

Chapter no 10 : Simulation

It is the name of the technique by Monte Carlo to solve the following types of problems

- i) If the demand of the particular product is uncertain
- ii) If the final result of a particular event is uncertain
- iii) Steps for Solving the Sum

I] Statement showing TAG numbers

II] Statement showing Final Answer

Q2. Step 1 : Statement Showing TAG numbers

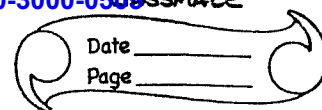
Daily Demand	probability	cum probability	TAG numbers
0	0.01	0.01	00 - 00
15	0.15	0.16	01 - 15
25	0.20	0.36	16 - 35
35	0.50	0.86	36 - 85
45	0.12	0.98	86 - 97
Avg Demand 50	0.02	1.00	98 - 99

$$\begin{array}{r} 270 \\ = 320 \end{array}$$

10 days

Step 2 : Statement showing final Answer

R.No	Demand	op stock	op stK + product ⁿ = Total	Total - Demand = clsg stK
48	35	-	35	35 - 35 = 0
78	35	0	35	35 - 35 = 0
09	15	0	35	35 - 15 = 20
51	35	20	35	55 - 35 = 20
56	35	20	35	55 - 35 = 20
77	35	20	35	55 - 35 = 20
15	15	20	35	55 - 15 = 40
14	15	40	35	75 - 15 = 60
68	35	60	35	95 - 35 = 60
09	15	60	35	95 - 15 = 80



Q9. step 1 : Statement showing TAG numbers

Sales	probability	cumulative probability	Tag Numbers
27	0.10	0.10	00 - 09
28	0.15	0.25	10 - 24
29	0.20	0.45	25 - 44
30	0.35	0.80	45 - 79
31	0.15	0.95	80 - 94
32	0.05	1.00	95 - 99

Step 2 : Statement showing final answers if Demand = 30 items

R.No	Sales	profit on sales	loss on unsold	Penalty	Net P/L
10	28	$28 \times 10 = 280$	$2 \times 15 = 30$	-	250
99	32	$30 \times 10 = 300$	-	$2 \times 5 = 10$	290
65	30	$30 \times 10 = 300$	-	-	300
99	32	$30 \times 10 = 300$	-	$2 \times 5 = 10$	290
95	32	$30 \times 10 = 300$	-	$2 \times 5 = 10$	290
01	27	$27 \times 10 = 270$	$3 \times 15 = 45$	-	225
79	30	$30 \times 10 = 300$	-	-	300
11	28	$28 \times 10 = 280$	$2 \times 15 = 30$	-	250
16	28	$28 \times 10 = 280$	$2 \times 15 = 30$	-	250
20	28	$28 \times 10 = 280$	$2 \times 15 = 30$	-	250

2695

Statement showing final answer if Demand = 29 items

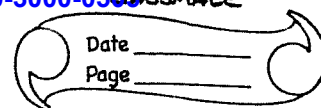
Sales	profit on sales	loss on unsold	penalty	P/L
28	$28 \times 10 = 280$	$1 \times 15 = 15$	-	265
32	$29 \times 10 = 290$	-	$3 \times 5 = 20$	270.5
30	$29 \times 10 = 290$	-	$1 \times 5 = 5$	285
32	$29 \times 10 = 290$	-	$3 \times 5 = 15$	275
32	$29 \times 10 = 290$	-	$3 \times 5 = 15$	275
27	$27 \times 10 = 270$	$2 \times 15 = 30$	-	240
30	$29 \times 10 = 290$	-	$1 \times 5 = 5$	285
28	$28 \times 10 = 280$	$1 \times 15 = 15$	-	265
28	$28 \times 10 = 280$	$1 \times 15 = 15$	-	265
28	$28 \times 10 = 280$	$1 \times 15 = 15$	-	265
				<u>2695</u>

* If probability is not given

Q5. Step 1: Statement Showing Tag Numbers

Supply	Probability	cum prob.	Tag Numbers
10 kg	$40 \div 500 = 0.08$	0.08	00-07
20	$50 \div 500 = 0.1$	0.18	08-17
30	$190 \div 500 = 0.38$	0.56	18-55
40	$150 \div 500 = 0.30$	0.86	56-85
50	$70 \div 500 = 0.14$	0.99	86-99

Demand	probability	cum prob.	Tag Numbers
10	$50 \div 500 = 0.1$	0.1	00-09
20	$110 \div 500 = 0.22$	0.32	10-31
30	$200 \div 500 = 0.40$	0.72	32-71
40	$100 \div 500 = 0.20$	0.92	72-91
50	$40 \div 500 = 0.08$	1.00	92-99



Step 2 : Statement showing final answer

R.No	supply	R.No	Demand	Profit on Sale	loss on unsold	Penalty	Net Pft/loss
31	30	18	20	$20 \times 10 = 200$	$10 \times 20 = 200$	-	-
63	40	84	40	$40 \times 10 = 400$	-	-	400
15	20	79	40	$20 \times 10 = 200$	-	$20 \times 8 = 160$	40
07	10	32	30	$10 \times 10 = 100$	-	$20 \times 8 = 160$	(60)
43	30	75	40	$30 \times 10 = 300$	-	$10 \times 8 = 80$	220
81	40	27	20	$20 \times 10 = 200$	$20 \times 20 = 400$	-	(200)
Net profit							<u>400</u>

Q4. Step 1 : Statement showing Tag Numbers

Daily Demands	probability	cum prob	Tag Number
4	$4 \div 50 = 0.08$	0.08	00 - 07
5	$10 \div 50 = 0.20$	0.28	08 - 27
6	$16 \div 50 = 0.32$	0.60	28 - 59
7	$14 \div 50 = 0.28$	0.88	60 - 87
8	$6 \div 50 = 0.12$	1.00	88 - 99

Step 2 : Statement Showing final Answer

R.No	Daily Demand	Rented	Rental lost
15	5	5	-
48	6	6	-
71	7	6	1
56	6	6	-
90	8	6	2
		29	3
		$\div 5$	
Avg cars rented		<u>5.8</u>	

(3)

* Application of Simulation in Costing

Q3. Step 1: statement showing Tag Numbers

Selling price	prob	cum prob	Tag Number
3	0.2	0.2	00 - 19
4	0.5	0.7	20 - 69
5	0.3	1.0	70 - 99

Variable cost	prob	cum prob	Tag Number
1	0.30	0.30	00 - 29
2	0.60	0.90	30 - 89
3	0.10	1.00	90 - 99

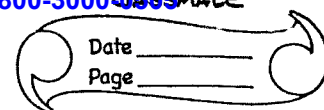
Sales volume	prob	cum prob	Tag Number
2000	0.30	0.30	00 - 29
3000	0.30	0.60	30 - 59
5000	0.40	1.00	60 - 99

Step 2: Statement showing final answers

R.No	SP	R.No	VC	R.No	S-volume	Total (SP-VC) × Sale = contribut ⁿ	Fixed cost	Profit
81	5	32	2	60	5000	(5-2) × 5000 = 15000	4000	11000
04	3	46	2	31	3000	(3-2) × 3000 = 3000	4000	(1000)
67	4	25	1	24	2000	6000	4000	2000
10	3	40	2	02	2000	2000	4000	(2000)
39	4	68	2	08	2000	4000	4000	-
59	4	66	2	90	5000	10,000	4000	6000
12	3	64	2	79	5000	5000	4000	1000
31	4	86	2	68	5000	10,000	4000	6000
82	5	89	2	25	2000	6000	4000	2000
11	3	98	3	16	2000	-	4000	(4000)

(4)

$$\therefore \text{Avg profit} = \frac{21000}{10} = 2100$$



* Application of Simulation in FM.

Q 6. Step 1 : Statement showing Tag Numbers

Demand	prob	cum prob	Tag Numbers
25	0.05	0.05	00 - 04
30	0.10	0.15	05 - 14
35	0.20	0.35	15 - 34
40	0.30	0.65	35 - 64
45	0.20	0.85	65 - 84
50	0.10	0.95	85 - 94
55	0.05	1.00	95 - 99

profit	prob	cum prob	Tag Numbers
3	0.10	0.10	00 - 09
5	0.20	0.30	10 - 29
7	0.40	0.70	30 - 69
9	0.20	0.90	70 - 89
10	0.10	1.00	90 - 99

Investment	prob	cum prob	Tag Number
2750	0.25	0.25	00 - 24
3000	0.50	0.75	25 - 74
3500	0.25	1.00	75 - 99

Step 2 : Statement Showing final Answer

R.No	Demand	R.No	profit	R.No	Investment	$\frac{\text{Demand} \times \text{pft}}{\text{Invest}} \times 100 = R$
30	35	12	5	16	2750	$6.36\% \dots \left(\frac{35 \times 5}{2750}\right)$
59	40	09	3	69	3000	4%
63	40	94	10	26	3000	13.33% .. Highest
27	35	08	3	74	3000	3.5%
64	40	60	7	61	3000	9.33%
28	35	28	5	72	3000	5.83%
31	35	23	5	20 ⁵⁷	3000	5.83%
54	40	85	9	20	2750	13.09%
64	40	68	7	18	2750	10.18%
32	35	31	7	87	3500	7%

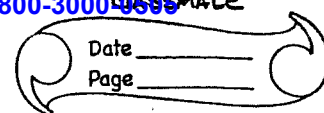
Q7. Step 1 : statement Showing Tag Numbers

Defect A	cum prob	Tag Num	Defect B	cum prob	Tag No	Defect C	cum prob	Tag No.
0.15	0.15	00-14	0.20	0.20	00-19	0.10	0.10	00-09
0.85	1.00	15-99	0.80	1.00	20-99	0.90	1.00	10-99

Step 2 : Final Answer

R.No	Result A	R.No	Result B	R.No	Result C	Final Res
48	No	47	No	82	No	No
55	No	36	No	95	No	No
91	No	57	No	18	No	No
40	No	04	Yes	96	No	Yes - B
93	No	79	No	20	No	No
01	Yes	55	No	84	No	Yes - A
83	No	10	Yes	56	No	Yes - B
63	No	13	Yes	11	No	Yes - B
47	No	57	No	52	No	No
52	No	09	Yes	03	Yes	Yes - B, C

∴ 5 items without defect - 1 item Scraped , Total rework time $4 \times 30 = 120$ minutes



Step 1 :

Q 8 . Statement showing Tag Numbers

category	Time req.	probability	cum prob	Tag No.
Filing	45min	0.40	0.40	00 - 39
crown	60min	0.15	0.55	40 - 54
cleaning	15min	0.15	0.70	55 - 69
Extraction	45min	0.10	0.80	70 - 79
checkup	15min	0.20	1.00	80 - 99

R.No	Time required	Patient arrival time	Service start time	Service complete time	Waiting Time of patient	idle time of doctor
40	60min	8.00	8.00	9.00	-	-
82	15min	8.30	9.00	9.15	30min	-
11	45min	9.00	9.15	10.00	15min	-
34	45min	9.30	10.00	10.45	30min	-
25	45min	10.00	10.45	11.30	45min	-
66	15min	10.30	11.30	11.45	60min	-
17	45min	11.00	11.45	12.30	45min	-
79	45min	11.30	12.30	1.15	60min	-

285

$$\text{Avg waiting time} = \frac{285}{8} = 35.625$$

Q10. Step 1: Statement Showing Tag Numbers

Demand	prob	Cum prob	Tag Numbers
0	$\frac{0.05}{0.50}$	0.50 0.05	00 - 04
1	0.10	0.60 0.15	05 - 14
2	0.30	0.90 0.45	15 - 44
3	0.45	1.00 0.90	45 - 89
4	0.10	1.00	90 - 99

Ans no A:

Step 2: Statement Showing final Answer

ordering cost $(4 \times 10) = 40$
carrying cost $(39 \times 0.5) = 19.5$
Total cost 59.5

R.No.	Demand	op stk	order placed	order received	Total	Demand	clsq stk
89	3	8	-	-	8	3	5
34	2	5	-	6	11	2	9
78	3	9	-	-	9	3	6
63	3	6	5	-	6	3	3
61	3	3	-	-	3	3	0
81	3	0	5	5	5	3	2
39	2	2	5	-	2	2	0
16	2	0	-	5	5	2	3
13	1	3	-	5	8	1	7
73	3	7	5	-	7	3	4
			4 times				39

Ans no B:

Demand	op stk	order placed	order received	Total	Demand	clsq stk	
3	8	-	-	8	3	5	∴ ordering cost
2	5	-	6	11	2	9	cost
3	9	-	-	9	3	6	$(2 \times 10) = 20$
3	6	8	-	6	3	3	carrying cost
3	3	-	-	3	3	0	$(45 \times 0.5) = 22.5$
3	0	-	8	8	3	5	∴ Total cost = 42.5
2	5	8	-	5	2	3	
2	3	-	-	3	2	1	
1	1	-	8	9	1	8	
3	8	-	-	8	3	5	
			2 times			45	

28

* If Random numbers are not given.

