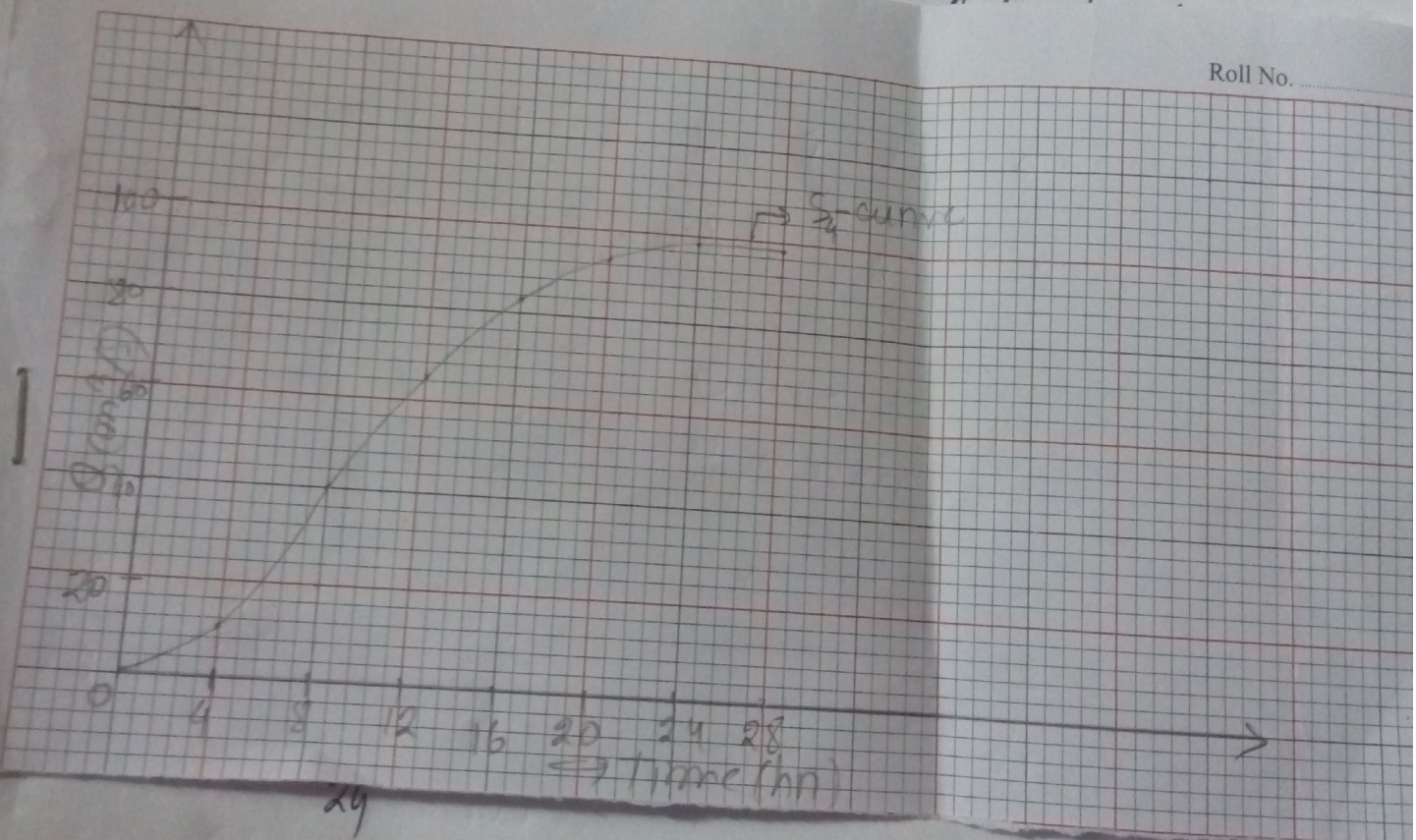
Example - 6.10: Derive the S-curve for the 4-h unit hydrograph given below:

| Time (h) | 0 | 4 | 8 | 12 | 16 | 20 | 24 | 28 |
|---|---|---|---|---|---|---|---|---|
| Ordinate of 4h UH ($m^3/s$) | 0 | 10 | 30 | 25 | 18 | 10 | 5 | 0 |

Soln:




Roll No. .....

