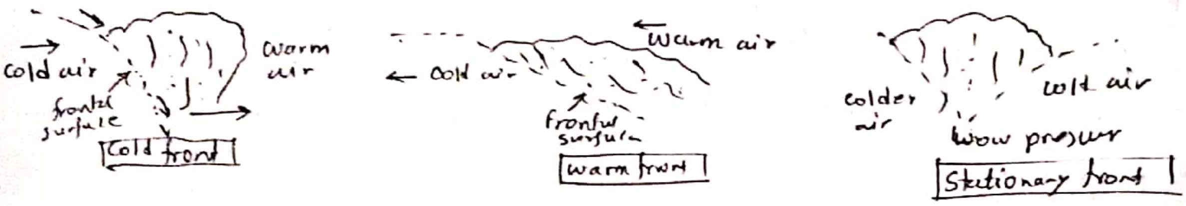
Chapter 2: Precipitation

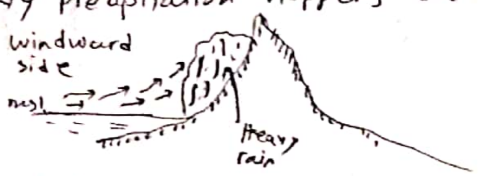
Types of Precipitation:

(i) Thermal precipitation: (convectional Precipitation) — is in the form of local thunderstorms — happens in tropics - forms cauliflower shaped cloud — bursts into thunderstorm — when wind is accompanied, tornado is formed.

(ii) Conflict between two air-masses (frontal precipitation: — air masses of constrasting temperaturature and density clashes with eachother, condensation & precipitation occur — [cold front] cold air mass drives out warm air mass. It causes intense precipitation in small areas. Cold front moves faster than warm fronts, usually overtake them. [Warm front] If a warm air mass replaces a cold air mass. less intense precipitation but over large area. Slower than cold front. [Stationary front] If two air masses are drawn simultaneously towards a low pressure area, the developed front is stationary. [Occluded front] When the frontal surfaces of cold and warm air slide against each other, it's called occlusion. and the resulting front called 'Occluded front.'



(iii) Orographic lifting (orographic precipitation): — The mechanical lifting of moist air over moutain barriers. — heavy precipitation happens on the windward side.



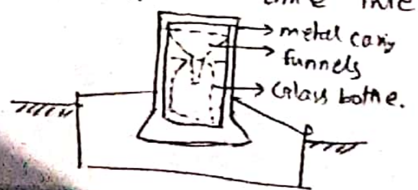
(iv) Cyclonic Precipitation: — due to lifting of moist air converging into a low pressure belt. — due to pressure differences created by the unequal heating of the earth's surface. — Winds blow counterclockwise in Northern Hemi — clockwise in southern hemi. Cyclones two types: [tropical] hurricane, typhoon, dia = 300–1500 km, velocity precipitation high [extra-tropical] — Dia = 3000 km, wide spread frontal type precipitation.

Measurement of precipitation:

Raingauge is an instrument, used for measuring the precipitation depth falling on the land at a particular point and time.

Types:

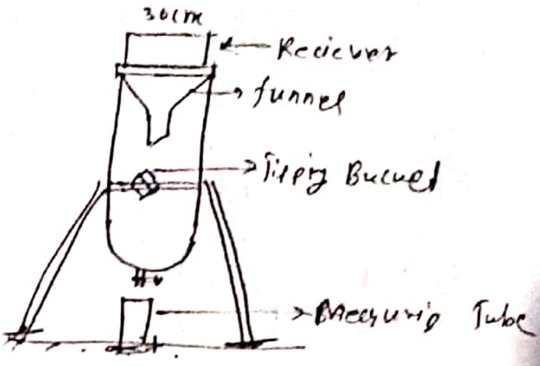
(i) Non Recording Type: Symon's raingauge: [consists of a funnel with a circular rim of 12.7 cm dia, a glass bottle as a reciever. It's protected by a metal casing of 30.5 cm height fixed vertically in a masonry foundation] — When full, it can measure 1.25 cm of rain — gives total rain depth of 24 hrs — {doesn't give the rainfall intensity and duration of rainfall during different time intervals of the day.} — Demerits