Q1. Statement showing allocation of Random numbers

Cumulative villages	Tag Numbers	Random Numbers
720	600 - 719	0591 (5)
850	720 - 849	0744 (1)
1000	850 - 999	
1240	1000 - 1239	1053 (2) 1025 (2)
2200	1240 - 2199	2158 (3)
2300	2200 - 2299	
2352	2300 - 2351	
2388	2352 - 2387	
2920	2388 - 2919	2878 (4)

Assignment

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* It means assign particular Job to particular person with a object of minimize the cost & maximise the profit.

Steps for solving the sum

- i] Row minimum
- ii] Column minimum and draw the line in such a way to cover all the zeros but line should be minimum. [This is also known as test of optimality]
- iii] Final Answer

checklist before solving the sums.

- i] A.P. [Assignment problem]
- ii] min cost or max profit
- iii] Balanced or unbalanced problem.

Hamy - 75

अभिल भारती

नोट

स्व. शशीकांत जेतशी महे
श्री विनोदचंद्र छगनवाल
स्व. शांतिलास वखराज
मे. गुडलक जनरल स्टोर्स
स्व. दिवाणीबेन देवचंद
मे. मोहनस-स अम्ब्रेला मे
श्री वीसनज्ज दामज्ज महेत
स्व. मणीलाल डावीभांछ
श्री मनसुजलाल रायशी
श्री मगनलाल वीरज्ज मो
श्री युक्ताशुभार शांतिलास
स्व. गोपालज्ज पोपटलाल
स्व. हंसराज प्रेमचंद पा
श्री प्रभुलाल कुशलचंद
स्व. बाबुलाल नाथालाल
स्व. जेठालाल नाथालाल
स्व. मणीलाल भांशोकचं
गं. स्व. वीलावतीबेन
स्व. वाडीलाल भाषज्ज
श्री लोणीलाल शामज्ज
श्री महादेवलाल सेजपा
श्रीमती वसंतबेन छव
श्रीमती लोपाबेन नरेश

- ❖ सस्ता दर नोट
- ❖ स्कूल ई, कोले
- ❖ अभिल भारती
- ❖ सलासदना अ

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Q12

i) AP ii) min iii) Balance

Step i] Row minimum

	I	II	III	IV
1	0	18	9	3
2	9	24	0	22
3	23	4	3	0
4	9	16	14	0

Step ii] Column min.

	I	II	III	IV
1	<u>0</u>	18	9	3
2	9	<u>20</u>	<u>0</u>	22
3	23	<u>0</u>	3	0
4	9	12	14	<u>0</u>

Test of optimality No of line = 4

∴ optimality is achieved.

∴ final answer 1 → I = 8 ∴ Total = 41 hrs
2 → III = 4
3 → II = 19
4 → IV = 10

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Q17

i) AP ii) min iii) Bal

Step 1 : row min.

	I	II	III	IV
1	0	36	18	6
2	18	48	0	44
3	46	8	6	0
4	18	32	28	0

Step 2 : column min.

	I	II	III	IV
1	<u>0</u>	36	18	6
2	18	40	<u>0</u>	44
3	46	<u>0</u>	6	0
4	18	24	28	<u>0</u>

final answer : 1 → I = 16
2 → III → 8
3 → II → 38
4 → IV → 20
min. 82 hrs

Q12

i) AP

Step i]

- 1
- 2
- 3
- 4

Step ii]

- 1
- 2
- 3
- 4

Test

∴ 04
% final

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Row min / Col min

Q16.

4
10
10
2
2

Row min.	E1	E2	E3
1	30	15	0
2	0	20	60
3	0	10	20

Col min.	E1	E2	E3
1	30	5	10
2	10	10	60
3	10	0	20

Final answer
1 → E3 = 70
2 → E1 = 50
3 → E2 = 120

240 min.

AP		min		Bal.	
i)	AP	ii)	min	iii)	Bal.
		EP1	EP2	EP3	
1	100	85	70		
2	50	70	110		
3	110	120	130		

Row min.	E1	E2	E3
1	30	15	0
2	0	20	60
3	0	10	20

Col min.	E1	E2	E3
1	30	5	10
2	10	10	60
3	10	0	20

Final answer
1 → E3 = 70
2 → E1 = 50
3 → E2 = 120

240 min.

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Q 14

i) AP ii) min iii) Bal.

step 1: Introduce dummy & row min/col min

	J	K	L	M	N
m_1	0	4	12	2	4
m_2	6	10	-	2	2
m_3	-	8	14	8	10
m_4	14	2	10	10	2
m_5 (Dummy)	2	2	0	2	2

$m_1 \rightarrow J = 18$

$m_2 \rightarrow K = 18$

$m_3 \rightarrow N = 14$

$m_4 \rightarrow M = 14$

64 min.

Q 18.

i) AP ii) min iii) Bal.

step 1: Row min

	A	B	C	D
R_1	0	8	12	4
R_2	0	8	12	4
R_3	0	8	12	4
R_4	0	8	12	4

Q 16.

i) A

1

2

3

Row min

Col min

Final ac

Eno.

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D
4
20
36
52
D
4
4
4
4

Step 2: column min

	A	B	C	D
R ₁	0	2	2	2
R ₂	2	0	2	2
R ₃	2	2	0	2
R ₄	2	2	2	0

R₁ → A = 4
R₂ → B = 28
R₃ → C = 48
R₄ → D = 56
136

Ans no.

ii) Profit matrix

i) AP ii) max iii) Bal.

	A	B	C	D
R ₁	96	88	84	92
R ₂	80	72	68	76
R ₃	64	56	52	60
R ₄	48	40	36	44

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	A	B	C	D
R ₁	0	8	12	4
R ₂	16	24	28	20
R ₃	32	40	44	36
R ₄	48	56	60	52

Step 2 : c

	A	B	C	D
1	0	8	12	4
2	0	8	12	4
3	0	8	12	4
4	0	8	12	4

R₁ → 1
R₂ → 1
R₃ → C
R₄ → D

final ans = 96
72
52
44
264

Ans no. 11
Profit matrix
i) A
R₁
R₂
R₃
R₄

check list
4 x 200 sales = 800
4 x 100 cost = 400
G) 136
264

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4 5

6

4 0

6

0

5

Q13

i) AP ii) min iii) Bal.
min Row

	1	2	3	4	5
I	7	1	2	0	8
II	4	2	0	3	1
III	11	2	9	0	8
IV	8	0	10	2	1
V	5	3	4	0	7

min Colⁿ

	1	2	3	4	5
I	3	1	2	0	7
II	0	2	0	3	0
III	7	2	9	0	7
IV	4	0	10	2	0
V	1	3	4	0	6

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	1	2	3	4	5
I	2	0	1	6	
II	4	2	0	4	0
III	6	1	8	0	6
IV	4	10	3	0	
V	0	2	3	5	

I → 2 = 3
II → 3 = 8
III → 4 = 0
IV → 5 = 1
V → 1 = 7
19 ms.

Q13

i)

min

I

II

III

IV

V

min

I

II

III

IV

V

i) AP ii) max iii) Bal.

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Q15

	A	B	C	D
P	140	20	110	154
Q	90	72	63	99
R	110	88	77	121
S	80	64	56	88

Loss matrix

	A	B	C	D
P	14	42	56	0
Q	64	82	91	85
R	44	66	77	33
S	74	90	98	66

Row min

	A	B	C	D
P	14	42	56	0
Q	9	27	36	0
R	11	33	44	0
S	8	24	32	0

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Q15

i) A

Col min

	A	B	C	D
P	6	18	24	0
Q	1	3	4	0
R	3	9	12	0
S	0	0	0	0

Loss

	A	B	C	D
P	5	17	23	0
Q	0	2	3	0
R	2	8	11	0
S	0	0	0	1

Row

	A	B	C	D
P	5	15	21	0
Q	0	0	1	0
R	2	6	9	0
S	2	0	0	3

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Bal .

chennai

84
6 11
to 2pm) (8am to 7pm)
8 9
to 2pm) (10 to 7pm)
22 27
to 2pm) (4 to 7pm)
16 21
(10 to 2pm) (10 to 7pm)

mumbai .

84

1 9
to 6am) (9pm to 6am)
6 11
to 8am) (9pm to 8am)
22 17
to 2pm) (9pm to 2pm)
28 23
to 8pm) (9pm to 8pm)

	A	B	C	D
P	3	13	19	10
Q	8	10	1	2
R	10	4	7	8
S	2	8	10	5

$P \rightarrow D = 154$
 $Q \rightarrow B = 72$
 $R \rightarrow A = 110$
 $S \rightarrow C = 56$
392

min of both

	B ₁	B ₂	B ₃	B ₄
A ₁	20	19	6	9
A ₂	22	21	16	9
A ₃	16	17	22	17
A ₄	10	9	16	21

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Q11

i) AP ii) min iii) Bal.

Arrival mumbai, Departure chennai

option I

	B ₁	B ₂	B ₃	B ₄
A ₁	24 (8am to 8am)	25 (8am to 9am)	26 (8am to 2pm)	11 (8am to 7pm)
A ₂	22 (10am to 8am)	23 (10 to 9)	28 (10 to 2pm)	9 (10 to 7pm)
A ₃	16 (4pm to 8am)	17 (4pm to 9)	22 (4 to 2pm)	27 (4 to 7pm)
A ₄	10 (10pm to 8am)	11 (10pm to 9am)	16 (10 to 2pm)	21 (10 to 7pm)

Arrival chennai, Departure mumbai.

option II

	B ₁	B ₂	B ₃	B ₄
A ₁	20 (10am to 6am)	19 (10 to 6am)	14 (4pm to 6am)	9 (9pm to 6am)
A ₂	22 (10am to 8am)	21 (11am to 8am)	16 (4pm to 8am)	11 (9pm to 8am)
A ₃	28 (10am to 2pm)	27 (1pm to 2pm)	22 (1pm to 2pm)	17 (9pm to 2pm)
A ₄	10 (10am to 8pm)	9 (11am to 8pm)	28 (4pm to 8pm)	23 (9pm to 8pm)

min of both

A₁ 9
A₂ 21
A₃ 16
A₄ 10

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Step 1 : row min

	B ₁	B ₂	B ₃	B ₄
A ₁	14	13	0	3
A ₂	13	12	7	0
A ₃	0	1	6	1
A ₄	1	0	7	12

Step 2 : colⁿ min

	B ₁	B ₂	B ₃	B ₄
A ₁	14	13	0	3
A ₂	13	12	7	0
A ₃	0	1	6	1
A ₄	1	0	7	12

$$A_1 \rightarrow B_3 = 6$$

$$A_2 \rightarrow B_4 = 9$$

$$A_3 \rightarrow B_1 = 16$$

$$A_4 \rightarrow B_2 = 9$$

40 hrs

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Chapter 12: Learning Curve Theory

Meaning of Learning Curve Ratio (L.C.R.)