29

28 0 98

Example-6.10: Derive the S-curve for the 4-h unit hydrograph given below:

| Time (h) | 0 | 4 | 8 | 12 | 16 | 20 | 24 | 28 |
|---|---|---|---|---|---|---|---|---|
| Ordinate of 4h UH ($m^3/s$) | 0 | 10 | 30 | 25 | 18 | 10 | 5 | 0 |

Solve:

| Time (hr) | Ordinates of 4h UH ($m^3/s$) | Ordinates of S-curve |
|---|---|---|
| 0 | 0 | 0 |
| 4 | 10 | 10 |
| 8 | 30 | 40 |
| 12 | 25 | 65 |
| 16 | 18 | 83 |
| 20 | 10 | 93 |
| 24 | 5 | 98 |
| 28 | 0 | 98 |

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Problem: Given the ordinates of a 4-h unit hydrograph as below. Derive the ordinates of a 12-h unit hydrograph for the same catchment by S-curve method.

| Time (hr) | 0 | 4 | 8 | 12 | 16 | 20 | 24 | 28 | 32 | 36 | 40 | 44 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ordinate of 4-h UH ($m^3/s$) | 0 | 20 | 80 | 130 | 150 | 130 | 90 | 52 | 27 | 15 | 5 | 0 |

Solve: Here, $T = 12$ hr $D = 4$ hr $T/D = 3$ cm

| Time (hr) | Ordinates of 4-h UH ($m^3/s$) | S-curve Ordinates ($m^3/s$) | S-curve lagged by 12 h ($m^3/s$) | DRH of 3 cm | Ordinates of 12-h UH |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 20 | 20 | 0 | 20 | 6.7 |
| 8 | 80 | 100 | 0 | 100 | 33.33 |
| 12 | 130 | 230 | ~~230~~ 0 | 230 | 76.7 |
| 16 | 150 | 380 | ~~100~~ 20 | 360 | 120 |
| 20 | 130 | 510 | ~~230~~ 100 | 410 | 136.7 |
| 24 | 90 | 600 | ~~380~~ 230 | 370 | 123.3 |
| 28 | 52 | 652 | ~~510~~ 380 | 272 | 90.7 |
| 32 | 27 | 679 | ~~600~~ 510 | 169 | 56.3 |
| 36 | 15 | 694 | ~~652~~ 600 | 94 | 31.3 |
| 40 | 5 | 699 | ~~679~~ 652 | 47 | 15.7 |
| 44 | 0 | 699 | ~~694~~ 679 | 20 | 6.7 |

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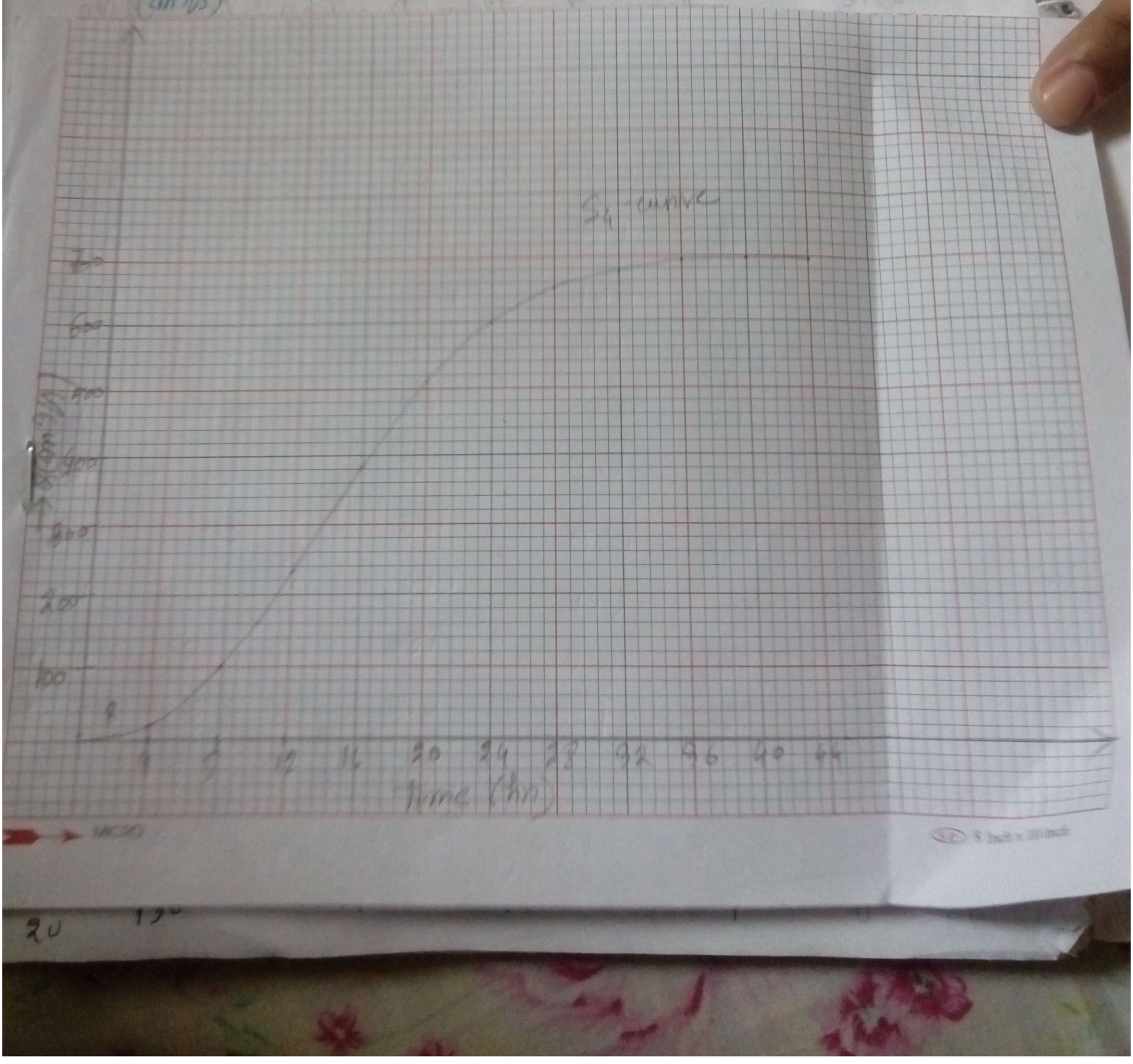
| | | | | | |
|---|---|---|---|---|---|
| 48 | 0 | 699 | ~~699~~ 694 | 5 | 1-7 |
| 52 | 0 | 699 | 699 | 0 | 0 |