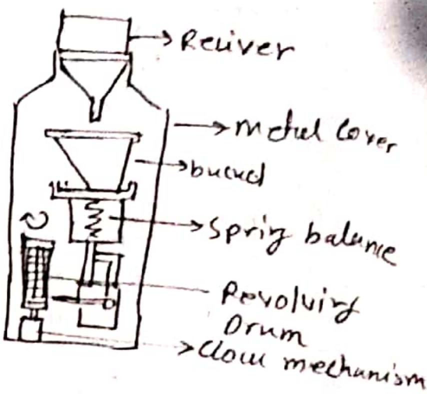
11) Recording Type: (i) ~~Tipping Bucket~~ - also called self Recording/automatic/integrating gauge.
- has an automatic mechanical arrangement consisting of [a clockwork + drum with a graph paper around it + a pencil point] - [Determinations] - depth of rainfall in a given time - rate or intensity of rainfall - time of ~~offset~~ onset - cessation of rainfall

(a) Tipping bucket gauge

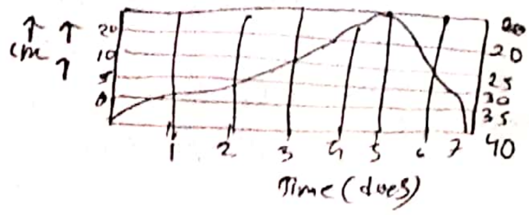
* Cylindrical reciever with 30cm dia
- have funnel inside
- Two/a pair of buckets used.
- buckets pivot when 0.25mm rainfall occur
- Tipping actuates a electric circuit which causes a pen to move on a chart wrapped around a drum.
- Can't record snow



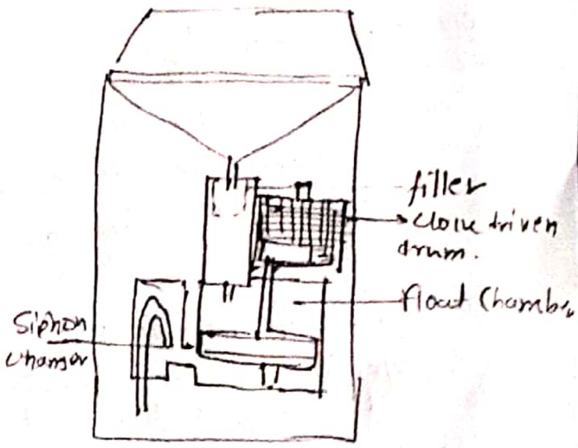
(b) Weighing Type:
- A tank rests on a spring-lever balance
- The spring makes a pen to move on ~~drum~~ a clock driven drum when a certain amount of water is recorded
- Can store snow



(c) Float Type/Syphon rain gauge:
- Rain is collected in a float chamber.
- There's a clock driven drum.
- The rain is collected as the float moves up which makes the pen to move.
- When the chamber fills up, the water siphons out.
- The clockwork revolves the chamber once in 24 hours.



- Can store snow



Raingauge Density: The number of rain gauges to be erected in a given area is called rain-gauge density.

Area	Density	Area	Length of Record
Plains	- 1 in 520 km²	Islands	- 30 yrs
Elevated Regions	- 1 in 260-390 km²	Shores	- 40 yrs
Hilly and very Heavy Rainfall Areas	- 1 in 130 km²	Plains	- 40 yrs
		Mountains	- 50 yrs

a.a.r: The mean of yearly rainfall observed for a period of 35 consecutive years. Depends on:

(i) Distance from the ocean
(ii) Direction of the prevailing winds
(iii) The mean annual temp.
(iv) Altitude of the place.
(v) Topography

Index of wetness: The ratio of rainfall of a particular year to the a.a.r

Index of wetness > a.a.r = wet (good) years
" " " < a.a.r = dry (bad) "
" " " = a.a.r = average (normal) years

Isohyet: A line joining the places with same a.a.r.

Climates:

① Arid = a.a.r < 40 cm → (i) Drought is normal state of affairs
(ii) while calculating runoff, each fall of rainfall has to be considered as seperate unit

② Semi Arid = a.a.r 40 to 75 cm → (i) Drought once a year

③ Humid = a.a.r > 75 cm → (i) Drought doesn't occur normally

Estimates of Missing Data:

1. **Station Year method:** In the same area, index of wetness is same for all stations,

$$\left(\frac{\text{Rainfall of a Year}}{\text{a.a.r}}\right)_A = \left(\frac{\text{Rainfall of a Year}}{\text{a.a.r}}\right)_B$$