It is a ratio related to human efficiency. Hence, it is applicable only for human & not for Machine

Q.34

<u>Initial Batch</u>	<u>Hrs reqd. per batch</u>	<u>L.C. Ratio</u>
10 units	1000	90%
20 units	900 (p.b.)	(90% of 1000)
40 units	810 (p.b.)	(90% of 900)
80 units	729 (p.b.)	(90% of 810)
160 units	656.10 (p.b.)	(90% of 729)
320 units	590.49 (p.b.)	(90% of 656.1)

Lab. (p.b.)
cost 8.00

V.O. (p.b.) 2.00
10.00

Statement showing labour & Related cost(i) If prodⁿ = 320 units

$$\text{Total labour hrs reqd.} = 590.49 \times \frac{320 \text{ units}}{10 \text{ units}}$$

$$= \underline{18895.68}$$

$$\text{Total cost} = (18895.68 \times 10) = 188956.80$$

$$\text{Avg. C.P.U.} = \left(\frac{188956.8}{320 \text{ units}} \right) = \boxed{\text{₹ } 590.49 \text{ p.u.}}$$

(ii)(a) If prodⁿ = 40 units

$$\text{Total hrs} = 810 \times \frac{40 \text{ units}}{10 \text{ units}}$$

$$= \underline{3240 \text{ hrs}}$$

$$\text{Total cost} = 3240 \times 10 = 32400.00$$

$$\text{Avg. cost (p.u.)} = \frac{32400}{40} = \boxed{\text{₹ } 810 \text{ p.u.}}$$

(b) If prodⁿ = 80 units

$$\text{Total hrs} = 729 \times \frac{80 \text{ units}}{10 \text{ units}} = \underline{5832}$$

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$$\text{Total cost} = 5832 \times 10 = ₹58320$$

$$\text{Avg. cost} = (58320 \div 80) = ₹729/-$$

(c) Avg. cost of 100 units

It means if prodⁿ = 100 units

$$\text{Hrs per batch} = \log(k) + \left(\frac{\log L \cdot C \cdot R}{\log 2} \right) \times \log(x)$$

↓
base
hrs / base
cost
↓
constant
↓
no. of
batches

$$= \log 1000 + \left(\frac{\log 0.90}{\log 2} \right) \times \log(10)$$

$$= 3.0000 + \left(\frac{-1 + 0.9542}{0.3010} \right) \times 1.0000$$

$$= 2.8478 \text{ (Antilog)}$$

$$\begin{array}{r} 7031 \\ 13 \\ \hline 7044 \end{array}$$

$$\text{Total hrs} = 704.4 \times \frac{100 \text{ units}}{1 \text{ unit}} = 7044 \text{ hrs}$$

$$\text{Total cost} = 7044 \times 1.0 = ₹70440/-$$

$$\text{Avg. cost} = \frac{70440}{100} = 704.40$$

(iii)
(28)

If prodⁿ = 200 units

$$\text{Hrs per batch} = \log K + \frac{\log L \cdot R}{\log 2} \times \log(x)$$

$$= \log 1000 + \frac{\log 0.90}{\log 2} \times \log(20)$$

$$= 3.0000 + \left(\frac{-1 + 0.9542}{0.3010} \right) \times 1.3010$$

$$= 2.8020 \text{ (Antilog)}$$

$$= \underline{\underline{633.9}}$$

$$\text{Total hrs} = \frac{633.9 \times 200 \text{ units}}{10 \text{ units}}$$

$$= 12678 \text{ hrs}$$

$$\text{Total cost} = 12678 \times 10 = \underline{\underline{126780}}$$

$$\text{Avg. cost} = \frac{126780}{200} = \underline{\underline{633.9}}$$

(iii) (a) Incremental Cost of 41-80 units

Note - If in the question, the language is used like Incremental, differential, repeat, additional, extra, then calculation will be as follows:-

(28)

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5

Incr. cost (41-80)

Total Cost for 80 units ₹ 58320

Total cost for 40 units (32400)

Incr. cost (41-80) units :- 25920(b) Incr. cost (101-200)
units

Total Cost for 200 units ₹ 126780

Total cost for 100 units (70440)
56340Q.33

<u>Initial batch</u>	<u>Cost per batch</u>	<u>L.C.R.</u>
100	10000 (p.b.) (100x100)	90%
200	9000 (p.b.)	(10000x90%)
400	8100 (p.b.)	(9000x90%)
800	7290 (p.b.)	(8100x90%)
1600	6561 (p.b.)	(7290x90%)

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Ans no. (a)Total lost if prodⁿ - 800 units

Total cost	₹ 58320
$(7290 \times \frac{800}{100})$	

Ans no. (b)Incremental labour cost (800-1600 units)

Total labour cost for 1600 units	104976
$(6561 \times \frac{1600}{100})$	

Total labour cost for 800 units	(58320)
(Ans no. a)	

Incr. labour cost (800-1600 units)	<u>₹ 46656</u>
------------------------------------	----------------

Ans. no. (c)Incr. labour cost (800-900 units)

Cost for 900 units	64422
--------------------	-------

Cost for 800 units	(58320)
--------------------	---------

Incr. Cost for 800-900 units	<u>6102</u>
------------------------------	-------------

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31

$$\text{If prod}^n = 900 \text{ units}$$

$$\text{Cost per batch} = \log k + \left(\frac{\log L \cdot (1-R)}{\log 2} \right) \times \log(q)$$

$$= \log 10000 + \frac{\log 0.90}{\log 2} \times \log 9$$

$$= 4.0000 + \frac{-1 + 0.9542}{0.3010} \times 0.9542$$

$$= 3.8548 \text{ (Antilog)}$$

7145

13

7158

$$7158 \times \frac{900}{100}$$

$$= 64422$$

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Q.32

<u>Initial batch</u>	<u>Hrs per batch</u>	<u>L.L.R.</u>	<u>Total hrs</u>	<u>Marginal hrs</u>
1	100 (p.b.)	80%	100 hrs	100
2	80 (p.b.)	(80% of 100)	2 x 80 = 160	¹⁶⁰⁻¹⁰⁰ = 60
3	70.21 (p.b.)	<u>Note no. (1)</u>	3 x 70.21 = 210.63	^{210.63-160} = 50.63
4	64 (p.b.)	(80% of 80)	4 x 64 = 256	^{256-210.63} = 45.37

Note no. (1) If prodⁿ = 3 units

$$\text{Hrs per batch} = \log k + \left(\frac{\log L.L.R.}{\log 2} \right) \times \log(x)$$

$$= \log 100 + \frac{\log 0.80}{\log 2} \times (\log 3)$$

$$= 2.0000 + \left(\frac{-1 + 0.9031}{0.3010} \right) \times 0.4771$$

$$= 1.8464 \text{ (Antilog)}$$

$$\begin{array}{r} 7015 \\ 6 \\ \hline 7021 \end{array}$$

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Q.30

Initial batch
1 unit

Hrs reqd.
40

L.C.R.
80%

Hrs reqd. for 30 units

↓

Refer note no. (ii)

Hrs reqd. for 20 units (REPEAT)

Hrs. reqd. for 30 units

$$\text{Hrs per batch} = \log k + \frac{\log \text{L.C.R.}}{\log 2} \times \log(x)$$

$$= \log 40 + \frac{\log 0.80}{\log 2} \times \log(30)$$

$$= 1.6021 + \left(\frac{-1 + 0.9031}{0.3010} \right) \times 1.4771$$

$$= 1.1266 \text{ (Antilog)}$$

1337

2

1339

$$13.39 \times 30$$

$$= 401.70 \text{ i.e. } 402 \text{ hrs}$$

(33)

Hrs reqd. for 20 units (Repeat)

$$\begin{array}{r}
 = \text{Hrs reqd. for 50 units [Note (iii)]} \quad 568 \\
 (-) \text{Hrs reqd. for 30 units} \quad (402) \\
 \text{Hrs reqd. for 20 units} \quad \underline{\underline{166 \text{ hrs}}} \\
 \text{(Repeat order)}
 \end{array}$$

Note (iii) Hrs reqd. for 50 units

$$= \log 40 + \frac{(\log 0.80)}{\log 2} \times \log (50)$$

$$= 1.6021 + \left(\frac{-1 + 0.9031}{0.3010} \right) \times (1.6990)$$

$$= \underline{\underline{1.0551}} \text{ (Antilog)}$$

$$\begin{array}{r}
 1135 \\
 0 \\
 \hline
 1135
 \end{array}$$

$$11.35 \times 50$$

$$= 567.5 \text{ (say 568 hrs)}$$

Standard Absorpⁿ Rate

= Budgeted FOH

Budgeted hrs

$$= \frac{7500}{[(10 \times 25 \times 8) - 25 \times 1]}$$

$$= \frac{7500}{1500}$$

$$= \underline{\underline{25 \text{ per hr}}}$$

(34)

Statement showing Cost sheetBvd.
units

= 30

20 Repeat

(I) Direct cost

DM

Total

p.u.

Total

p.u.

1800

60.00

1200

60.00

DL

2412

80.40

996

49.80

(402 X 6)

(166 X 6)

4212

140.40

2196

109.80

(II) Indirect cost

F.O.

(1) Variable

2010

67.00

830

41.50

(402 X 5)

(166 X 5)

(2) Fixed

2010

67.00

830

41.50

(402 X 5)

(166 X 5)

Total cost

8232

224.40

3856

192.80

Profit

-

-

1286

64.30

(3856 X 25)
75

Sales

5142

257.10

Imp. point

The L.C.R. is only applicable for human & not for machine

Q.31

Initial order	x	y 80%
100	$\frac{100}{100} = 1.00$	Normal time
60	$\frac{160}{100} = 1.60$	86.1% of normal time
40	$\frac{200}{100} = 2.00$	80% of normal time

Dept A (L.C. is not applicable)

$$\begin{aligned} 100 \text{ nos} &\rightarrow (100 \times 20) = 2000 \text{ hrs} \\ 60 \text{ nos} &\rightarrow (60 \times 20) = 1200 \text{ hrs} \\ 40 \text{ nos} &\rightarrow (40 \times 20) = 800 \text{ hrs} \end{aligned}$$

Dept B (L.C. Ratio is applicable)

$$(100 \times 40) = 4000 \text{ hrs}$$

Hrs for 60	Hrs for 40
Hrs for 160 (160 × 40 × 86.1%)	Hrs for 200 6400
(-) Hrs for 100	(-) Hrs for 160 (5510.4)
1510.4	889.60
1511	890

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Note no. (1) Labor cost

Dept A

100 nos

20000

(20000 X 10)

60 nos

12000

(12000 X 10)

40 nos

8000

(8000 X 10)

Dept B

60000

(40000 X 15)

22665

(1511 X 15)

13350

(8900 X 15)

80000

34665

21350

Note no. (2) V.O.

(20% of direct labor)

16000

(80000 X 20%)

6933

(34665 X 20%)

4270

(21350 X 20%)

Note no. (3) F.O.

Dept A

16000

(2000 X 8)

9600

(1200 X 8)

6400

(800 X 8)

Dept B

20000

(40000 X 5)

7555

(1511 X 5)

4450

(8900 X 5)

36000

17155

10850

Statement showing cost sheet

	100 nos		60 nos		40 nos	
	Total	p.u.	Total	p.u.	Total	p.u.
(i) <u>Direct cost</u>						
DM	50000	500	30000	500	20000	500

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D. Lab.	80000	800	34665	577.75	21350	533.75
(Note no. (i))						
	130000	1300	64665	1077.25	41350	1033.7
(II) Indirect Cost						
F.O.						
(1) Variable OH (Note 2)	16000	160	6933	115.55	4270	106.35
(2) Fixed OH (Note 3)	36000	360	17155	285.92	10850	271.25
Total Cost	182000	1820	88753	1479.22	56420	1411.7
Profit	45500	455	22188		14117.5	
	(182000 x 25%)		(88753 x 25%)		(56420 x 25%)	
Sales Value	227500	2275	110941.25	1849.02	70587.5	1764

Q.35

<u>Initial batch</u>	<u>Hrs reqd. p.b.</u>	<u>L.C.R.</u>
100 units	1000 hrs	80%

Hrs for 25th batch (25×354.7) 8867.5

Hrs for 24th batch (24×359.4) 8625.6

Incr. hrs $(24-25)$ 241.9

Hrs for 2500 units

Hrs per batch = $\log k + \left(\frac{\log L.C.R.}{\log 2} \right) \times \log(x)$

learning co-efficient $\rightarrow x$

$= \log 1000 + \frac{\log 0.80}{\log 2} \times \log(25)$

$= 2.5499$ (Antilog)

3540

354.7

5000 units

2500 $\rightarrow$ 8867.5

2500

$(2500 \times \frac{241.9}{100}) \rightarrow 6047.5$

14915 hrs

$y = ax^b$

$y = 1000(25)^{0.322}$

$= 1000 - 0.322(5 \times 5)$

$\log \Rightarrow 1000 - 0.322(\log 5 + \log 5)$

$= 3.0000 - 0.322$
 $(0.69897 + 0.69897)$

(39)

2.5499

Final Ans.Statement showing Cost sheet5000 unitsDirect lab. cost (14915×6) 89490Other V-c (5000×19) 95000

Fixed cost 40000

Total cost
+ Profit

Sales value

224490

80000

304490

$$\frac{4500}{\text{Units}}$$
 $= 4500 \times 64$ $= 288000$

16490

 $\div 500$ $= (32.98)$

Q 36

<u>Standard</u>	<u>Actual</u>
Hrs X Rate = Amt 91.42 X 660 = 60337.20 (119288) (180.74)	Hrs X Rate = Amt 118.08 X 675 = 79704

Labour Cost Variance = (60337.2 - 79704)
= 19366.80 (A)

Lab. Eff. Variance
= (91.42 - 118.08) X 660
= 17595.60 (A)

Lab. Rate Variance
= (660 - 675) X 118.08
= 1771.2 (A)

Statement showing Reco

Bud. cost	60337.20
Lab. Eff. Var.	17595.60(A)
Lab. Rate Var.	1771.2(A)
Actual cost	<u>79704</u>

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Initial batch	Hrs per batch	L.L. Ratio
1	10	80%

If prodⁿ = 15 units

$$= \log 10 + \frac{\log 0.80}{\log 2} \times \log 15$$

$$= 1.0000 + \left(\frac{-1 + 0.9031}{0.3010} \right) \times 1.1761$$

$$= 0.6213 \text{ (Antilog)} \rightarrow 4.178$$

3
4.181

i.e. 15 units X 4.181

$$= \underline{\underline{62.72}}$$

If prodⁿ = 14 units

$$= \log 10 + \frac{\log 0.80}{\log 2} \times \log 14$$

$$= 1.0000 + \left(\frac{-1 + 0.9031}{0.3010} \right) \times 1.1461$$

$$= \underline{\underline{0.6310 \text{ (Antilog)}}} \quad \underline{\underline{4.276}}$$

i.e. 14 units X 4.276 = 59.864 i.e. 59.85

Incr. hrs (14-15 units)

2.87

Actual prodⁿ = 25 units

$\frac{15}{(10 \times 2.87)}$

}

$\frac{62.72}{28.70}$

91.42

42

Chapter 13 :- Transportation

* Meaning of Transportation

It means transport particular quantity from particular place to particular place with the object of minimising the cost & maximising the profit.