Example - 6.12: Determine 2-h Unit Hydrograph from 4-h Unit Hydrograph given below

| Time (hr) | 0 | 4 | 8 | 12 | 16 | 20 | 24 | 28 | 32 | 36 | 40 | 44 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UH ordinates ($cm^3/s$) | 0 | 20 | 80 | 130 | 150 | 130 | 90 | 52 | 27 | 15 | 5 | 0 |

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| | | | | | |
|---|---|---|---|---|---|
| 48 | 0 | 699 | 699 | 5 | 17 |
| 52 | 0 | 699 | 699 | 0 | 0 |

Example - 6.12: Determine 2-h Unit Hydrograph from 4-h Unit Hydrograph given below

| Time (hr) | 0 | 4 | 8 | 12 | 16 | 20 | 24 | 28 | 32 | 36 | 40 | 44 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UH ordinates ($cm^3/s$) | 0 | 20 | 80 | 130 | 150 | 130 | 90 | 52 | 27 | 13 | 5 | 0 |

Solve: Here, $T = 2$, $D = 4$, $T/D = 0.5$ cm

common sum between 2 and 4 is 2

| Time | 4-hr UH ordinates | S curve Ordinates | S curve lagged by 2hr | DRH of 0.5cm | UH for 2hr coordinates |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 2 → from graph | 8 | 0 | 8 | 16 |
| 4 | 20 | 20 | 8 | 12 | 24 |
| | 43 - | 51 | 20 | 31 | 62 |
| | 80 | 100 | 51 | 49 | 98 |
| | 110 - | 161 | 100 | 61 | 122 |
| | 130 - | 230 | 161 | 69 | 138 |
| | 146 - | 307 | 230 | 77 | 154 |
| | 150 | 380 | 307 | 73 | 146 |
| | 142 - | 449 | 380 | 69 | 138 |
| | 130 | 510 | 449 | 61 | 122 |

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| | | | | | |
|---|---|---|---|---|---|
| 22 | 112 | 561 | 510 | 51 | 102 |
| 24 | 90 | 600 | 561 | 39 | 78 |
| 26 | 70 | 631 | 600 | 31 | 62 |
| 28 | 52 | 652 | 631 | 21 | 42 |
| 30 | 38 | 669 | 652 | 17 | 34 |
| 32 | 27 | 679 | 669 | 10 | 20 |
| 34 | 20 | 689 | 679 | 10 | 20 |
| 36 | 15 | 694 | 689 | 5 | 10 |
| 38 | 10 | 699 | 694 | 5 | (10)6 |
| 40 | 5 | 699 | 699 | 0 | (0)3 |
| 42 | 2 | 701 | 699 | -2 | 0 |
| 44 | 0 | 699 | 701 | -2 | 0 |
| 48 | 0 | 699 | 699 | 0 | 0 |