CamScanner

2. Normal Ratio Method:

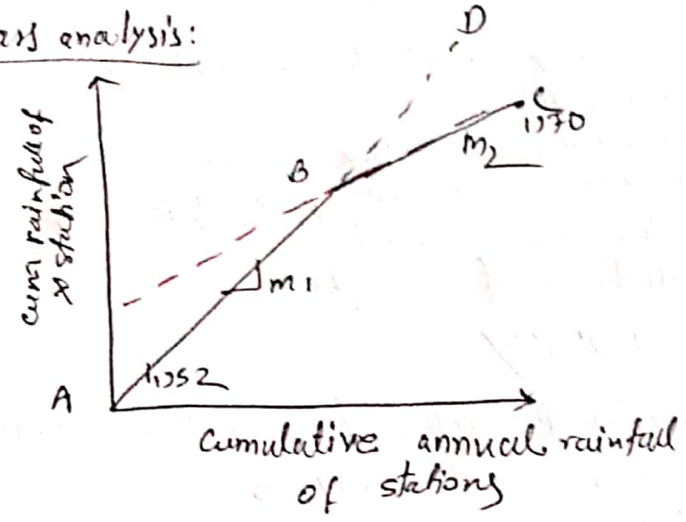
$$P_x = \frac{1}{m}\left(\frac{P_1}{N_1} \times P_x + \frac{P_2}{N_2} \times P_x + \dots + \frac{P_m}{N_m} \times P_x\right)$$

where, $P_1 P_2 .. P_m$ = Rainfall in a year or month

N_1 = a.a.r of that station

P_x = a.a.r of x station

③ Double mass analysis:



correction factor $= \frac{m_2}{m_1}$

* Adjusted cum rainfall of x from A to B, ~~= cum~~

= cum rainfall fall of x at point B × $\frac{m_2}{m_1}$

* Cum rainfall of x after change, B to C =

* Final adjusted rainfall from A to C

= Adjusted rainfall from A to B + Cum rainfall of B to C

= Cum rainfull of point B × $\frac{m_2}{m_1}$ + (Cum rain of C − cum rain of B)

* AA.R adjusted

$$= \frac{\text{Adjusted Rainfall of A to C}}{(1970 - 1952 + 1)}$$

Average Depth of Precipitation:

Point Rainfall: It is the rainfall of a single station. For an area of 50 km², point rainfall can be taken as average rainfall.

There are three methods. First two, doesn't require any special skill. and these two are purely mechanical processes. But, third method requirs good judgement on accuracy.

Methods:

(i) Arithmatic Method: $P = \frac{\Sigma P}{n}$

- simplest of all methods
- Also known as unweighted mean method
- Same weightage is given to all all the gauges irrespective of their locations.
- For flat areas, uniformly distributed gauges provide satisfactory results
- Very rapid
- Excellent Adaptibility to computer processing

(ii) Thiessen Polygon Method: (weighted mean method)

$$P = \frac{A_1P_1 + A_2P_2 + \cdots + A_nP_n}{A_1 + A_2 + \cdots + A_n}$$; $A_1 + A_2 + \cdots + A_n =$ Area of Basin

- Suggested by A.M. Thiessen in 1911
- Attempts to make allowance for irregularities by weighing the record of each gauge in proportion the area which is closer to the gauge than to any other gauge.

$$\therefore P = \frac{A_1P_1 + A_2P_2 + \cdots A_nP_n}{A} = \frac{\sum_{1}^{n=n} A_nP_n}{A}$$

$$\therefore P = \frac{A_1}{A}P_1 + \frac{A_2}{A}P_2 + \cdots + \frac{A_n}{A}P_n$$

- The factors $\frac{A_1}{A}, \frac{A_2}{A}, \ldots \frac{A_n}{A}$ which adds up to unity are called Thiessen weights.

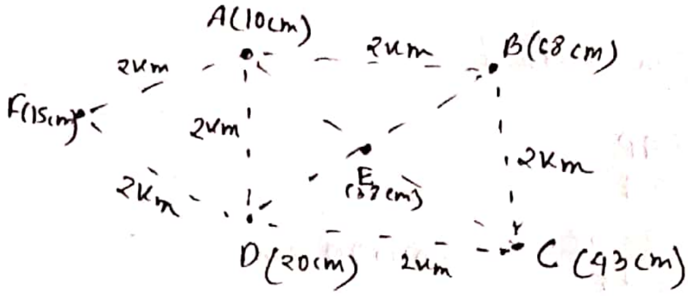
Limitations :

