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#14, Raghuvanahalli, Kanakapura Main Road, Bengaluru - 560109

BLUE BOOK

COMPUTER SCIENCE

Name of the student : Gagana K

Class / Sem : 6th Sem 'A' Branch : CSE

USN : 1 K S 2 0 C S 0 2 9

SUBJECT : System Modelling And Simulation

SUBJECT CODE : 18CS645

MAXIMUM MARKS

Test	I	II	III	Average Marks Obtained
Date	18/04/2023	6/06/2023	7/07/2023	**Test**
Marks Obtained	26	29	30	29
Signature of Student				**Assignment** 10
Initials of Faculty				**Total** 39

NAME OF FACULTY : Dr. REKHA B. VENKATAPUR

SIGNATURE OF FACULTY :

SIGNATURE OF H.O.D :

K. S. INSTITUTE OF TECHNOLOGY

First Internal Test

Q. No	Marks	CO	Q. No	Marks	CO	CO	Total
1(a)	5	CO1	3(a)	5	CO2	CO1	16
1(b)	6	CO1	3(b)	5	CO2		
1(c)	5	CO1	3(c)	R		CO2	10
OR			OR				
2(a)			4(a)				
2(b)			4(b)				
2(c)			4(c)			Grand Total	26/30 R

Second Internal Test

Q. No	Marks	CO	Q. No	Marks	CO	CO	Total
1(a)	6	CO3	3(a)			CO2	6
1(b)	6	CO3	3(b)				
1(c)	5	CO3	3(c)			CO3	17
OR			OR			CO4	6
2(a)			4(a)	6	CO2		
2(b)			4(b)	6	CO4		
2(c)			4(c)			Grand Total	29/30 R

Third Internal Test

Q. No	Marks	CO	Q. No	Marks	CO	CO	Total
1(a)			3(a)			CO4	12
1(b)			3(b)				
1(c)			3(c)			CO5	18
OR			OR				
2(a)	6 R	CO5	4(a)	6	CO4		
2(b)	6	CO5	4(b)	6	CO4		
2(c)	6	CO5	4(c)			Grand Total	30/30 R

R

R

Signature of the Faculty

18/04/2023

IA - 1

Part - A

1(a) **Simulation** :

Simulation is a process of immetating a real world system for multiple usage.

There are many cases where simulation is appropriatt.

(1) Simulation in training

For example aircraft pilot training can be done by using simulations.

In this case the person need not start with the real life aircraft instead a simulation model with animations will be created through which a trainee can experience the real world circumstances. Once ~~it~~ done, the same thing can be implemented in real world.

(2) Network Simulation

Simulation can be used in the research field for gaining the knowledge.

In this case many criterial like routing, switching, packet dropping situations can be analyzed before actually working on a network.

(3) Improving the quality of existing system

Simulations gives the analytical results from which we can improve the system performance.

Example, travelling simulations.

According to the performance analyzed by the simulations, we can increase or decrease the speed of travelling as per over requirements.

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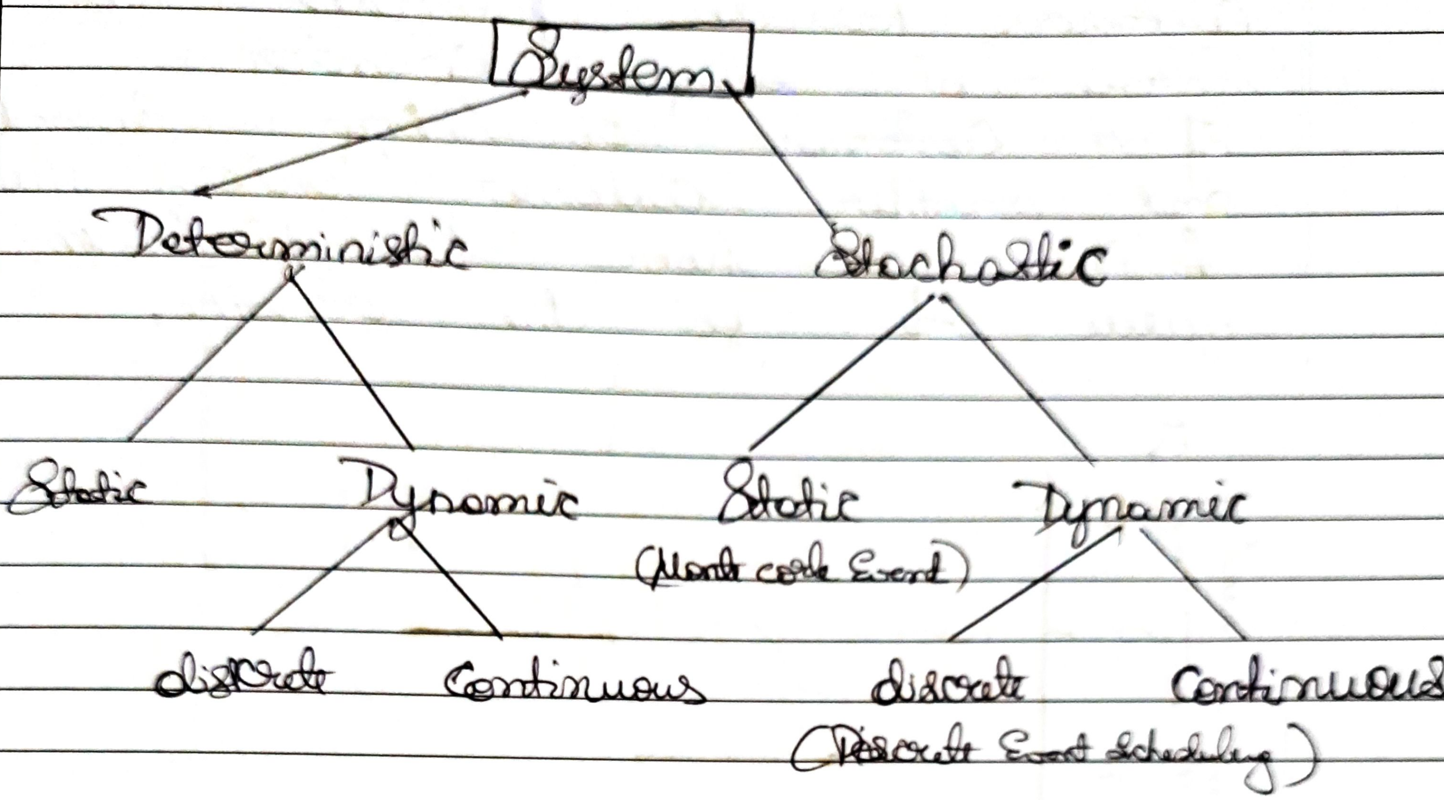
1(b.)