Exam problem: Ordinates of a 4-h unit hydrograph are given. Using this derive the ordinates of a 6-h unit hydrograph for the same catchment

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time (h) | 0 | 4 | 8 | 12 | 16 | 20 | 24 | 28 | 32 | 36 | 40 | |
| Ordinate of 4h UH ($m^3/s$) | 0 | 20 | 80 | 130 | 150 | 130 | 90 | 52 | 27 | 15 | 5 | |

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Solve: here, D = 4. T = 6 T/D = 6/4 = 1.5 cm

least common number bet$^{n}$ 4 and 6 is 2.

| Time (hr) | 4-h UH ordinates | S-curve Ordinates | S-curve lagged by 6hr | DRH of 1.5cm | 6-h UH ordinates |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 8 | 8 | 0 | 8 | 5.33 |
| 4 | 20 | 20 | 0 | 20 | 13.33 |
| 6 | 43 | 51 | 0 | 51 | 34 |
| 8 | 80 | 100 | 8 | 92 | 61.33 |
| 10 | 110 | 161 | 20 | 141 | 94 |
| 12 | 130 | 230 | 51 | 179 | 119.33 |
| 14 | 146 | 307 | 100 | 207 | 138 |
| 16 | 150 | 380 | 161 | 219 | 146 |
| 18 | 142 | 449 | 230 | 219 | 146 |
| 20 | 130 | 510 | 307 | 203 | 135.3 |
| 22 | 112 | 561 | 380 | 181 | 120.67 |
| 24 | 90 | 600 | 449 | 151 | 100.7 |
| 26 | 70 | 631 | 510 | 121 | 80.7 |
| 28 | 52 | 652 | 561 | 91 | 60.7 |
| 30 | 38 | 669 | 600 | 69 | 39.3 |
| 32 | 27 | 679 | 631 | 48 | 32 |
| 34 | 20 | 689 | 652 | 37 | 24.7 |

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| | | | | | |
|---|---|---|---|---|---|
| 36 | 15 | 694 | 669 | 25 | 16.7 |
| 38 | 10 | 699 | 677 | 20 | 13.3 |
| 40 | 5 | 699 | 689 | 10 | 6.7 |
| 42 | 2 | 701 | 694 | 7 | 4.7 |
| 44 | 0 | 699 | 699 | 0 | (0) 2 |
| 46 | 0 | 699 | 699 | 0 | 0 |
| 48 | 0 | 699 | 701 | -2 | (-1.3) 0 |
| 50 | 0 | 699 | 699 | 0 | 0 |

2013-14, 3(c) Four rain gauge gages located within a rectangular area with four corners at (0,0), (0,13), (14,13), and (14,0) having the following coordinates and recorded rainfalls

| Rain gage location | Rain-fall (mm) |
|---|---|
| (2,9) | 18 |
| (7,11) | 25 |
| (12,10) | 35 |
| (6,2) | 42 |

All coordinates are expressed in km. Compute the average rain-fall in the area by isohyetal Method (use isohyets of 20 and 40mm) Use plain graph paper.