* Methods of Transportation

↓
Prof. Vogel
V.A.M.

↓
North/West

↓
Least Cost

* Steps for solving the sum as per V.A.M.

Step I :- Initial Solution

Step II :- Test of Optimality (T.O.O.)

Step III :- Final Answer

* Checklist before solving the sum

1. T.P. (Transportation problem)
2. Minimum cost or Maximum profit
3. Balanced or Unbalanced problem

Q.19

(i) T.P (ii) Minimum cost (iii) Balanced

Step (I) Initial Solution

	D ₁	D ₂	D ₃	D ₄	Qty	Penalty		
Q ₁	5	3	(18)	6	(1)	2	19/1/0	1/2/2/1
Q ₂	4	(12)	7	9	1	(25)	37/12/0	3/3
Q ₃	3	(4)	4	7	(30)	5	34/30/0	1/1/1/4
Qty	16/4/0	18/0	31/0	25/0	90	90		
Penalty	$\frac{1}{1}$ $\frac{1}{2}$ $\frac{1}{2}$	$\frac{1}{1}$ $\frac{1}{1}$	$\frac{1}{1}$ $\frac{1}{1}$ $\frac{1}{1}$	1				

Step (II) :- Test of Optimality

	D ₁	D ₂	D ₃	D ₄	u _i		
Q ₁	5	3	(18)	6	(1)	0	
Q ₂	4	(12)	7	9	11	(25)	2
Q ₃	3	(4)	4	7	(30)	5	1
v _j	2	3	6	-1			

Calculation of u_i & v_j

$u_i = \text{cost} - v_j$

$v_j = \text{cost} - u_i$

(44)

$R + C - 1 = \text{All loc}^n$
 $3 + 4 - 1 = 6$

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Step III:- Final Ans.

$$Q_1 \rightarrow D_2 \quad (18 \times 3) = 54$$

$$Q_1 \rightarrow D_3 \quad (1 \times 6) = 6$$

$$Q_2 \rightarrow D_1 \quad (12 \times 4) = 48$$

$$Q_2 \rightarrow D_4 \quad (25 \times 1) = 25$$

$$Q_3 \rightarrow D_3 \quad (30 \times 7) = 210$$

$$Q_3 \rightarrow D_1 \quad (4 \times 3) = 12$$

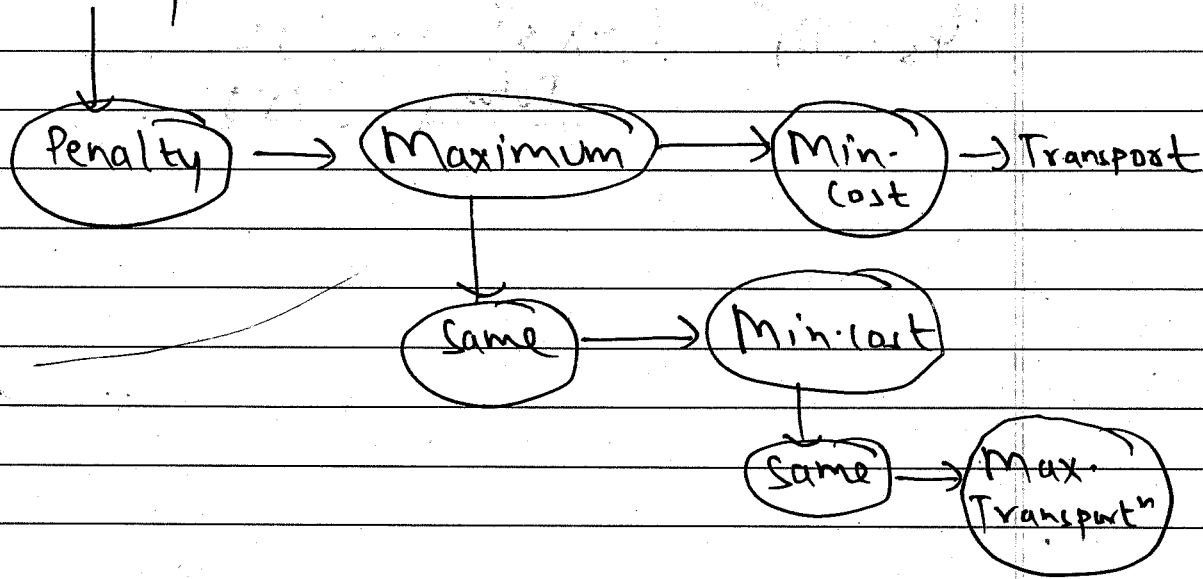
$$\text{Total} \rightarrow \underline{355}$$

Notes (Not for exam)

* Calculation of Penalty

Meaning of penalty $\Rightarrow$ It is a difference between min. cost to next min. cost.

Penalty : Diff. between Min. cost to next min. cost



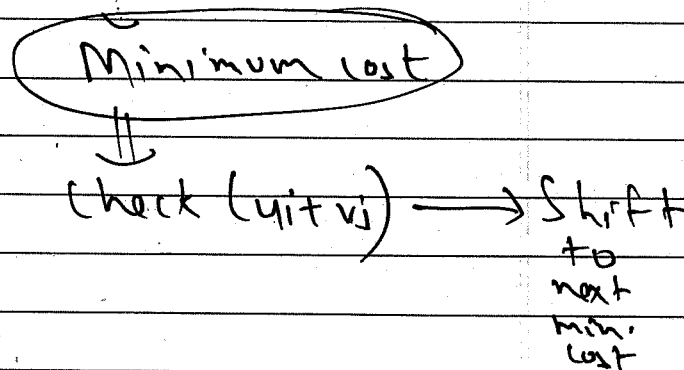
* Calculation of u_i & v_j

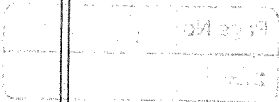
$$\left. \begin{aligned} u_i &= (cost - v_j) \\ &\& \\ v_j &= (cost - u_i) \end{aligned} \right\} \text{for allocated cells}$$

$$\frac{cost - (u_i + v_j)}{\Downarrow} \text{for unallocated cells.}$$

$$R + C - 1 = \text{Alloc}^n$$

* Application of epsilon (ϵ)

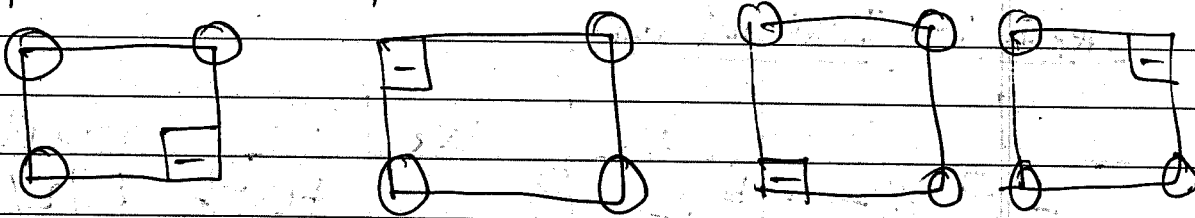




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Notes

* Application of loop



Q.26 (i) T-P (ii) Minimum cost (iii) Balanced

Step(I) :- Initial soln

	W_1	W_2	W_3	Penalty
A	(65)	(5)		70/5/0
B		(30)	(6)	30/0
C		(7)	(43)	50/7/0
	65	41	43	150/150
Penalty	1	3	1	
	1	0	1	

Step(II) :- Test of Optimality

	W_1	W_2	W_3	u_i
A	(65)	(5)		0
B		(30)	(6)	-3
C		(7)	(43)	0
v_j	5	7	7	

Calculation of u_i & v_j

$$\begin{aligned} R+(-1) &= (3+3)-1 \\ &= 5 \end{aligned}$$

$$\begin{cases} u_i = \text{cost} - v_j \\ v_j = \text{cost} - u_i \end{cases}$$

(48)

Step III:- Final Ans.

	Qty x Rate	Amt
A → W ₁	65 × 5	325
A → W ₂	5 × 7	35
B → W ₂	30 × 4	120
C → W ₂	7 × 7	49
C → W ₃	43 × 7	301
		<u>830</u>

Q.20

(i) T.P (ii) Minimum cost (iii) Bal.

Step I Initial Solⁿ

	1	2	3		Penalty
A	5	10	3	10	4
B	20	10	50	80	1/1
C	15		5	15	1
Dummy	40	3	3	40	1
Demand	75	20	50		
Penalty	2	1	2		
	<u>2</u>	<u>0</u>	<u>2</u>		
	3	2	0		

Step (II) Test of Optimality

	1	2	3	ui
A	5	10	7	0
B	6	4	5	3
C	3	2	5	0
Dummy	1	3	3	-2
vj	3	1	2	

$R + C - 1 = \text{Alloc}^n$

$4 + 3 - 1 = 6$

Step III - Final Answer

$A \rightarrow 2 = 10 \times 1 = 10$

$B \rightarrow 1 = 20 \times 6 = 120$

$B \rightarrow 2 = 10 \times 4 = 40$

$B \rightarrow 3 = 50 \times 5 = 250$

$C \rightarrow 1 = 15 \times 3 = 45$

T. cost

Dummy $\rightarrow 1 = 40 \times 1 = 40 \rightarrow$ Penalty cost

50

505 (Total cost)

Ans. to Q.21

(i) T-P (ii) Max. (iii) Bal.

Profit - matrix

(Paise)

Plant	A	B	C	
Standard	1495-800 = 695	1495-795 = 700	1495-810 = 685	450
Deluxe	1895-850 = 1045	1895-860 = 1035	1895-845 = 1050	1050
New Deluxe	2195-925 = 1270	2195-920 = 1275	2195-930 = 1265	600
	800	600	700	2100 2100

Loss - Matrix Step I :- Initial Solⁿ

Plant Model	A	B	C	Qty	Penalty
S	580 (450)	525	590	450	5/10
D	230 (350)	240	225 (700)	1050/350	5/5
ND	5 (600)	0	10	600/0	5
Qty	800	600/0	700	2100 2100	
Penalty	225	240	215		

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Step II:- Test of Optimality (T.O.O.)

	A	B	C	u_i
S	580 (450)	575 0	590 15	0
D	230 (350)	240 15	225 (700)	-350
ND	5 (e)	0 (600)	10 10	-575
v_j	580	575	575	

Calculation of u_i & v_j

$u_i = \text{cost} - v_j$
 $v_j = \text{cost} - u_i$

(check! - $R+C-1 = \text{All } u^n$)

$(3+3)-1 \neq (5)$

Appln of epsilon (e)

Final Ans.

Std. $\rightarrow A = 450 \times 6.95 = 3127.5$
Deluxe $\rightarrow A = 350 \times 10.45 = 3657.5$
Deluxe $\rightarrow C = 700 \times 10.50 = 7350$
New Deluxe $\rightarrow B = 600 \times 12.75 = 7650$
Total $\rightarrow \underline{\underline{21785}}$

Q.28 (i) T-P (ii) Min. (iii) Bal.

Step I: - Initial Solⁿ (given)

	V	W	X	Y	Z	ui
A	11	2	8	6	2	41
		(8)		(6)	(4)	0
	2		3			
B	9	9	12	9	6	0
			7	7	3	4
C	7	6	3	8	7	2
		0	6	3	7	
D	9	2	5	2	11	0
			(2)	(2)	9	
vi	9	2	5	6	2	

Final Ans.

A → W	:- (8x2)	= 16
A → Y	:- (6x6)	= 36
A → Z	:- (4x2)	= 8
B → V	:- (10x9)	= 90
C → X	:- (8x3)	= 24
D → V	:- (2x9)	= 18
D → Y	:- (2x6)	= 12
		<u>204</u>

Ans. to Q. no. 22

(check :- i) T-P ii) Min. cost iii) Bal.