- Does not make allowance for orthographic influences in the basin
- Every time a gauge is added or removed the whole network change and the whole process is to be done again
- This inflexeibility is the greatest limitation to this method

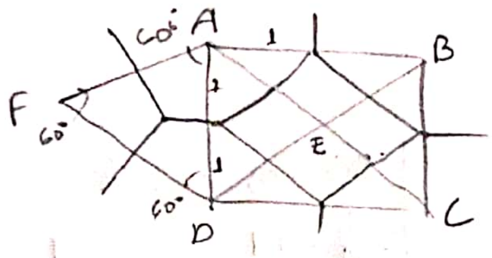
(III) Isohyetal Method:

- The most accurat method
- This method utilises all the data available in the interpolation and it's well adapted to display and discussion.
- Highly dependent on the skill of the analyst
- very slow compared to others
- Very poor adaptibility to computer processing.

7(c) 2017/ Find the mean precipitation for the area shown in figure below by thiessen Polygon method. The area is compound of a square plus an equilateral triangular plot of side 2km. Rainfall readings are in cm at the various station indicated.



Soln:



Area of inner square plot $= (\sqrt{2})^2 = 2\ km^2$

Aream of outer " " $= 2^2 = 4\ km^2$

$\therefore$ Difference $= 4-2 = 2\ km^2$

$\therefore$ Area of each triangle of ABCD square $= \frac{2}{4} = 0.5\ km^2$

$\therefore$ Area of $\Delta AFD = \frac{\sqrt{3}}{4}a^2 = \frac{\sqrt{3}}{4} \times 2^2 = \sqrt{3}\ km^2$

$\therefore$ Area of each section of three $= \frac{\sqrt{3}}{3} = \frac{1}{\sqrt{3}}\ km^2$

Station	A (km²)	P (cm)	A×P (km²-cm)
A	$0.5+\frac{1}{\sqrt{3}} = 1.077$	10	10.77
B	0.5	68	34
C	0.5	43	21.5
D	$0.5+\frac{1}{\sqrt{3}} = 1.077$	20	21.54
E	2	38	76
F	$\frac{1}{\sqrt{3}}$	15	8.66
	$\Sigma A = 5.73$	$\Sigma P = 194$	$\Sigma AP = 172.47$

n = 6

∴ Arithmatic mean, $= \frac{\Sigma P}{n}$

$= \frac{194}{6}$

$= 32.33$ cm

By thiessen polygon method,

$= \frac{\Sigma AP}{\Sigma A}$

$= \frac{172.47}{5.73} = 30.099$ cm

Ans

Reddy: 5.8

Here,

$P_1 = 132$

$P_2 = 114$

$P_3 = 162$

$P_4 = 138$

$P_5 = 207$

$P_6 = 156$

$P_7 = 135$

$P_8 = 158$

$P_9 = 168$

$P_{10} = 150$ mm

$\Sigma P = 1520$

Thiessen weights,

$\frac{A_1}{A} = 0.1$

$\frac{A_2}{A} = 0.16$

$\frac{A_3}{A} = 0.12$

$\frac{A_4}{A} = 0.11$

$\frac{A_5}{A} = 0.09$

$\frac{A_6}{A} = 0.08$

$\frac{A_7}{A} = 0.07$

$\frac{A_8}{A} = 0.11$

$\frac{A_9}{A} = 0.06$

$\frac{A_{10}}{A} = 0.10$

∴ Arithmatic Average $= \frac{\Sigma P}{10}$

$= \frac{1520}{10}$

$= 152$ mm

Thiessen average, $= \frac{A_1}{A} \times P_1 + \frac{A_2}{A} \times P_2 + \dots + \frac{A_{10}}{A} \times P_{10}$