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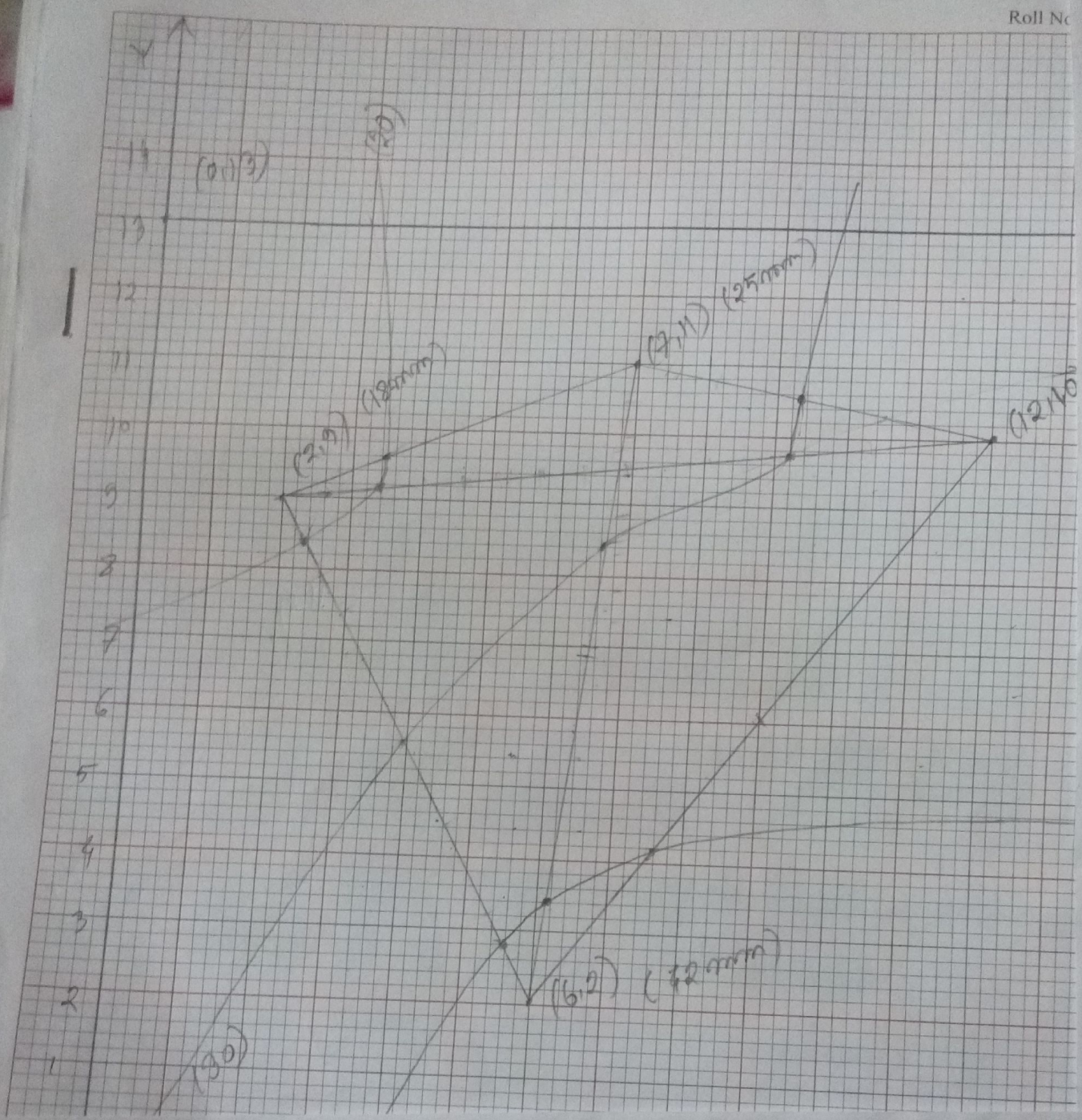
Roll No




Where $L_{max}$ = Maximum length of travel of water

From Graph!

| Isohyets | Area enclosed | Avg rainfall | Rainfall volume |
|---|---|---|---|
| 20 | ~~202~~ 400 | 10 | 4000 |
| 30 | 1375 | 25 | 34375 |
| 40 | 1800 | 35 | 63000 |
| | 975 | 20 | 19500 |
| | 4550 | | 120875 |

Average rainfall = $\frac{120875}{4550}$

= 26.57 mm (Ans)

2013-14 4(a). Consider the following two catchment areas

Catchment A
Slope = 0.002
L = 1500m
Sandy soil
High vegetative cover
A = 2~~m~~ km²

Catchment B
slope = 0.02
L = 2000m
Clay soil
No vegetative cover
A = 3km²

Where L = Maximum Length of travel of water

i) The runoff coefficients of 0.2 and 0.8. Which runoff coefficients will be applicable to which catchment and why?

ii) Find out the time of concentration of catchment A

iii) Compute the peak discharge for catchment A for a return period of 100 years using Rational Method. Use IDF curves shown in Fig 1.

Solve: i) Catchment A has sandy soil so infiltration will be high as a result runoff will be low. At the same time catchment B has clay soil so impermeable as a result runoff will be high. Catchment A has higher vegetative cover so lower runoff. Catchment B has no vegetative cover so higher runoff.

So. for catchment ~~area~~ A runoff coefficient $C = 0.2$

for catchment B runoff coefficient $C = 0.8$

ii) here, $L = 1500\,m$ $S = 0.002$

time of concentration, $t_c = 0.01947\, L^{0.77} S^{-0.385}$

$= 0.01947 \times (1500)^{0.77} \times (0.002)^{-0.385}$

$= 50.44$ minutes (Ans)

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iii) here, T = 100 and $t_c$ = 50.44

so, i = 3.25 cm/h

= 8.255 cm/h

Peak discharge, $Q_p = CiA$

$= 0.21 \frac{8.255}{100 \times 360} \times (2) \times 10^6$

$= 9.17 m^3/s$ (Ans)