★ <u>Discrete System</u>

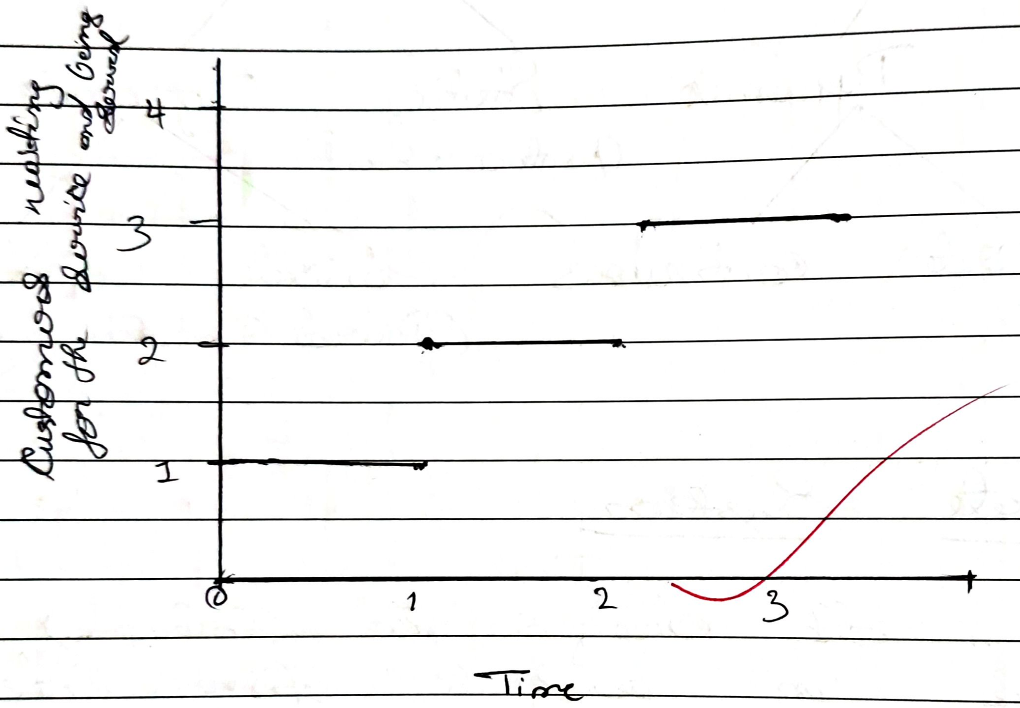
Here, the changes in state of system occurs in discrete time intervals.

For example: Billing Counter

The components are

Billing counter (Server)
Customer (units)

Customers will be provided with the Service of billing Counter. If a Customer is being Served and another Customer enters than he/she will have to Wait in queue to get the Service.



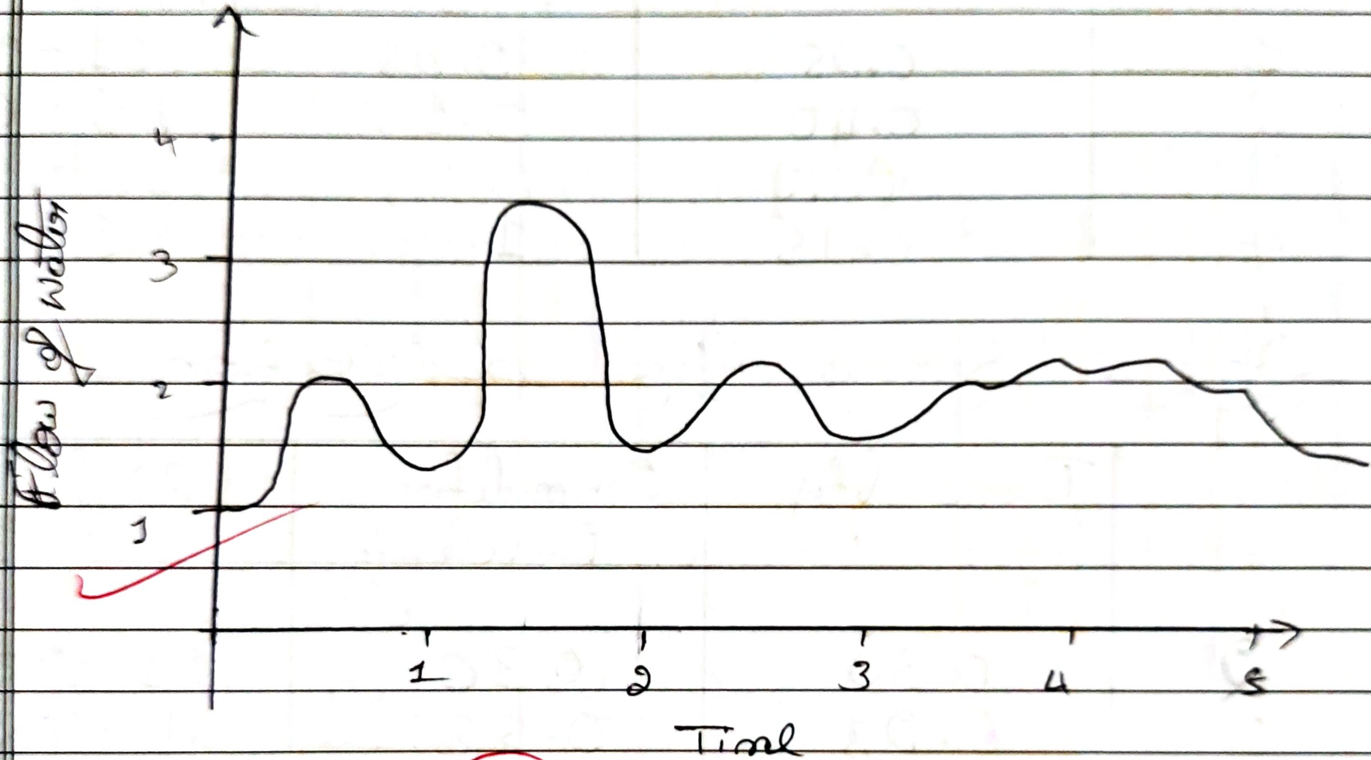
Continuous System

Here, Changes in the State of the System occurs Continuously.

For example: Water flow behind the dam

Components: Dam, Water flow.

If there is a continuous flow of water behind the dam then the state of system changes continuously.