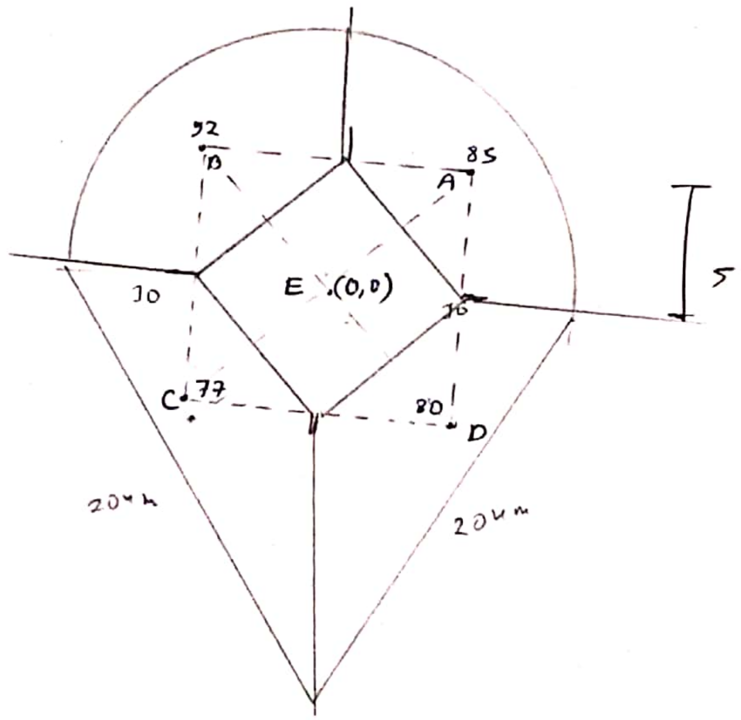
$= 0.1 \times 132 + 0.16 \times 114 + 0.12 \times 162 + 0.11 \times 138 + 0.09 \times 207$
$+ 0.08 \times 156 + 0.07 \times 135 + 0.11 \times 158 + 0.06 \times 168 + 0.1 \times 150$

$= 147.08$ mm

2020

Ex: 5.2 A semicircle of dia of 20km with an equilateral triangle of side 20km below it's diameter is a close approx to a river basin. The position coordinates of 5 raingauge station A, B, C, D and E located within the basin with respect to a coordinate axes system whose x-axis and origin are coincident with diameter and centre of the circle are (5, 5), (−5, 5), (−5, −5), (5, −5), and (0, 0) km respectively. If the rainfall recorded at these raingauges are 85, 92, 77, 80, and 105mm respectively determine the average depth of rainfall using Thiessen polygon method.

Soln:



Area of the inner square = $(\sqrt{5^2+5^2})^2 = 50\ km^2$

Area of the Half circle = $\frac{\pi D^2}{4\times2} = 157.07\ km^2$

" " Triang = $\frac{\sqrt{3}}{4}\times 20^2 = 173.2\ km^2$

Area of A & B

$= \frac{1}{2}\times 157.04 - \frac{1}{4}\times 50 = 66.04\ km^2$

Area of C & D

$= \frac{1}{2}\times 173.2 - \frac{1}{4}\times 50 = 74.1\ km^2$

Ex: 5.10 Reddy The analysis of a storm yielded the following information regarding isohyets. Calculate the average depth of rainfall.

Isohyet Interval in mm	70-80	80-90	90-100	100-110	110-120	120-130
Area in km^2	10	85	113	98	136	67

Soln:

Isohyetal Interval	Average Value of Isohyet, P	Area, A	A×P km^2-mm
70-80	75	10	750
80-90	85	85	7225
90-100	95	113	10735
100-110	105	98	10290
110-120	115	136	15640
120-130	125	67	8375
		509	53015

$\therefore$ Average Depth of rainfall $= \frac{53015}{509}$

$= 104.16$ mm

Optimum Number of Raingauge:

Ex: 5.15 Reddy: The average annual rainfall δ in cm at 4 existing raingauge stations in a basin are 105, 79, 70, 66. If the average depth of rainfall over the basin is to be estimated within 10% error. Determine the additional number of gauges needed.

Solⁿ:

Station	A.A.r (cm)	$(x-\bar{x})$	$(x-\bar{x})^2$
1.	105	25	625
2.	79	-1	1
3.	70	-10	100
4.	66	-14	196
n=4	320		922

$\therefore \bar{x} = \frac{320}{4} = 80 \text{ cm}$

$\therefore \sigma = \sqrt{\frac{(x-\bar{x})^2}{n-1}}$

$= \sqrt{\frac{922}{4-1}} = 17.53 \text{ cm}$

$\therefore$ We know, $C_v = \frac{\sigma}{\bar{x}} \times 100 = \frac{17.53}{80} \times 100 = 21.91\%$

$\therefore N = \left(\frac{C_v}{P}\right)^2 = \left(\frac{21.91}{10}\right)^2 = 4.80 \approx 5$

$\therefore$ Additional gauges required $N = 5$

Question

Introduction: 2020

Q 1 (a) What are the basic data required for hydrological studies? Explain "hydrologic equation."

(b)

2017

(a) Explain with the help of a neat sketch, the hydrologic cycle in nature, indicating it's various phases.