	A	B	C	Supply	Penalty
X	15	9 (10)	6	10	3/3
Y	21	12	6 (10)	10/0	6/6
Z	6 (10)	18	9	10/0	3
Reqd Qty	10/0	10	10	30/30	
Penalty	0	3/3	0/0		

Step II :- T.O.D.

	A	B	C	ui
X	15 12	9 (10)	6 (2)	0
Y	21 18	12 3	6 (10)	0
Z	6 (10)	18 12	9 (2)	3
uj	3	9	6	

$(R+(-1)) \neq 5$

Step III :- Final Ans

(54) $X \rightarrow B = (10 \times 9) \times \frac{1}{2} = 45$
 $Y \rightarrow C = (10 \times 6) \times \frac{1}{2} = 30$
 $Z \rightarrow A = (10 \times 6) \times \frac{1}{2} = 30$
105

Ans. to Q. no. 24

(1) T.P.

(2) Max.

(iii) Unbal.

Loss matrix / Dummy column

Initial solⁿ

	P	Q	R	S	Dummy	Avail.
1	0	15	25	35	0	70
2	20	30	35	45	0	40
3	25	50	45	55	0	90
4	35	55	55	65	0	30
Max. Inst	40	50	60	60	20	230 230

Calculation of penalty

	P	Q	R	S	Dummy	Qty	Penalty
1	0 (40)	15 (30)	25	35	0	70/30/0	0/15/10/10
2	20	30 (60)	35 (20)	45	0	40/20/0	20/10/20/5/10
3	25	50	45 (40)	55 (50)	0	90/50/0	25/20/5/5/10
4	35	55	55	65 (10)	0 (20)	30/10/0	35/20/0/0/10
Qty	40/0	50/20/0	60/40/0	60/0	20/0		
Penalty	20 20 40	15 15 15	10 10 10	10 10 10	0		(55)

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Step II: T.O.O.

Step II	P	Q	R	S	Dummy	u _i	
1	0 (40)	15 (30)	25	35	0	0	
			5	5		35	
2	20	30 (20)	35 (20)	45	0	15	
		5		10		20	
3	25	50	45 (40)	55 (50)	0	25	
		0	10			10	
4	35	55	55	65	0	35	
		10	5	10 (10)	(20)		
u _j	0	15	20	30	-35		

$$R + (-1) = 8$$
$$4 + 5 - 1$$

Step III: Final Ans.

Year	Invest	₹	X	Return (%)	= Exp. Return
1	P	40	X	0.95	= 38
1	Q	30	X	0.80	= 24
2	Q	20	X	0.65	= 13
2	R	20	X	0.60	= 12
3	R	40	X	0.50	= 20
3	S	50	X	0.40	= 20
4	S	10	X	0.30	= 3
4 4	Dummy	20	X	0	= 0
					<u>130</u>

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Alternative Answer

Introducing Dummy column

	P	Q	R	S	Dummy	
1	95	80	70	60	0	70
2	75	65	60	50	0	40
3	70	45	50	40	0	90
4	60	40	40	30	0	30
	40	50	60	60	20	230

Step(I) Initial Solⁿ

Loss Matrix

	P	Q	R	S	Dummy	Qty
1	0/40	15/30	25	35	95	70/15/10
2	20	30/20	35	45	95	40/10/5/5/10
3	25	50	45/40	55/50	95	90/20/5/5/10
4	35	55	55	65/10	95/20	30/20/0/0/10
Qty	40/0	50/20/0	60/40/0	60/10/0	20	230
Penalty	20	15/15/20	10/10/10	10/10/10	0/0/0	

Step II :- Test of Optimality

	P	Q	R	S	Dummy	u _i
1	0 (40)	15 (30)	25	35	95	0
2	20	30 (20)	35 (20)	45	95	15
3	25	50	45 (40)	55 (50)	95	25
4	35	55	55	65 (10)	95 (20)	35
v _j	0	15	20	30	50	

$R + 1 - 1 = \text{Alloc}^n$
 $4 + 5 - 1 = 8$

Step III :- Final Ans $\Rightarrow$ 130

Ans no. 25

	I	II	III	IV	u_i
A	5	2	4	3	0
B	4	8	1	6	-3
C	4	6	3	5	3
v_j	1	2	4	3	

$R + (-1) = \text{Alloc}^n$
 $3 + 4 - 1 = 6$

Minimum of -0 ① ⑨
Add ① where there is +0 to alloc.
& deduct ① where there is -0

Step II :- Revised

	I	II	III	IV	u_i
A	5	2	4	3	0
B	4	8	1	6	-3
C	4	6	3	5	2
v_j	2	2	4	3	

Step III :- Final Ans.

$A \rightarrow II = 12 \times 2 = 24$
 $A \rightarrow III = 2 \times 4 = 8$
 $A \rightarrow IV = 8 \times 3 = 24$
 $B \rightarrow III = 15 \times 1 = 15$
 $C \rightarrow I = 7 \times 4 = 28$
 $C \rightarrow IV = 1 \times 5 = 5$

104

(59)

North-West

- (i) T-P (ii) Min. cost (iii) Balanced.

Step(I) :- Initial Soln

	S_1	S_2	Capacity
F_1	2 (50)	5	50/0
F_2	4 (25)	7 (25)	50/25/0
	75/25/0	25/0	100/100

Step (II) :-

Final Ans :-

$F_1 \rightarrow S_1 \quad 50 \times 2 = 100$

$F_2 \rightarrow S_1 \quad 25 \times 4 = 100$

$F_2 \rightarrow S_2 \quad 25 \times 7 = 175$
375

Least cost method

- (i) T-P (ii) Min. (iii) Bal.

	S_1	S_2	
F_1	2 (50)	5	50/0
F_2	4 (25)	7 (25)	50/0
	75/25/0	25/0	

(60)

Q.29 (i) NWCR method
(i) T-P (ii) Min. cost (iii) Balanced

Step I :- Initial Soln

	A	B	C	
X	3 (20)	9	6	20/0
Y	4 (20)	4 (20)	6	40/20/0
Z	8	3 (30)	5 (30)	60/30/0
	40/20/0	50/30/0	30	120/120

Final Ans

$$\begin{aligned} X \rightarrow A &= (20 \times 3) = 60 \\ Y \rightarrow A &= (20 \times 4) = 80 \\ Y \rightarrow B &= (20 \times 4) = 80 \\ Z \rightarrow B &= (30 \times 3) = 90 \\ Z \rightarrow C &= (30 \times 5) = 150 \\ &\underline{460} \end{aligned}$$

(ii) Least cost method (i) T-P (ii) Min. (iii) Bal.

	A	B	C	Qty Available
X	3 (20)	9	6	20/0
Y	4 (20)	4	6 (20)	40/20/0
Z	8	3 (50)	5 (10)	60/10/0
Qty demanded	40/20/0	50/0	30/20	120/120

Final Ans

$$\begin{aligned} X \rightarrow A &= (20 \times 3) = 60 \\ Y \rightarrow A &= (20 \times 4) = 80 \\ Y \rightarrow C &= (20 \times 6) = 120 \\ Z \rightarrow B &= (50 \times 3) = 150 \\ Z \rightarrow C &= (10 \times 5) = 50 \\ \hline &460 \end{aligned}$$

(iii) V.A.M. (i) T-P (ii) Min- (iii) Bal.

Step I :- Initial soln

	A	B	C	Total Demand	Penalty
X	3 (20)	9	6	20/0	3
Y	4 (20)	4	6 (20)	40/20/0	0/0/2
Z	8	3 (50)	5 (10)	60/10/0	2/2/2
Total Supply	10/20/0	50/0	30/0	120	120
Penalty	1/4	1/1	1/1		

Step II :- T.O.O.

(62)

	A	B	C	ui
X	3 (20)	9	6	0
Y	4 (20)	4	6 (20)	1
Z	8	3 (50)	5 (10)	2
uj	3	3	5	

$R + C - 1 = \text{All } a^n$

$3 + 3 - 1 = 5$

Step III :- Final Ans.

$X \rightarrow A = (20 \times 3) = 60$

$Y \rightarrow A = (20 \times 4) = 80$

$Y \rightarrow C = (20 \times 6) = 120$

$Z \rightarrow B = (50 \times 3) = 150$

$Z \rightarrow C = (10 \times 5) = 50$

460

Q.23

(i) T-P (ii) Max. (iii) Unbal.

Profit Matrix {S.P - (O.P - Shipping cost)}

	S ₁	S ₂	S ₃	S ₄	S ₅	
P ₁	30-20-1 = 10	32-20-1 = 11	31-20-5 = 6	34-20-9 = 5	29-20-4 = 5	150
P ₂	-1	3	1	9	1	200
P ₃	8	9	10	14	4	125
Demand	80	100	75	45	125	425 / 475

Step I:-

Loss Matrix Introducing S_6 (dummy column)

	S_1	S_2	S_3	S_4	S_5	S_6 (dummy)	Penalty
P_1	5 (50)	3 (100)	8	9	9	0	150/50 3/2
P_2	15	11	13	5 (45)	13 (105)	0 (50/5)	200/150 5/6
P_3	6 (30)	5	4 (75)	0	10 (20)	0	125/0 0/4 1/4
	80/30/0	100/0	75	45/0	125/0	50/0	475/425
Penalty	1 1 1 1/9	2 2 2	4 4	5 5	9 1 1 1/3	0	

Step II:- T, O, O

	S_1	S_2	S_3	S_4	S_5	S_6	u_i
P_1	5 (50)	3 (100)	8	9	9	0	
P_2	15	11	13	5 (45)	13 (105)	0 (50)	0 4
P_3	6 (30)	5	4 (75)	0	10 (20)	0	1
v_j	5	3	3	1	9	-4	

Min. of - θ

$45 - 20 = 25$ $105 + 20 = 125$ $0 + 20 = 20$ $20 - 20 = 0$

$R + C - 1$

$3 + 6 - 1 = 8$

(64)

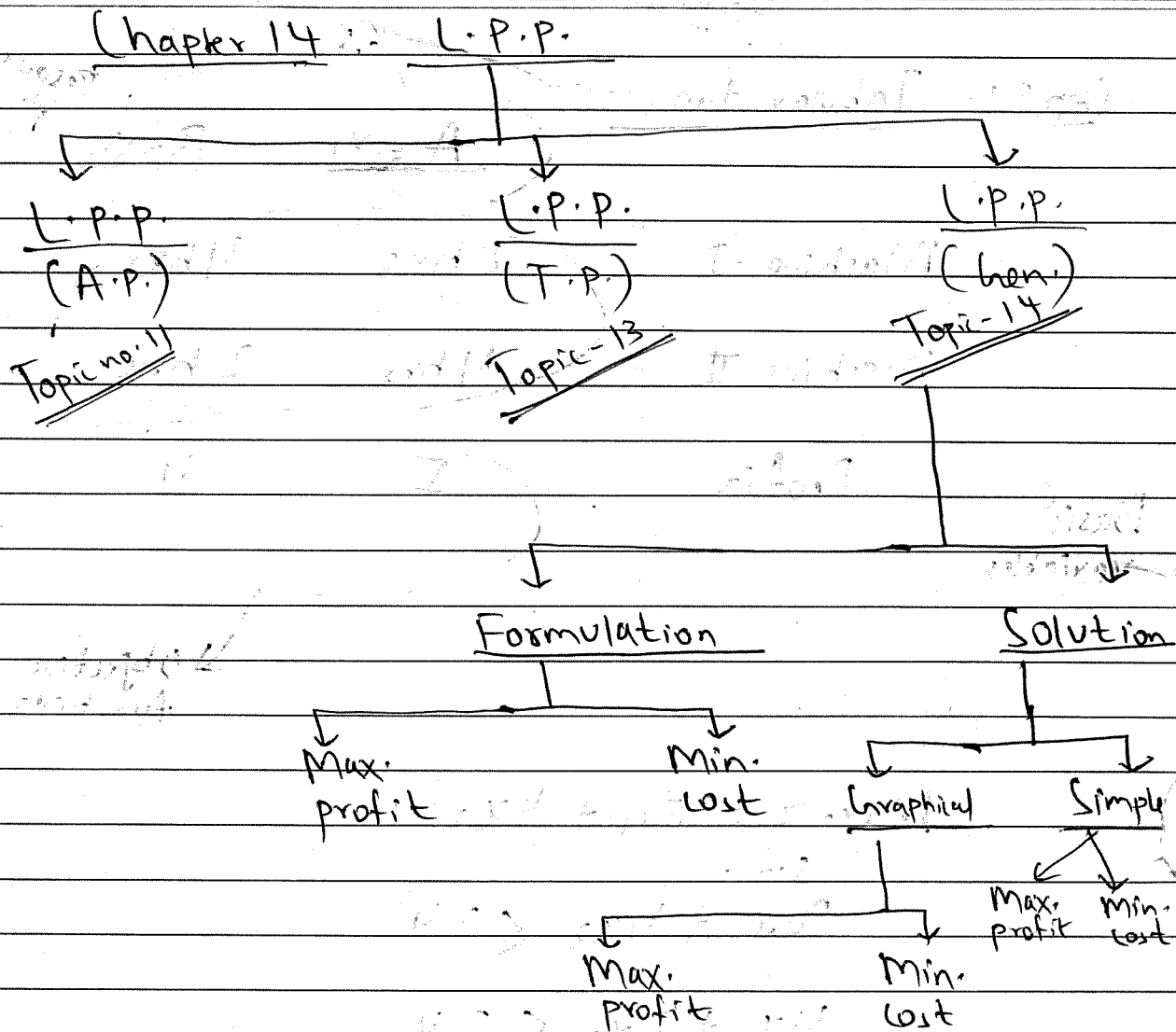
	S ₁	S ₂	S ₃	S ₄	S ₅	S ₆ Dummy	ui
P ₁	5 (50)	3 (100)	8 (5)	9 (10)	9 (2)	0 (6)	0
P ₂	15 (4)	11 (2)	3 (4)	25 (25)	125 (125)	0 (50)	6
P ₃	6 (30)	5 (1)	4 (75)	0 (20)	0 (2)	0 (5)	1
v _j	5	3	3	-1	7	-6	