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1(c) IAT distribution table

IAT	Probability	Commulative Probability	RD for IAT
1	0.25	0.25	01-25
2	0.40	0.65	26-65
3	0.20	0.85	66-85
4	0.15	1.00	86-00

Able's Service time distribution

ST	Probability	Commulative Probability	RD for ST
2	0.30	0.30	01-30
3	0.28	0.58	31-58
4	0.25	0.83	59-83
5	0.17	1.00	84-00

Baker's Service time Distribution

ST	Probability	Commulative Probability	RD for ST
3	0.35	0.35	01-35
4	0.25	0.60	36-60
5	0.20	0.80	61-80
6	0.20	1.00	81-00

RD for calls - 26, 98, 90, 26, 42
RD for ST - 95, 21, 51, 92, 89, 38

Call No	IAT	AT	Able arrive	Baker arrive	Server Chosen	RD	ST	Service Begins	Able Completes	Baker Completes	Call Delay	Time Spent in System
1	–	0	0	0	Able	95	5	0	5	–	0	5
2	2	2	5	0	Baker	21	3	2	–	5	0	3
3	4	6	5	5	Able	51	3	6	9	–	0	3
4	4	10	9	5	Able	92	5	10	15	–	0	5
5	2	12	15	5	Baker	89	6	12	–	18	0	6
6	2	14	15	18	Able	38	3	15	18	–	1	4
Total	14										1	

- Able's Service time : 16 cm
- Baker's Service time : 9
- Average Service time by Able $= \frac{16}{4} = 4$ units
- Total IAT = 14
- Average Service time by Baker $\frac{9}{2} = 4.5$ units

Seminar time nor arrival

Utilization of Able = $\frac{\text{Able's S.T}}{\text{Able's sim. end time}}$ R.W

$= \frac{16}{18} = 0.88 = 88\%$

//// for Baker

Part B

3(b)

		2nd	3rd	4	5	6	7	8	9
IAT		~~1~~	~~1~~	~~6~~	~~3~~	7	5	2	4	1
ST	~~4~~	~~2~~	~~5~~	~~4~~	1	5	4	1	4
	1	2	3	4	5	6	7	8	9

Cust No	Stock LQ(t)	LS(t)	Check out line	FEL	Statistical S	N_D	F
0	0	1	$(C_1, 0)$	$(A, C_2, 1)(D, C_1, 4)(E, 15)$	0	0	0
1	1	1	$(C_1, 0)(C_2, 1)$	$(A, C_3, 2)(D, C_1, 4)(E, 15)$	0	0	0
2	2	1	$(C_1, 0)(C_2, 1)(C_3, 2)$	$(D, C_1, 4)(A, C_4, 8)(E, 15)$	0	0	0
4	1	1	$(C_2, 1)(C_3, 2)$	$(D, C_2, 6)(A, C_4, 8)(E, 15)$	4	1	0
6	0	1	$(C_3, 2)$	$(A, C_4, 8)(D, C_3, 11)(E, 15)$	4	1	0
8	1	1	$(C_3, 2)(C_4, 8)$	$(D, C_3, 11)(A, C_5, 11)(E, 15)$	4	1	0
11	0	1	$(C_4, 8)$	$(A, C_5, 11)(E, 15)$	11	2	1

5

$11 - 2 = 9$

1

1

11	1	1	(C4, 8) (C5, 11)	(D, C4, 15) (D, C8, 18) (E, 15)	11	2	9
15	0	1	(C5, 11)	~~(D, C5, 16)~~ (D, C6, 18) (E, 15)	15	3	1

15-8 = 6

∴ The total number of customers who spent 5 or more minutes in the system is 1

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N_D - No. of Depart

r = No. of custom

3(a) Queuing System

Grocery Shop :

Entity

Grocery Shop (Server) (Checkout)
Customers (units)

Event

Customer Arrival
Customer departure
Customer Wait ✗

Activity

Grocery Service
Server idle.

For example Inter Arrival Time be between 1 to 6 and Service time be between 1 to 4
Inter Arrival time with equal probability $\frac{1}{6} = 1.66$ probability

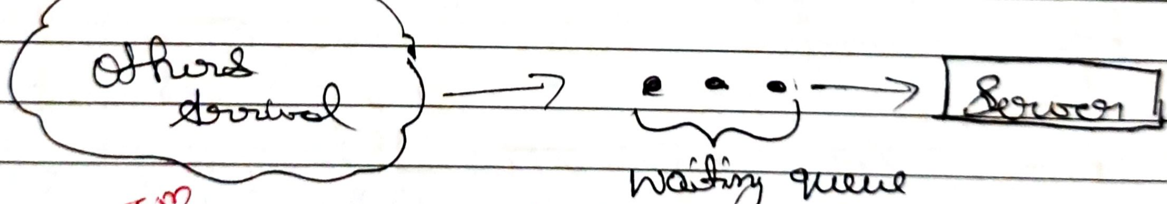
Service time will be there with their probability.

There will be no inter arrival time for the first Customer.

The first customer will be served immediately after his entry, his arrival Time will be 0.

If any other customers enters when the first customer is being served then he/she should join a queue to get the service.

When the first customer's service is done the second customer gets the service.



Service Mechanism / Single channel / Multi channel

Queuing discipline FIFO / priority / Shortest job first.

System capacity – space for customer who can wait in Que

If there is no customer in queue nor a service is provided to the customer then the server / service is said to be idle.

System capacity is the capacity of the server to provide the service.
For our case it is grocery shop.

Service mechanism tells that how the service is provided to the customer.

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06/06/2023

IA - 2

Part A

1(a) Given: $x_0 = 45$, $a = 21$ $c = 49$ $m = 40$

$X_{i+1} = (a x_i + c) \bmod m$ $R_i = \frac{x_i}{m}$

- $x_1 = (a x_0 + c) \bmod m$

$x_1 = (21 \times 45 + 49) \% 40$
$= 994 \% 40$
$x_1 = 34$

$R_1 = \frac{x_1}{m} = \frac{34}{40} = 0.85 \Rightarrow \boxed{R_1 = 0.85}$

- $x_2 = (a x_1 + c) \bmod m$
$= (21 \times 34 + 49) \% 40$
$= 763 \% 40$
$x_2 = 3$