(b) What are the functions of hydrology in water resources development

(c) Explain hydrologic equation? What are the basic data required for hydrological studies.

2018

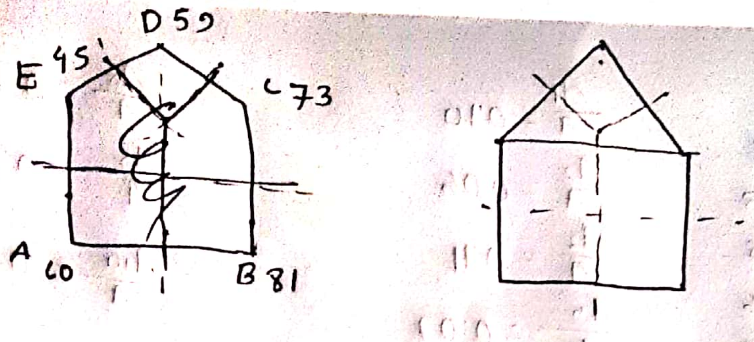
Q1(a) Discuss the practical applications of hydrology in the field of water resources engineering.

2016

Q 1 (a) hydrologic cycle with sketch

(b) What are the functions of hydrology in water resource development? (Pr)

25:



Area for Station $A = \frac{20}{2} \times \frac{20}{2} = 10 \times 10 = 100\ km^2$

Area " " $B = 20/2 \times 20/2 = 100 km^2$

" " " $D = \left(\frac{\sqrt{3}}{4} \times 20^2\right)/3 = 173.20/3 = 57.73\ km^2$

" " " $E\ \&\ C = 100 + 57.73 = 157.73\ km^2$

Station	Area	Preci.	A × P (km²-mm)
A	100	60	6000
B	100	81	8100
C	157.73	73	11514.29
D	57.73	59	3406.07
E	157.73	45	7097.85
	573.19		36118.21

∴ Average depth of Rainfall $= \frac{36118.21}{573.19}$

$= 63.01$ mm

Ans:

5.26

$P_1 = 150$	$\frac{A_1}{A} = 0.10$	$\frac{A_8}{A} = 0.12$
$P_2 = 168$	$\frac{A_2}{A} = 0.06$	$\frac{A_9}{A} = 0.16$
$P_3 = 158$	$\frac{A_3}{A} = 0.11$	$\frac{A_{10}}{A} = 0.10$
$P_4 = 135$	$\frac{A_4}{A} = 0.07$	
$P_5 = 156$	$\frac{A_5}{A} = 0.08$	
$P_6 = 207$	$\frac{A_6}{A} = 0.09$	
$P_7 = 138$	$\frac{A_7}{A} = 0.11$	
$P_8 = 162$		
$P_9 = 114$		
$P_{10} = 132$		

Arithmatic Mean: Arithmatic এ বেশি আসে

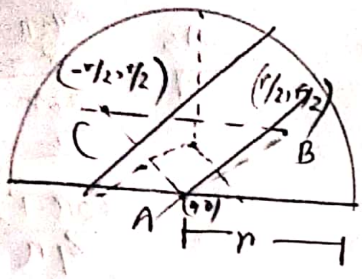
$$\text{Depth} = \frac{150\times\cancel{01} + 158 + 207 + 138 + 162 + 114 + 132}{7}$$

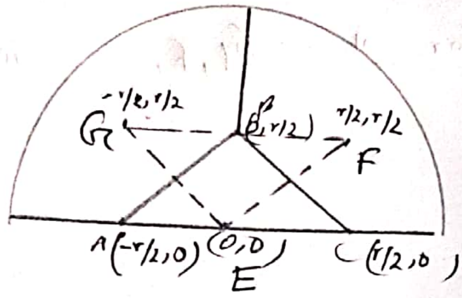
$= 151.57 \text{ mm}$

Thiessen Mean: Thiessen এ কম আসবে

$$\text{Depth} = 150\times0.1 + 168\times0.06 + 158\times0.11 + 135\times0.07 + 156\times0.08 + 207\times0.09 + 138\times0.11 + 162\times0.12 + 114\times0.16 + 132\times0.1$$

$= 149.08 \text{ mm}$





Area of the triangle $= \frac{1}{2}\begin{vmatrix} x_1 & y_1 & 1 \\ x_2 & y_2 & 1 \\ x_3 & y_3 & 1 \end{vmatrix}$