Final Ans 6

~~$P_1 \rightarrow S_1 \quad (50 \times 9)$
 $P_1 \rightarrow S_2 \quad (100 \times 11)$
 $P_2 \rightarrow S_4 \quad (25 \times 9)$
 $P_2 \rightarrow S_5 \quad (125 \times 1)$
 $P_2 \rightarrow S_6 \quad (50 \times 0)$
 $P_3 \rightarrow \text{Dummy} \quad (30 \times 8) = 0$
 $P_3 \rightarrow S_1 \quad (30 \times 8) = 240$
 $P_3 \rightarrow S_3 \quad (75 \times 10) = 750$
 $P_3 \rightarrow S_4 \quad (20 \times 14) = 280$~~

$P_1 \rightarrow S_1 \quad (50 \times 9) = 450$
 $P_1 \rightarrow S_2 \quad (100 \times 11) = 1100$
 $P_2 \rightarrow S_4 \quad (25 \times 9) = 225$
 $P_2 \rightarrow S_5 \quad (125 \times 1) = 125$
 $P_2 \rightarrow \text{Dummy} \quad (50 \times 0) = 0$
 $P_3 \rightarrow S_1 \quad (30 \times 8) = 240$
 $P_3 \rightarrow S_3 \quad (75 \times 10) = 750$
 $P_3 \rightarrow S_4 \quad (20 \times 14) = 280$
3170

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* Meaning of Formulation

If we put all the given info into equation form, it is known as formulation.

* Steps for solving the sum

Step I - Tabular form

Step II - Formulation

Example I

Step 1:- Tabular form

	Products		Resource
	<u>A = x_1</u>	<u>B = x_2</u>	<u>Max. hrs</u>
Machine - I	2 hrs	4 hrs	24
Machine - II	4 hrs	2 hrs	24
Profit	5	4	

Basic Variables

Objective function

$$\text{Max. } Z = 5x_1 + 4x_2$$

s.t.

$$2x_1 + 4x_2 \leq 24$$

$$4x_1 + 2x_2 \leq 24$$

$$x_1, x_2 \geq 0$$

Q.38

Step 1:- Tabular form

	<u>P₁ = x_1</u>	<u>P₂ = x_2</u>	<u>Max. hrs</u>
M ₁	2 hrs	5 hrs	16
M ₂	6 hrs	—	30
Profit	2	10	

(67)

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$$\text{Max. } z = 2x_1 + 10x_2$$

s.t.

$$2x_1 + 5x_2 \leq 16$$

$$6x_1 + 0x_2 \leq 30$$

$$x_1, x_2 \geq 0$$

Q-39

	<u>A</u>	<u>B</u>	<u>Max. hrs</u>
M_1	1 min	1 min	450 hrs
M_2	2 mins	1 min	600 max
Profit	1 3	4	

$$\text{Max. } z = 3x_1 + 4x_2$$

s.t.

$$1x_1 + 1x_2 \leq 450$$

$$2x_1 + 1x_2 \leq 600$$

$$x_1, x_2 \geq 0$$

Q-40

	<u>X</u>	<u>Y</u>	<u>Max. hrs</u>
M_1	2	1	70 hrs
M_2	1	1	40 hrs
M_3	1	3	90 hrs
Profit	50	30	(68)

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$$\text{Max. } z = 50x_1 + 30x_2$$

s.t.

$$2x_1 + x_2 \leq 70$$

$$1x_1 + 1x_2 \leq 40$$

$$1x_1 + 3x_2 \leq 90$$

$$x_1, x_2 \geq 0$$

Q.37

	<u>x_1</u>	<u>x_2</u>	
Weight	4 gms	5 gms	≤ 40
protein	2 gms	1 gm	≥ 10
Cost	30	10	

$$\text{Min. } (z) = 30x_1 + 10x_2$$

s.t.

$$4x_1 + 5x_2 \leq 40$$

$$2x_1 + 1x_2 \geq 10$$

$$x_1, x_2 \geq 0$$

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Q.50

	<u>A</u>	<u>B</u>	<u>Max. hrs</u>
Hobbing m/c	3	3	36
Shaping m/c	5	2	60
Grinding m/c	2	6	60

S.P	820	960
(-) V.C	(780)	(900)
Cont ⁿ	<u>40</u>	<u>60</u>

$$\text{Max.}(z) = 4x_1 + 60x_2$$

s.t.

$$3x_1 + 3x_2 \leq 36$$

$$5x_1 + 2x_2 \leq 60$$

$$2x_1 + 6x_2 \leq 60$$

$$x_1, x_2 \geq 0$$

Q.45

	<u>A</u>	<u>B</u>	<u>Max. qty</u>
P	16	20	160
Q	10	25	150
R	<u>4</u>	<u>0</u>	32
Cont ⁿ	240	140	<u>200</u>

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$$\text{Max. } z = 240x_1 + 140x_2 - 1200$$

s.t.

$$16x_1 + 20x_2 \leq 160$$

$$10x_1 + 25x_2 \leq 150$$

$$4x_1 + 0x_2 \leq 32$$

$$x_1, x_2 \geq 0$$

Q.46

	<u>D₁</u>	<u>D₂</u>	<u>Max. m</u>
R ₁	2	5	16
R ₂	6	-	30
Profit margin	<u>2</u>	<u>10</u>	

$$\text{Max. } z = 2x_1 + 10x_2$$

s.t.

$$2x_1 + 5x_2 \leq 16$$

$$6x_1 + 0x_2 \leq 30$$

$$x_1, x_2 \geq 0$$

(71)

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Q.47

	<u>A</u>	<u>B</u>	<u>Total hrs available</u>
Dept P	2	4	1400
Dept Q	5	4	2000
S.P	300	200	
V.C	(160)	(60)	
Sales commission	(60)	(40)	
Contribution	<u>80</u>	<u>100</u>	Fixed costs 14000 + 20000

$$\text{Max.}(z) = 80x_1 + 100x_2 - 34000$$

s.t.

$$2x_1 + 4x_2 \leq 1400$$

$$5x_1 + 4x_2 \leq 2000$$

$$x_1, x_2 \geq 0$$

Q.49

	<u>y_1</u>	<u>y_2</u>	<u>y_3</u>	
x_1	$30 \times \frac{1}{2}$ $= 15$	$30 \times \frac{3}{7}$ $= 12.86$	30×0 $= 0$	20 kg
x_2	$50 \times \frac{1}{4}$ $= 12.5$	$50 \times \frac{2}{7}$ $= 14.29$	$50 \times \frac{2}{3}$ $= 33.33$	15 kg
x_3	$120 \times \frac{1}{4}$ $= 30$	$120 \times \frac{2}{7}$ $= 34.29$	$120 \times \frac{1}{3}$ $= 40$	15 kg
T. cost	57.5	61.44	73.33	
Profit	<u>32.5</u>	<u>38.56</u>	<u>46.67</u>	
S.P	90	100	120	

$$\text{Max. } Z = 32.5y_1 + 38.56y_2 + 46.67y_3$$

s.t.

$$\frac{1}{2}y_1 + \frac{3}{7}y_2 \leq 20$$

$$\frac{1}{4}y_1 + \frac{2}{7}y_2 + \frac{2}{3}y_3 \leq 15$$

$$\frac{1}{4}y_1 + \frac{2}{7}y_2 + \frac{1}{3}y_3 \leq 15$$

$$y_1, y_2, y_3 \geq 0$$

Q.42

(73)

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	A = x ₁	B = x ₂	Min. cost
X	36	6	108
Y	3	12	36
Z	20	10	100
Cost	20	40	

Min. (z) = 20x₁ + 40x₂
s.t.

36x₁ + 6x₂ ≥ 108

3x₁ + 12x₂ ≥ 36

20x₁ + 10x₂ ≥ 100

x₁, x₂ ≥ 0

Q.44

	x ₁	x ₂	x ₃	x ₄	x ₅	x ₆	De
1"	6	0	1	0	0	4	3000
2"	3	3	1	0	4	2	2000
3"	0	2	1	2	1	1	1500
5"	0	0	1	1	0	0	1000
Waste	0	0	1	1	1	1	

$$\text{Max. (Z)} = 0x_1 + 0x_2 + 1x_3 + 1x_4 + 1x_5 + 1x_6$$

s.t.

$$6x_1 + 0x_2 + 1x_3 + 0x_4 + 0x_5 + 4x_6 \leq 3000$$

$$3x_1 + 3x_2 + 1x_3 + 0x_4 + 4x_5 + 2x_6 \leq 2000$$

$$0x_1 + 2x_2 + 1x_3 + 2x_4 + 1x_5 + 1x_6 \leq 1500$$

$$0x_1 + 0x_2 + 1x_3 + 1x_4 + 0x_5 + 0x_6 \leq 1000$$

$$x_1, x_2, x_3, x_4, x_5, x_6 \geq 0$$

Q.43

	M	F	D	Max. hrs.
Machining	15	12	14	3000 hrs
Assembly	4	3	5	1200 hrs
S.P	4100	7500	14600	
(-) V.C.	(2500)	(4500)	(9000)	Fixed cost
Contri	1600	3000	5600	13200
Minimum	2		8	

Cash A/c

To Op. bal.	140000	By Loan	40000
To Drs.	50000	By Salary	10000
		By Int.	2000
		(100000 x 24% x 1/2)	
		By Int. - TNC & Loan Bank	1200
			136800
	190000		190000

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$$\text{Max. } (z) = 1600x_1 + 3000x_2 + 5600x_3 - 13200$$

s.t.

$$2500x_1 + 4500x_2 + 9000x_3 \leq 136800$$

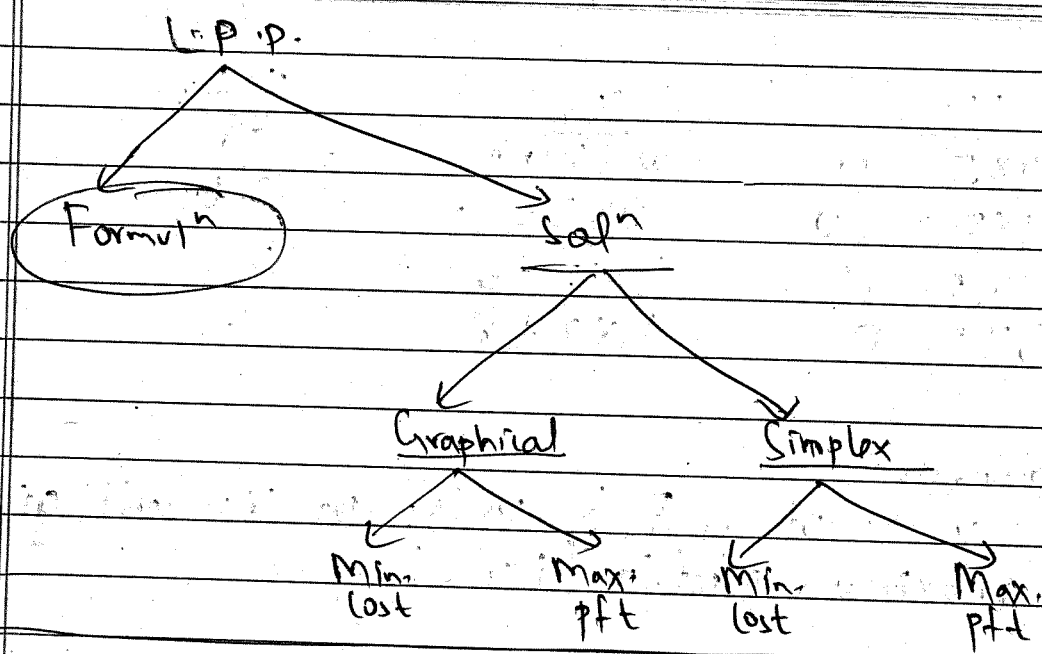
$$15x_1 + 12x_2 + 14x_3 \leq 3600$$

$$4x_1 + 3x_2 + 5x_3 \leq 1200$$

$$x_1, x_2 \geq 2$$

$$x_3 \geq 8$$

$$x_1, x_2, x_3 \geq 0$$



GRAPHICAL METHOD
Tabular form

~~Example (1)~~ Step (1)