$R_2 = \frac{x_2}{m} = \frac{3}{40} = 0.075 \Rightarrow \boxed{R_2 = 0.075}$

- $x_3 = (a x_2 + c) \bmod m$
$= (21 \times 3 + 49) \% 40$
$= 112 \% 40$
$= 32$

$R_3 = \frac{x_3}{m} = \frac{32}{40} = 0.8$

$\boxed{R_3 = 0.8}$

- $X_4 = (a x_3 + c) \bmod m$
$= (21 \times 32 + 49) \% 40$
$= 721 \% 40$
$= 1$

$R_4 = \frac{X_4}{m} = \frac{1}{40} = 0.025 \Rightarrow \boxed{R_4 = 0.025}$

- $X_5 = (a x_4 + c) \bmod m$
$= (21 \times 1 + 49) \% 40$
$= 70 \% 40$
$= 30$

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$R_5 = \frac{X_5}{m} = \frac{30}{40} = 0.75 \Rightarrow \boxed{R_5 = 0.75}$

- In the generation of random numbers most important thing is to focus on uniformity and independence.
There are three cases in selecting a, m, c

(1) $m = 2^b$, $c \neq 0$, maximum period $P = m = 2^b$
$a = 1 + 4K$ c, a ~~are~~ are prime to each other

(2) $m = 2^b$, $c = 0$, $P = 2^{b-2}$ where X is odd
$a = 3 + 8K$, $a = 5 + 8K$

(3) m is prime, $c = 0$, $P = m - 1$ where $a^k - 1$ is divisible by m [$k \to$ smallest integer]

1(b) K-S Goodness of fit test
0.54, 0.73, 0.98, 0.11, 0.68

- Arrange in ascending order

0.11, 0.54, 0.68, 0.73, 0.98

Given $D_{\alpha} = 0.565$ at $\alpha = 0.05$ significance

$$D^{+} = \max_{1 \le i \le N} \left\{ \frac{i}{N} - R_i \right\}$$

$$D^{-} = \max_{1 \le i \le N} \left\{ R_i - \frac{(i-1)}{N} \right\} \qquad \boxed{N=5}$$

i	1	2	3	4	5
R_i	0.11	0.54	0.68	0.73	0.98
i/N	0.2	0.4	0.6	0.8	1.0
$i/N - R_i$	0.09	(negative)	(negative)	0.07	0.02
$R_i - \frac{(i-1)}{N}$	0.11	0.34	0.28	0.13	0.18