~~$= \frac{1}{2}\begin{vmatrix} 0 & 0 & 1 \\ -r/2 & r/2 & 1 \\ r/2 & r/2 & 1 \end{vmatrix}$~~

~~$= \frac{1}{2}\left(-r/2 \times r/2 - r/2 \times r/2\right)$~~

~~$= \frac{1}{2}\left(-r^2/2 - r^2/2\right) = \frac{1}{2} - r^2$~~

~~$= \frac{1}{2}\begin{vmatrix} 0 & 0 & 1 \\ r/2 & r/2 & 1 \\ -r/2 & r/2 & 1 \end{vmatrix}$~~

~~$= \frac{1}{2}\left(r^2/2 + r^2/2\right)$~~

$\Delta = \frac{r^2}{2}$

∴ for ~~A, B, C~~, $A = \frac{1}{3} \times r^2/2$

~~Thiessen weigh for A =~~

Area of ABC, $\Delta = \frac{1}{2}\begin{vmatrix} x_1 & y_1 & 1 \\ x_2 & y_2 & 1 \\ x_3 & y_3 & 1 \end{vmatrix} = \frac{1}{2}\begin{vmatrix} -r/2 & 0 & 1 \\ r/2 & 0 & 1 \\ 0 & r/2 & 1 \end{vmatrix}$

$= \frac{1}{2}\left[-r/2 \times -r/2 + r^2/4\right]$

$= \frac{1}{2}\left(r^2/4 + r^2/4\right)$

for point E, $\Delta = \frac{r^2}{4}$

∴ for point, G, F $= \frac{\pi r^2}{4} - \frac{r^2}{8} =$ ~~$\frac{r^2(\pi - 1)}{4}$~~ $= \frac{r^2(2\pi - 1)}{8}$

Total area of basin $= \frac{\pi r^2}{2}$

For station E, Thiessen weight $= \frac{A_E}{A} = \frac{\frac{\pi r^2}{4}}{\frac{\pi r^2}{2}} = \frac{1}{2\pi} = \frac{0.5}{\pi}$

For " G, F, " " $= \frac{A_G}{A} = \frac{\frac{r^2(2\pi-1)}{84}}{\frac{\pi r^2}{2}}$

$= \frac{(2\pi-1)}{8\pi}$

$= \left(\frac{2\pi}{4\pi} - \frac{1}{4\pi}\right)$

$= \left(0.5 - 0.25/\pi\right)$ Ans:

5.27/

Isohyet Interval (mm)	Average Precip (mm)	Area (km²)	A×P km²mm
85-75	80	125	10000
75-65	70	236	16520
65-55	60	264	15840
55-45	50	175	8750
45-35	40	150	6000
		ΣA = 950	ΣAP = 57110

∴ Depth $= \frac{\Sigma AP}{\Sigma A}$

$= \frac{57110}{950}$

$= 60.1157$ mm Ans.

37/ Here,

$P_1 = 107\,mm$ $\quad$ $N_1 = 1120\,mm$

$P_2 = 89\,mm$ $\quad$ $N_2 = 935\,mm$

$P_3 = 120\,mm$ $\quad$ $N_3 = 1200\,mm$

$m = 3$ $\quad$ $N_x = 978\,mm$

$\therefore$ The missing rainfall $= \left(\frac{N_x}{N_1} P_1 + \frac{N_x}{N_2} P_2 + \frac{N_x}{N_3} + P_3\right) 1/3$

$= \left(\frac{978}{1120} \times 107 + \frac{978}{935} \times 89 + \frac{978}{1200} \times 120\right) 1/3$

$= 94.776\,mm$

Analytical

5.21 The cumulative rainfall depth with time during a storm as obtained from a recording raingauge at a station is given below.

Time in hours	*rainfall in mm*	*Time in hours*	*rainfall in mm*
10.00	0		
10.30	6	13.30	51
11.00	11	14.00	57
11.30	16	14.30	61
12.00	24	15.00	66
12.30	29	15.30	67
13.00	38	16.00	67

(*i*) Construct the hyetograph of this storm using uniform time interval of 30 minutes and also 2 hours.

(*ii*) Compute the maximum average intensities of rainfall for durations of 30 minutes, 1 hour, 2 hours, 3 hours and 5 hours in this storm and plot the resulting intensity duration curve.

(*iii*) Fit an appropriate regression equation for the intensity duration curve obtained above. Assume the best value of a as 10.