	<u>A = x_1</u>	<u>B = x_2</u>	<u>Max. hrs</u>
M_1	2	6	24
M_2	6	2	24
Pft	5	2	

$$\text{Max. } Z = 5x_1 + 2x_2$$
$$\text{s.t.}$$
$$2x_1 + 6x_2 \leq 24$$
$$6x_1 + 2x_2 \leq 24$$
$$x_1, x_2 \geq 0$$

Soln

$2x_1 + 6x_2 = 24$	$6x_1 + 2x_2 = 24$
$x_1 = 0, x_2 = 4$	$x_1 = 0, x_2 = 12$
$x_1 = 12, x_2 = 0$	$x_1 = 4, x_2 = 0$

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	x_1	x_2	Total
(a)	$0 \times 5 = 0$	$0 \times 2 = 0$	0
(b)	$4 \times 5 = 20$	$0 \times 2 = 0$	20
(c)	$3 \times 5 = 15$	$3 \times 2 = 6$	21
(d)	$0 \times 5 = 0$	$4 \times 2 = 8$	8

Comments

3 units of x_1 & 3 units of x_2 will give the maximum profit (i.e. 21)

Verification (Not for exam)

$$3 \times (2x_1 + 6x_2) = 24$$

$$6x_1 + 2x_2 = 24$$

$$6x_1 + 18x_2 = 72$$

$$16x_2 = 48$$

$$\therefore \boxed{x_2 = 3}$$

$$\therefore 2x_1 + 18 = 24$$

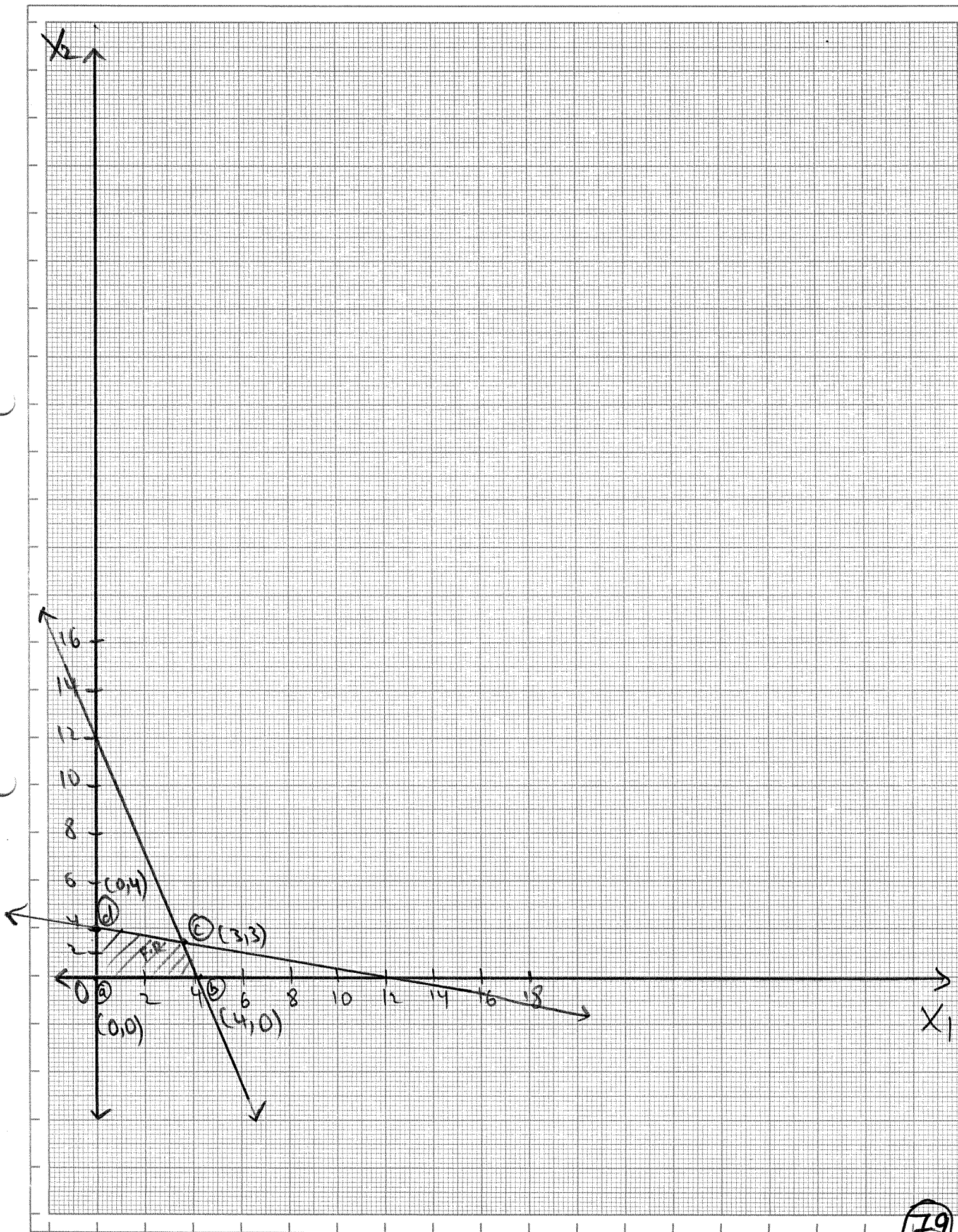
$$\therefore 2x_1 = 6$$

$$\therefore \boxed{x_1 = 3}$$



Example (1)

SCALE :-



Example 2

	A = x_1	B = x_2	Max hrs
m_1	4	2	60
m_2	2	4	48
Profit	80	60	

$$\text{Max. (Z)} = 80x_1 + 60x_2$$

s.t.

$$4x_1 + 2x_2 \leq 60$$

$$2x_1 + 4x_2 \leq 48$$

$$x_1, x_2 \geq 0$$

Soln

$$4x_1 + 2x_2 = 60$$

$$x_1 = 0 ; x_2 = 30$$

$$x_1 = 15 ; x_2 = 0$$

$$2x_1 + 4x_2 = 48$$

$$x_1 = 0 ; x_2 = 12$$

$$x_1 = 24 ; x_2 = 0$$

	A = x_1	B = x_2	Total
(a)	$0 \times 80 = 0$	$0 \times 60 = 0$	0
(b)	$16 \times 80 =$	$0 \times 60 = 0$	1280
(c)	$12 \times 80 = 960$	$6 \times 60 = 360$	1320
(d)	$0 \times 80 = 0$	$12 \times 60 = 720$	720

(80)

Comments :- 12 units of x_1 & 6 units of x_2 will give max. profit (i.e. ₹1320)

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Q.42

Step no (i) Tabular form

Products	A = x_1	B = x_2	Max. time
P	2	4	1400
Q	5	4	2000
S.P (p.u.)	300	200	
V.P (p.u.)	(160)	(60)	
Sales commission	(60)	(40)	
	80	100	Fixed cost (14000 + 20000) = 34000
Max. units	400	400	

$$\text{Max. (Z)} = 80x_1 + 100x_2 - 34000$$

s.t.

$$2x_1 + 4x_2 \leq 1400$$

$$5x_1 + 4x_2 \leq 2000$$

$$x_1 \leq 400$$

$$x_2 \leq 400$$

$$2x_1 + 4x_2 = 1400$$

$$5x_1 + 4x_2 = 2000$$

$$x_1 = 0 ; x_2 = 350$$

$$x_1 = 0 ; x_2 = 500$$

$$x_1 = 700 ; x_2 = 0$$

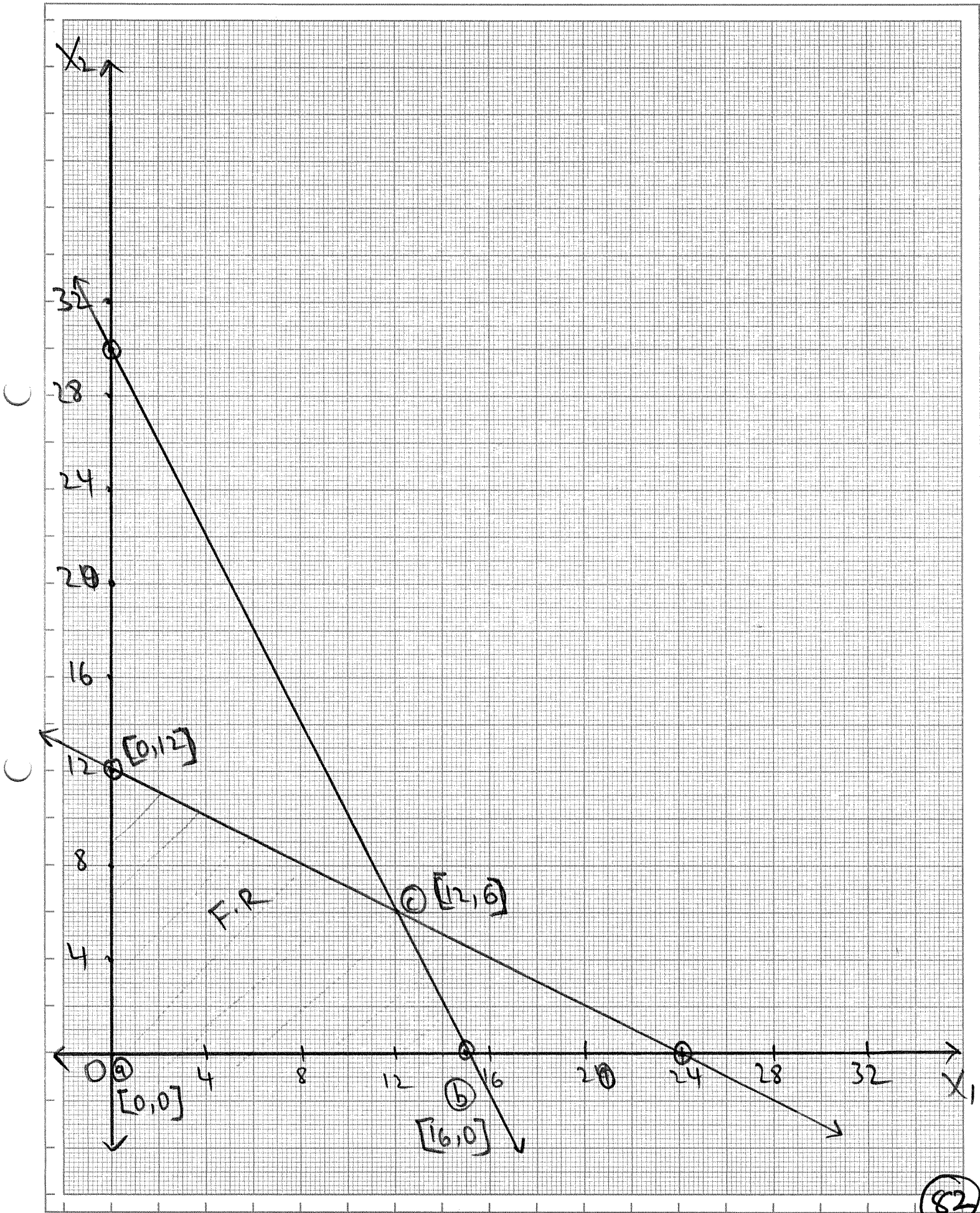
$$x_1 = 400 ; x_2 = 0$$

(81)