$i=1 \quad \frac{i}{N} - R_i = \frac{1}{5} - 0.11 = 0.2$

$R_i - \frac{(i-1)}{N} = 0.11 - \frac{(1-1)}{N} = 0.11 - \frac{0}{5} = 0.11$

$D^+ = \max(0.09, 0.07, 0.02) = 0.09$

$D^- = \max(0.11, 0.34, 0.28, 0.13, 0.18) = 0.34$

- Compute $D = \max\{D^+, D^-\}$

$$D = \max\{0.09, 0.34\}$$

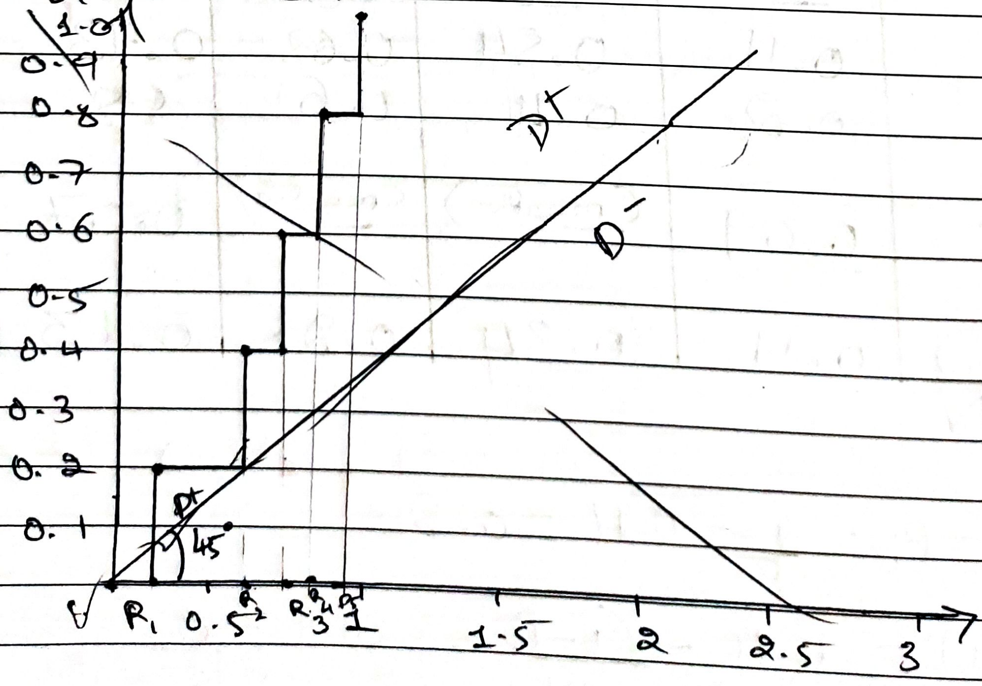
$$\boxed{D = 0.34}$$

The calculate value $D = 0.34$ is less than the table value $D_\alpha = 0.565$

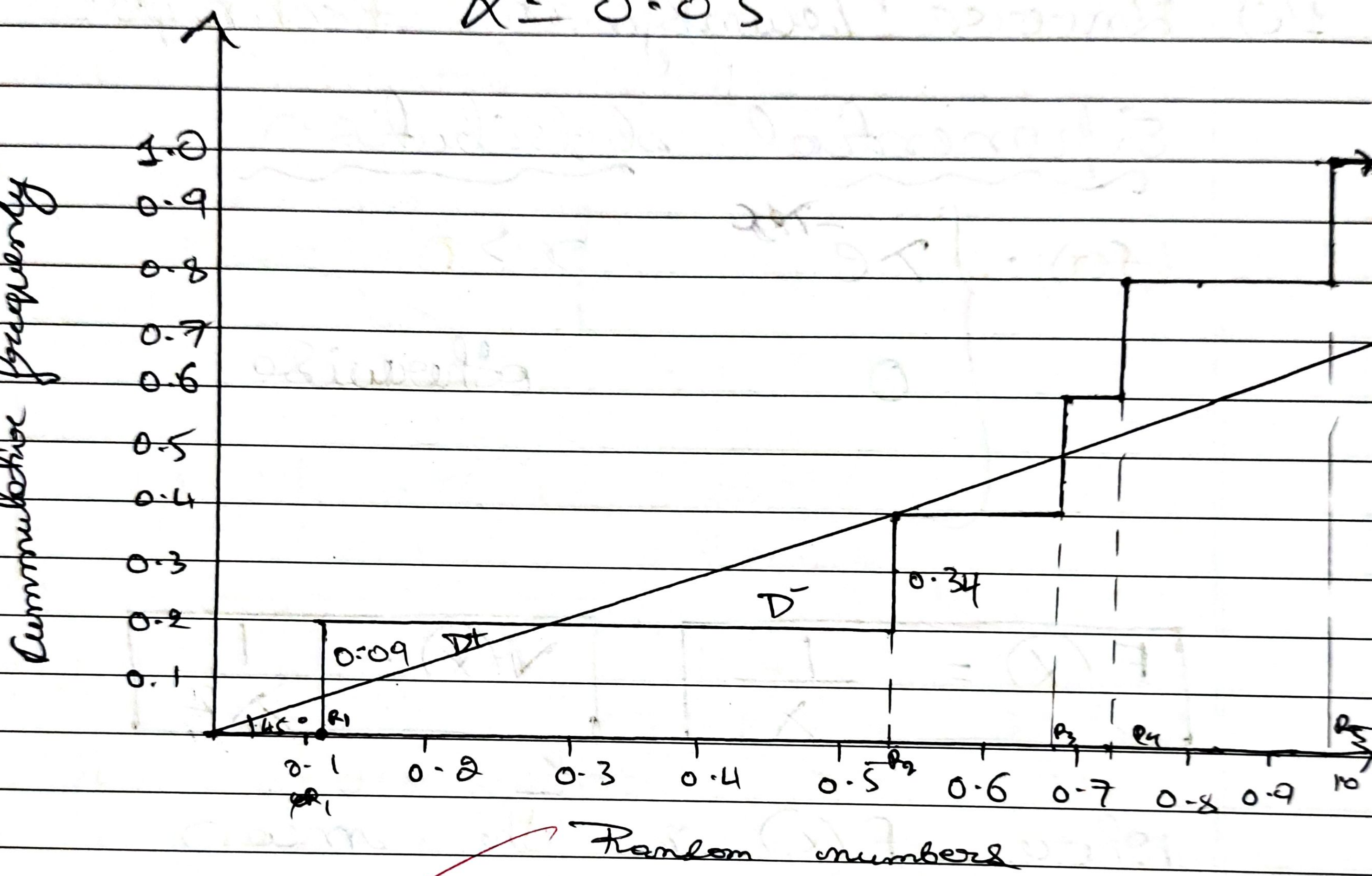
$\therefore$ ie $D < D_\alpha$ at $\alpha = 0.05$ significance level

Conclusion

hence the hypothesis can not be rejected at the significance level $\alpha = 0.05$.



$\alpha = 0.05$


Cummulative frequency
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.09
D+
D-
0.34
R1
R2
R3
R4
R5
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Random numbers

6

1(C) Inverse Transform technique

Exponential distribution

$$f(x) = \begin{cases} \lambda e^{-\lambda x} & x \geq 0 \\ 0 & \text{otherwise} \end{cases}$$

$$\boxed{E(X) = \frac{1}{\lambda}} \qquad \boxed{V(X) = \frac{1}{\lambda^2}}$$

Where $E(x)$ is the mean

and $V(x)$ ~~is~~ the variance

$$1 - e^{-\lambda x} = r$$

$$-e^{-\lambda x} = r - 1$$

$$e^{-\lambda x} = 1 - r$$

$$\ln(e^{-\lambda x}) = \ln(1 - r)$$

$$-\lambda x = \ln(1-r)$$
$$x = \frac{-\ln(1-r)}{\lambda}$$

$$\boxed{x = \frac{-\ln(R)}{\lambda}}$$

$1-r \rightarrow$ negligable

$$F(x) = \begin{cases} 1-e^{-\lambda x}, & x \geq 0 \\ 0, & \text{otherwise} \end{cases}$$

λ is the parameter which is unknown

and $\hat{\lambda} = \frac{1}{\bar{X}}$ is the estimator

of exponential distribution.

5

Part B

4(b) Poisson variates
mean $\alpha = 0.2$

$$P(x_1) = \frac{\alpha^x e^{-\alpha}}{x!} \qquad \alpha^{-0.2} = 0.8187$$

$$P(x_0) = \frac{(0.2)^0 e^{-0.2}}{0!} = 0.8187$$

Poisson variate N

- Step 1: $n = 0$ $P = 1$
  Step 2: $R_1 = 0.4347$ $P = 1 \times 0.4347 = 0.4347$
  Step 3 $P < 0.8187$ ✓ Accept $N = 0$

- Step 1: $n = 0$ $P = 1$
  Step 2: $R_2 = 0.9952$ $P = 1 \times 0.9952 = 0.9952$
  Step 3: $P > 0.8187$ ✗ Reject

  Step 1: $n = 1$ $P = 0.9952$
  Step 2: $R_3 = 0.1530$ $P = 0.9952 \times 0.1530$
  $P = 0.15226$
  Step 3: $P < 0.15226$ ✓ Accept $N = 1$

Step 1: $n = 0$ $P = 1$

R_4 $P = 1 \times 0.0153 = 0.0153$

$P < 0.8187$ ✓ Accept $N = 0$

$N = 0$ $N = 1$ $N = 0$ ⇒ Accepted

$P(x_0) = 0.8187$

$P(x_1) = \frac{(0.2)^1 e^{-0.2}}{1!} = 0.1637$

$P(x_3) = \frac{(0.2)^2 e^{-0.2}}{2!} = 0.01637$

$P(x_4) = \frac{(0.2)^3 e^{-0.2}}{3!} = 1.09164 \times 10^{-3}$ $P(x_4) = 0.001$

n	R_{n+1}	P	Accept / Reject	N variate
0	0.4347	0.4347	$P < e^{-\alpha}$ / Accept	$N = 0$
0	0.9952	0.9952	$P > e^{-\alpha}$ / Reject	
1	0.1530	0.15226	$P < e^{-\alpha}$ / Accept	$N = 1$
1	0.0014	~~0.000213~~ 0.0014	$P < e^{-\alpha}$ / Accept	$N = 1$

6

4(a) uniform distribution

~~pdf~~ CDF = $F(x) = \begin{cases} \frac{1}{b-a}, & a \leq x < b \\ \frac{x-a}{b-a} & x \geq b \\ 1 & x < a \end{cases}$