5.22 The hyetograph of a storm of 6 h duration is constructed with varying time intervals : at 20 minutes interval for the first one hour, at 40 minutes interval for the next 2 hours and at one hour interval for the last 3 hours. The successive ordinates of the hyetograph in mm/h are 66, 75, 54, 48, 69, 51, 38, 47 and 25. Determine the total rainfall depth produced by the storm.

5.23 The annual rainfalls in cm at a station for a period of 21 years from 1960 to 1980 are

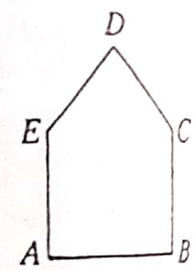
97, 125, 103, 81, 101, 119, 103, 79, 102, 118, 98
83, 105, 123, 100, 86, 99, 114, 91, 83 and 106

(*i*) Represent this data in the form of chronological chart, bar diagram and ordinate graph.

(*ii*) Construct the 5-year moving average curve and superimpose it on the chronological chart. Comment on the moving average curve.

5.24 For the data of Exercise 5.23, determine the 75% dependable rainfall from frequency analysis and also by using the normal distribution as the appropriate fit.

5.25 A basin has the area in the form of a pentagon with each side of length 20 km as shown in the figure. The five raingauges located at the corners A, B, C, D and E have recorded 60, 81, 73, 59 and 45 mm of rainfall respectively. Compute the average depth of rainfall over the basin by arithmetic mean and Thiessen polygon methods.



5.26 The network of 10 stations in and around a river basin have the Thiessen weights of 0.10, 0.06, 0.11, 0.07, 0.08, 0.09, 0.11, 0.12, 0.16 and 0.10 respectively. Stations 2, 4 and 5 lie outside the basin while the remaining are inside. If the rainfalls recorded at these gauges during a storm are 150, 168, 158, 135, 156, 207, 138, 162, 114 and 132 mm respectively. Determine the average depth of rainfall over the basin by arithmetic and Thiessen mean methods.

5.27 A major river basin is divided into four sub-basins with areas of 920, 705, 1075 and 1665 km^2. If the average annual rainfall on these sub-basins is 73, 85, 112 and 100 cm respectively. What is the average annual rainfall for the basin as a whole ?

5.28 The catchment area of a basin may be approximated as a semicircle of radius r km. With respect to the coordinate axis set up with its origin at the centre of the circle and the x-axis coincident with the diameter the area lies in the first and second quadrants and the position coordinates of the raingauge stations are (0, 0), $\left(\frac{r}{2}, \frac{r}{2}\right)$ and $\left(-\frac{r}{2}, \frac{r}{2}\right)$ km. Show that the Thiessen weights of the gauges are given by $0.5/\pi$, $(0.5 - 0.25/\pi)$ and $(0.5 - 0.25/\pi)$ respectively.

5.29 The isohyets drawn for a storm which occurred over a drainage basin of area 950 km^2 yielded the following information.

Isohyet interval in mm	85—75	75—65	65—55	55—45	45—35
Area between isohyets in km^2	125	236	264	175	150

Determine the average depth of rainfall over the basin.

5.30 The shape of a catchment is in the form of a pentagon *ABCDE*. There are 4 raingauge stations *P*, *Q*, *R* and *S* inside the catchment. The position coordinates in km are *A*(0, 0), *B*(50, 75), *C*(100, 70), *D*(150, 0), *E*(75, −50), *P*(50, 25), *Q*(100, 25), *R*(100, −25) and *S*(50, −25). If the rainfalls recorded at *P*, *Q*, *R* and *S* are 88, 102, 112 and 116 mm respectively, determine the average depth of rainfall over the catchment using Thiessen polygon method.

5.31 During a month a raingauge went out of order while the other three gauges in the basin reported rainfalls of 107, 89 and 120 mm. If the normal annual rainfalls for these three gauges are 1120, 935 and 1200 mm respectively and the normal annual rainfall of the broken gauge is 978 mm, estimate the missing monthly rainfall at the broken gauge.

5.32 Neighbouring raingauge stations *A*, *B*, *C*, *D*, *E* and *F* have normal annual rainfalls of 610, 554, 468, 606, 563 and 382 mm respectively. During a storm, stations *B*, *C*, *D*, *E* and *F* have reported rainfalls of 22, 29, 35, 13 and 25 mm respectively and station *A* did not report as it was inoperative. Estimate the missing storm rainfall at *A* by the arithmetic average method and the normal-ratio method.