F in range (a to b) $F(b) - F(a)$
$a < b$

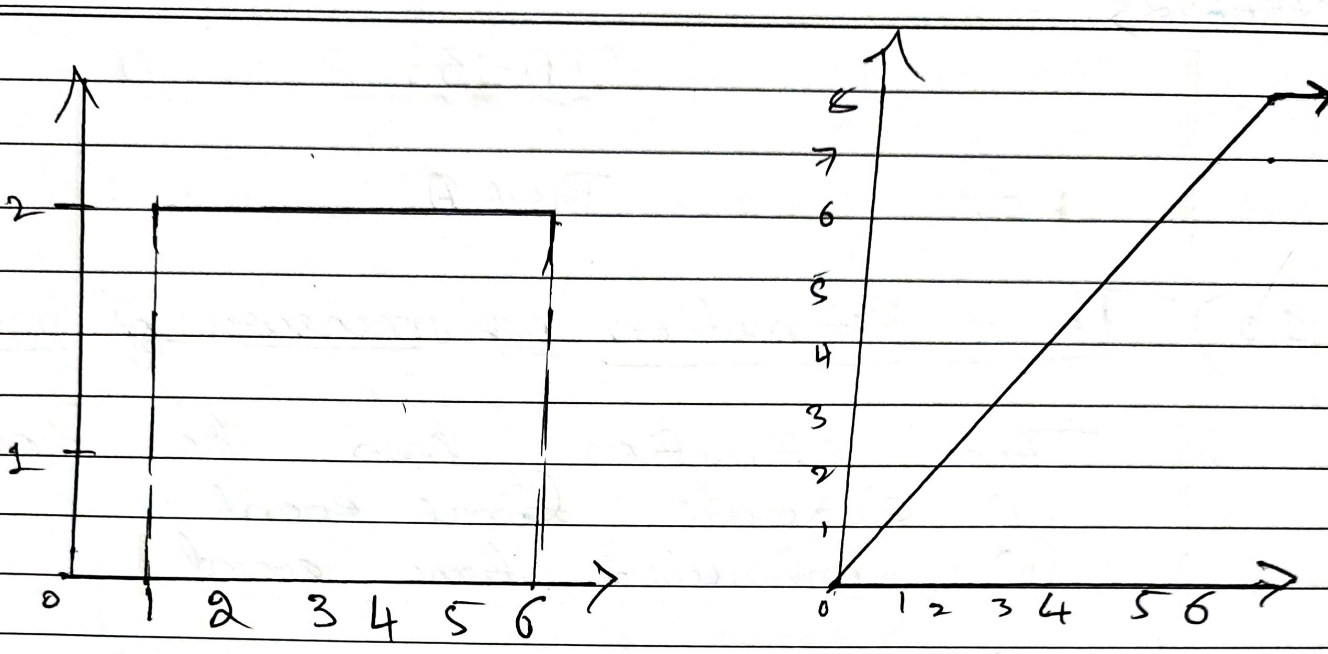
$\lim_{x \to \infty}$, $\lim_{x \to -\infty}$

~~Also~~ $P(x) = (x_1 < x < x_2)$

$$\boxed{\begin{array}{ll} \text{Mean:} & E(x) = \frac{a+b}{2} \\ \text{Variance:} & V(x) = \frac{(b-a)^2}{12} \end{array}}$$

ie $(a \leq x < b) - (a \leq x < b) = (a < x \leq b)$
$= (a < x < b)$

=



$\therefore a = 1 \qquad b = 6$ uniform distribution

$$\cancel{f(x)} = \int_a^b f(x)\,dx = F(b) - F(a)$$

~~Here~~ Here a and b are the range.

$\cancel{X} = x_1, x_2 \ldots$

x lies between the range

6

07/07/2023

IA-3

Part A

1a.) **Point Estimation as measure of performance**

Point estimation can be done on
(i) discrete time event
(ii) Continuous time event

(i) Discrete time event with regular mean θ

$$\theta = \frac{1}{N}\left[\sum_{i=1}^{N} y_i\right]$$

Cancelled.

where N is the ~~total~~ number of values

This takes the mean of all the occurances.

(ii) Continuous time cost

∅ is the mean of continuous time occurrence

∅ - -

2a) Confidence Interval estimation as measure of performance of error.

Confidence Interval is ~~the~~ comparing the simulation with the real system.

CI - Confidence Interval is ~~of~~ takes place in two forms

→ measure of error

→ measure of risk

This ~~is~~ means confidence interval versus prediction interval.

CI measure of error

$$Y \pm t_{\alpha/2, R-1} \frac{S}{\sqrt{R}}$$

Y is the output of the simulation model

α is the significance level

$R \Rightarrow$ Replications

$S \Rightarrow$ Standard Deviation.

also can be $\bar{Y} \pm t_{\alpha/2, n-1} \frac{S}{\sqrt{n}}$

$3+3=6$

This measure helps in knowing the appropriate errors ~~to~~ which can be fixed.

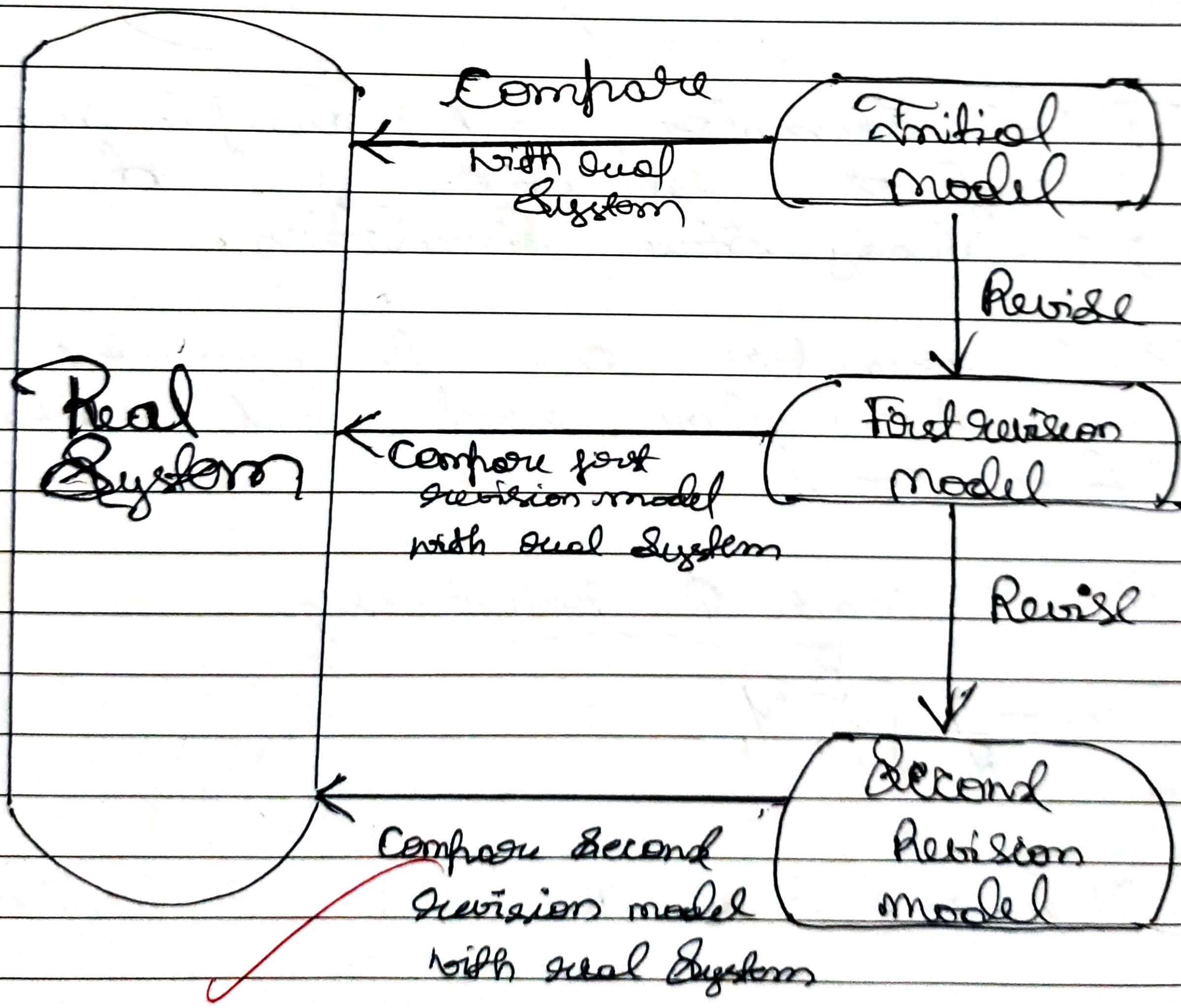
$$S^2 = \frac{1}{n-1} \sum_{i=1}^{n} (Y_i - \bar{Y})^2$$

2b.) Naylor - Fingord Validation Process

Iterative process

Validation: It is the overall Comparision of the Simulation model and the real system

Calibration: It is the iterative process of Comparing the Simulation model with real System.



As the calibration is an iterative process, on every iteration the simulation model will be revised and is compared with real system.

~~on~~ After certain revision the overall model will be validated with the real system on a whole.

To know that we have built a correct model or not.

6

2c) Point Estimator and sample mean through the replication method for steady state simulation.

Point estimator can be generated for discrete time event and continuous time event

ie θ and ϕ respectively

$$\theta = \frac{1}{R} \int \sum_{i=1}^{R} Y_i (n,d)$$

$Y(n,d)$ $E(\ldots)$

~~Y is the~~ R is the total replications.

$E(\Theta)$ is the expectation

If $E(\hat{\Theta}) = \Theta$ then it is unbiased

If $E(\hat{\Theta}) \neq \Theta$ then it is biased

Similarly for continuous time event

$E(\hat{\phi}) = \phi$ unbiased

$E(\hat{\phi}) \neq \phi$ biased

Sample mean

$$\Theta = \frac{1}{T_E}\int_0^{T_E} y(t)\, dt$$

Here the Terminating time TE will be the condition.

$2+4 = 6$

0-1.59
1.59-3.42
3.42-5.59
5.59-8.24
8.24-11.60
11.60-16.48
16.48 24.73

Part B

46.)

(8) 79.919	(2) 3.081	(1) 0.062	(2) 1.961	(4) 5.845
(2) 3.027	(4) 6.505	(1) 0.021	(1) 0.013	(1) 0.123
(4) 6.769	(8) 59.899	(1) 1.192	(8) 34.760	(3) 5.009
(7) 18.387	(1) 0.141	(8) 43.565	(7) 24.420	(1) 0.433
(8) 144.695	(2) 2.663	(7) 17.967	(1) 0.091	(5) 9.003
(1) 0.941	(1) 0.878	(2) 3.371	(2) 2.157	(4) 7.579
(1) 0.624	(3) 5.380	(1) 0.300	(4) 7.078	(7) 23.960
(1) 0.590	(2) 1.928	(1) 1.005	(1) 0.002	(1) 0.543
(4) 7.004	(8) 31.764	(1) 1.008	(1) 1.147	(1) 0.219
(2) 3.217	(6) 14.382	(2) 3.148	(2) 2.336	(3) 4.562
265.173	126.621	71.639	73.965	56.7873

$\frac{594.1853}{50}$

$$\bar{X} = \frac{265.173 + 126.621 + 71.639 + 73.965 + 56.7873}{50}$$

$$\bar{X} = 11.883706$$

$$\lambda = \frac{1}{\bar{X}} = \frac{1}{11.883706} \Rightarrow \lambda = 0.0841$$

$$E(i) = 50 \times \frac{1}{8} = n(P_i) = 6.25 \text{ (Expectations}$$

4-23

$$a_i = \frac{-1}{\lambda} \ln(1 - i(P_i))$$

$$a_1 = \frac{-1}{0.0841} \ln\left(1 - 1 \times \frac{1}{8}\right) = 1.589$$

$$a_2 = \frac{-1}{0.0841} \ln\left(1 - 2 \times \frac{1}{8}\right) = 3.42$$

$$a_3 = \frac{-1}{0.0841} \ln\left(1 - 3 \times \frac{1}{8}\right) = 5.59$$

$$a_4 = \frac{-1}{0.0841} \ln\left(1 - 4 \times \frac{1}{8}\right) = 8.24$$

$$a_5 = \frac{-1}{0.0841} \ln\left(1 - 5 \times \frac{1}{8}\right) = 11.6626 \simeq 11.66$$

$$a_6 = \frac{-1}{0.0841} \ln\left(1 - 6 \times \frac{1}{8}\right) = 16.48$$

$$a_7 = \frac{-1}{0.0841} \ln\left(1 - 7 \times \frac{1}{8}\right) = 24.73$$

2.16
4.82
8.24
13.063
21.305

	O_i
0 – 2.16	21
2.16 – 4.82	7
~~8.24~~	3
4.82 – 8.24	6
8.24 – 13.06	
13.06 – 21.305	

	Range	O_i	E_i	$(O_i - E_i)^2/E_i$
1	[0, −1.59)	19	6.25	26.01
2	[1.59 − 3.42)	10	6.25	2.25
3	[3.42 − 5.59)	3	6.25	1.69
4	[5.59 − 8.24)	6	6.25	0.01
5	[8.24 − 11.66)	1	6.25	4.41
6	[11.66 − 16.48)	1	6.25	4.41
7	[16.48 − 24.73)	4	6.25	0.81
8	[24.73 − ∞)	6	6.25	0.01
		50	50	39.6

The calculated value of χ_0^2 is 39.6

The tabulated value ie $\chi^2_{0.01, 8} = 16.8$

$39.6 > 16.8$

Hence the hypothesis that the numbers follow exponential distribution is rejected.

K=8 S=1 1 K−S−1 = 8 → degree

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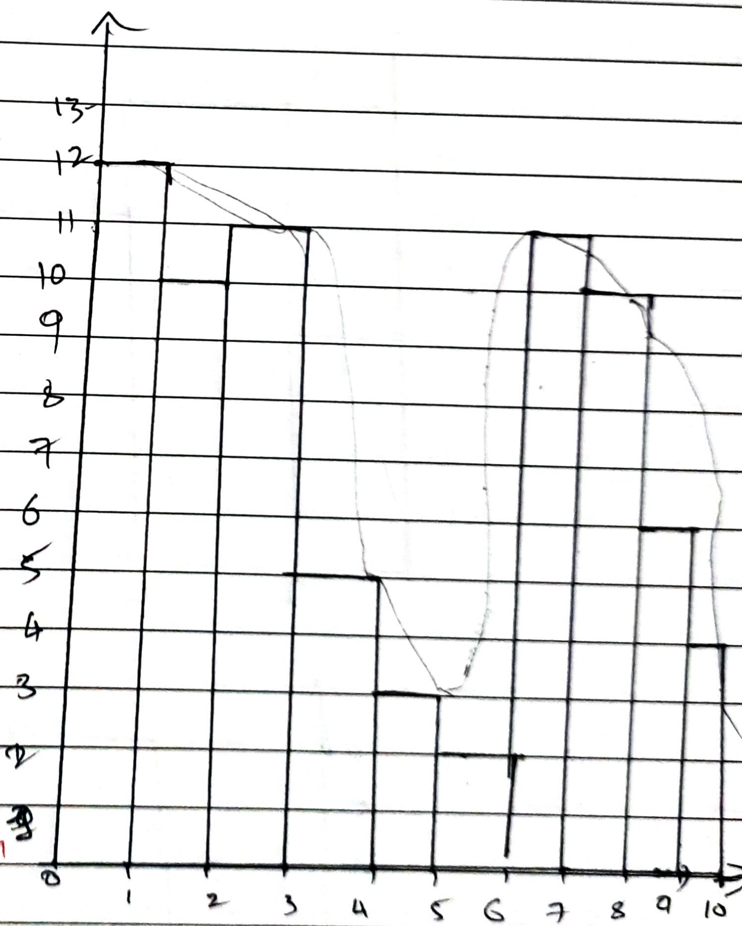
4 a) Histogram

Histogram is the graphical representation & analysis, which is also known as bargraph.

Histograms can be calculated ~~vo~~ for various intervals.

Suppose

Interval	Frequency
0	12
1	10
2	11
3	5
4	3
5	2
6	11
7	10
8	8
9	6
10	4

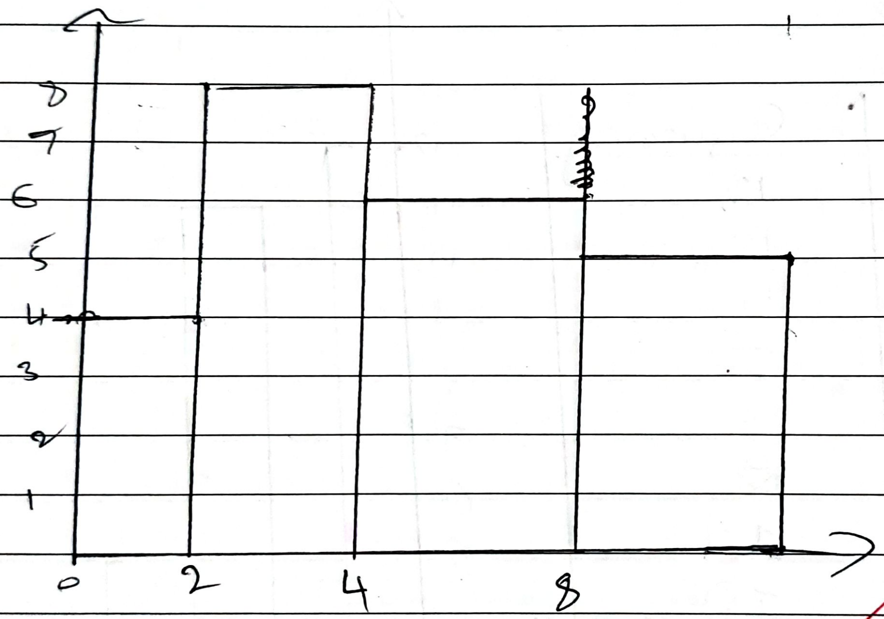


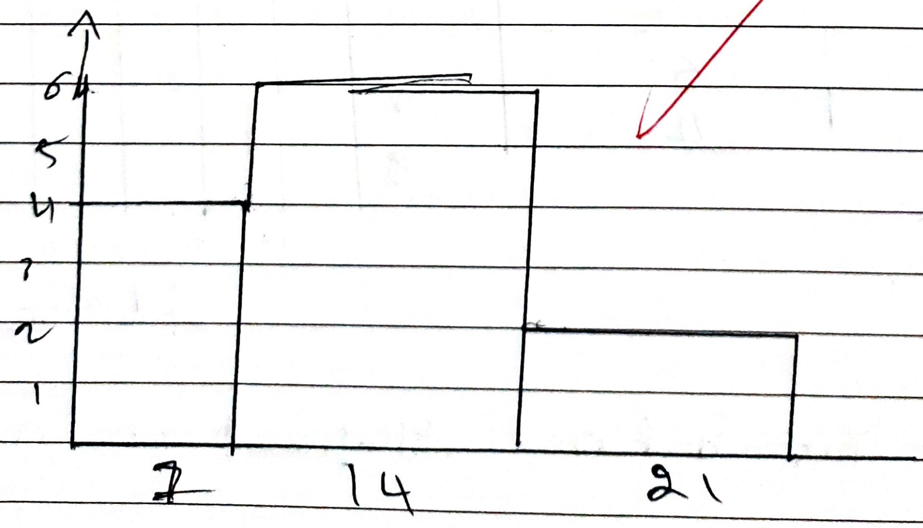
Histogram

Normal Distribution = Shape of the curve

Normal Distribution, exponential distribution and poison distributions are easy to generate.
Weibul, Triangular distributions are complex.

The histogram can be plotted with different interval size like





The shape of the distribution can be detected by seeing the nature of the graph.

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