Example 2

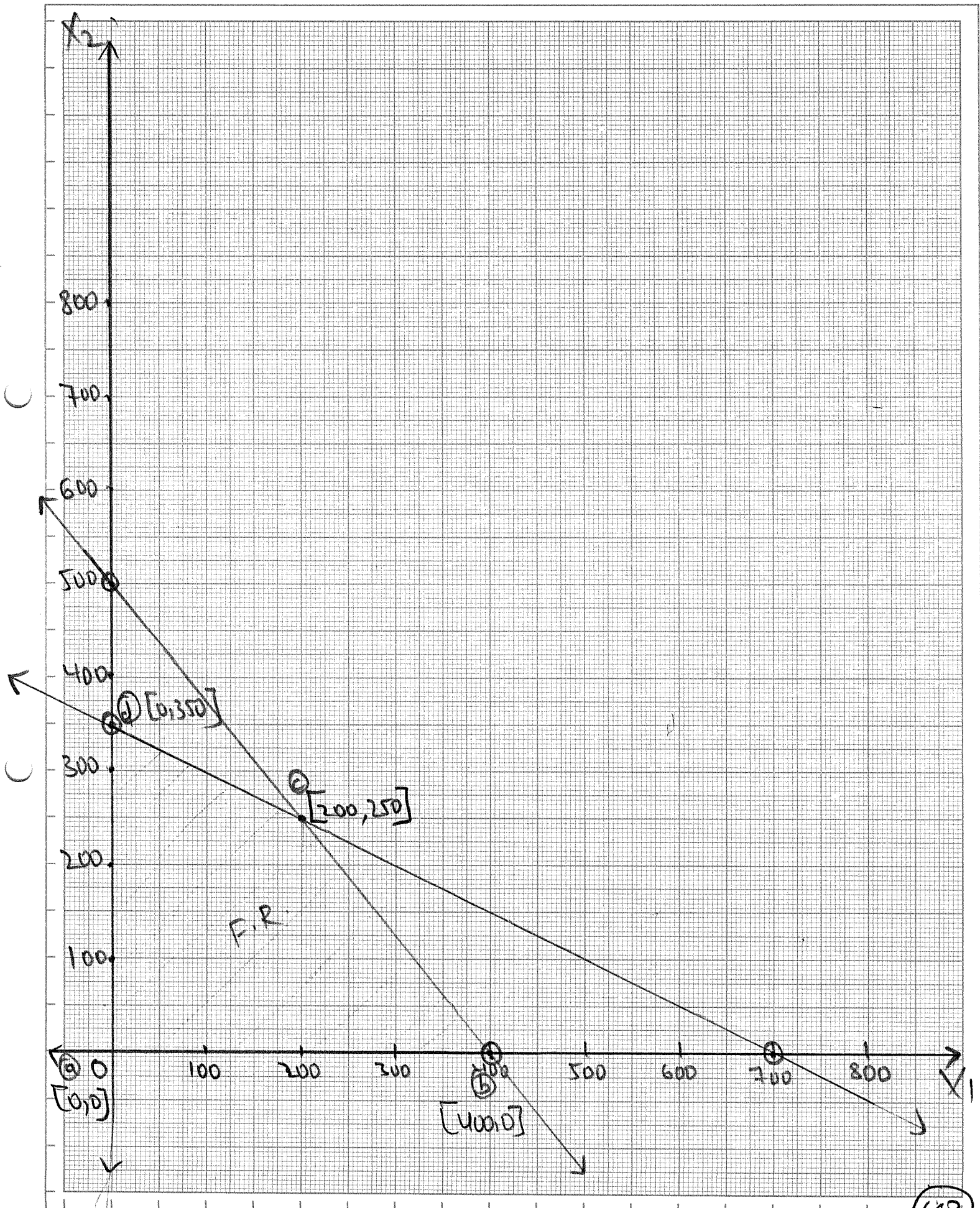
SCALE :-





Q.47

SCALE :-



	<u>A = x₁</u>	<u>B = x₂</u>	<u>Total Contⁿ</u>
(a)	0 x 80	0 x 80 100	0
(b)	400 x 80	0 x 100	32000
(c)	200 x 80	250 x 100	^{highest} 41000
(d)	0 x 80	350 x 100	35000

Contⁿ - F - C = Profit
41000 - 34000 = 7000 ✓

Q.42

Step 1 : Tabular form

	<u>A = x₁</u>	<u>B = x₂</u>	<u>Min.</u>
X	36	6	108
Y	3	12	36
Z	20	10	100
<u>Min. cost</u>	<u>20</u>	<u>40</u>	

Min. (z) = 20x₁ + 40x₂

s.t.

36x₁ + 6x₂ ≥ 108

3x₁ + 12x₂ ≥ 36

20x₁ + 10x₂ ≥ 100

x₁, x₂ ≥ 0

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$36x_1 + 6x_2 = 108$

$x_1 = 0 ; x_2 = 18$

$x_1 = 30 ; x_2 = 0$

$3x_1 + 12x_2 = 36$

$x_1 = 0 ; x_2 = 3$

$x_1 = 12 ; x_2 = 0$

$20x_1 + 10x_2 = 100$

$x_1 = 0 ; x_2 = 10$

$x_1 = 5 ; x_2 = 0$

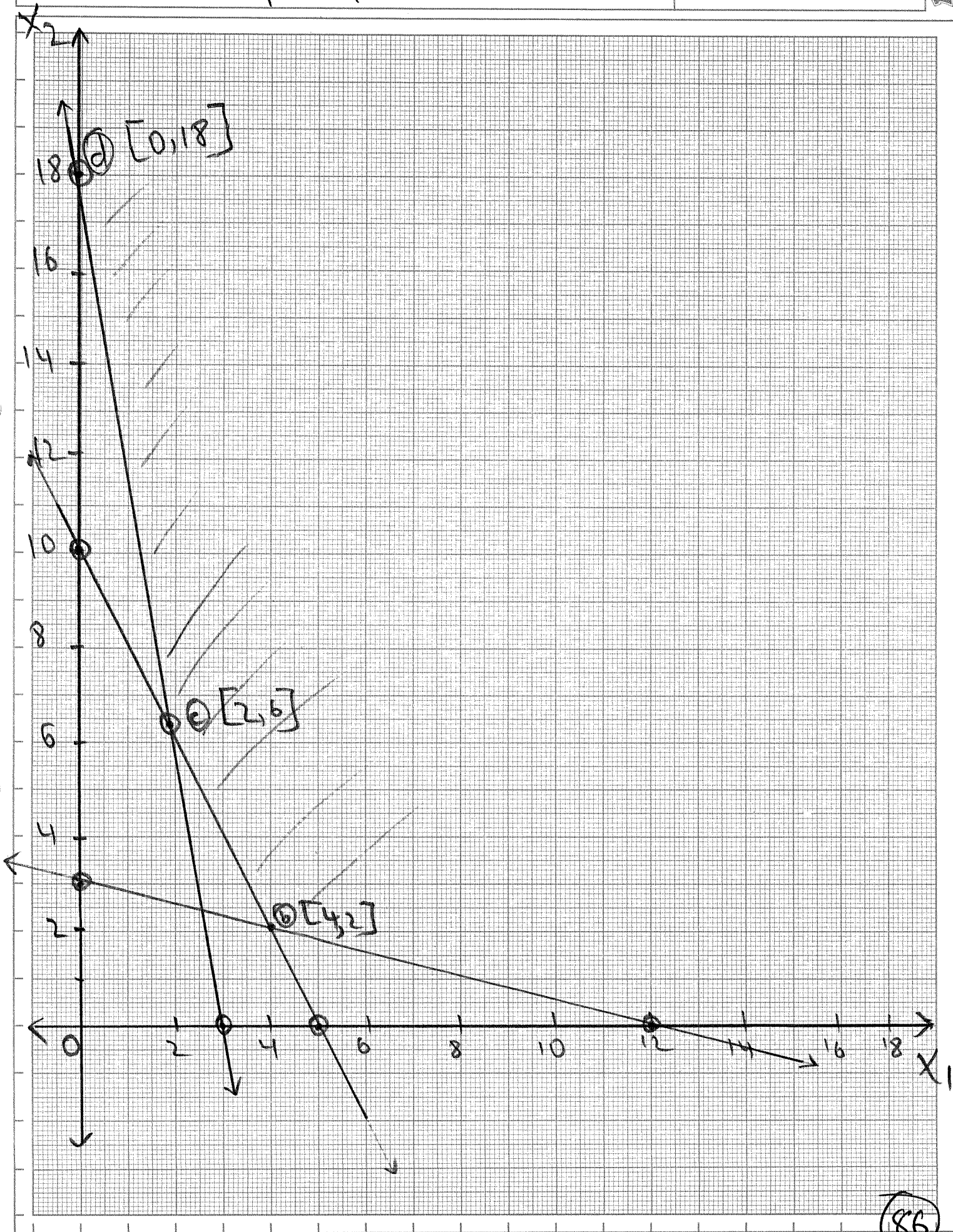
Soln

	<u>x_1</u>	<u>x_2</u>	<u>Total</u>
a	12×20	0×40	240
b	4×20	2×40	160
c	2×20	6×40	280
d	0×20	18×40	720



Example - 42

SCALE :-



SIMPLEX METHODQ.46Step 1 :- Tabular form

	<u>$D_1 = x_1$</u>	<u>$D_2 = x_2$</u>	<u>Max. hrs</u>
R_1	2	5	16
R_2	6	0	30
Profit	2	10	

$$\text{Max. } (z) = 2x_1 + 10x_2$$

s.t.

$$2x_1 + 5x_2 \leq 16$$

$$6x_1 + 0x_2 \leq 30$$

$$x_1, x_2 \geq 0$$

Introducing slack variable so that the eqⁿ be rewritten as :-

$$\text{Max. } (z) = 2x_1 + 10x_2 + 0S_1 + 0S_2$$

s.t.

$$2x_1 + 5x_2 + S_1 = 16$$

$$6x_1 + 0x_2 + S_2 = 30$$

Simplex Table

Fixed Ratio	Profit	Program	Qty	(Cj)	2	10	0	0	Replacement ratio
					x ₁	x ₂	s ₁	s ₂	
—	0	s ₁ → 16	16	2	5	1	0	0	16 ÷ 5 = 16/5 outgoing variable
0/5 = 0	0	s ₂	30	6	0	0	1	0	30 ÷ 0 = ∞
				(Zj)	0	0	0	0	
					(0x2 + 0x6)	(0x5 + 0x0)	(0x1 + 0x0)	(0x0 + 0x1)	
		N.E.R.	(Cj - Zj)	2	10	0	0	0	
						↑ (Incoming variable)			
10	x ₂	16/5	16/5	2/5	1	1/5	0/5	0	
0	s ₂	30	30	6	0	0	1	0	
				(Zj)	4	10	2	0	
					(10x2/5 + 0x6)	(10x1 + 0x0)	(10x1/5 + 0x0)	(10x0/5 + 0x1)	
		N.E.R.		-2	0	-2	0	0	

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Working notePg (2) - WN-1 - S₂

Other than - $\left(\begin{matrix} \text{Fixed} \\ \text{Ratio} \end{matrix} \times \begin{matrix} \text{K.F} \\ \text{Row} \end{matrix} \right)$
K.F Row

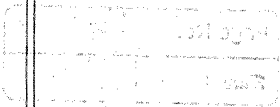
$$30 - (0 \times 16) = 30$$

$$6 - (0 \times 2) = 6$$

$$0 - (0 \times 5) = 0$$

$$0 - (0 \times 1) = 0$$

$$1 - (0 \times 0) = 1$$



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Final Ans.

<u>Product</u>	<u>Units</u>	<u>X</u>	<u>pft p-u.</u>	<u>Total profit</u>
X ₂	16 5	X	10	= (32) ✓

(90)

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My notes - Simplex
1.A. Tabular form
1.B. Formable eqⁿ

2.

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Q41SimplexIntroducing slack Variable

$$\text{Max. (z)} = 3x_1 + 4x_2 + 0 \cdot S_1 + 0 \cdot S_2$$

s.t.

$$2x_1 + 3x_2 + S_1 = 16$$

$$4x_1 + 2x_2 + S_2 = 16$$

(92)

Simplex Table

Fixed Ratio	Profit	Program	(C _j) Qty	X ₁	X ₂	S ₁	S ₂	key factor	Rep. Ratio
-	0	S ₁	16	2	(3)	1	0		16/3 → Outgoing Variable
2/3	0	S ₂	16	4	2	0	1		16/2 = 8
			(C _j)	0	0	0	0		
			N.F.R. (C _j - Z _j)	3	4	0	0		
					↑ Incoming variable				
2/3 ÷ 8/3 = 1/4	4	X ₂	16/3	2/3	1	1/3	0		16/3 ÷ 2/3 = 8
-	0	S ₂	16/3	(8/3)	0	-2/3	1		16/3 ÷ 8/3 = 2 → Outgoing Variable
			(Z _j)	8/3	4	4/3	0		
			N.F.R. (C _j - Z _j)	1/3	0	-4/3	0		
					↑ Incoming Variable				
	4	X ₂	4	0	1	1/2	-1/4		
	3	X ₁	2	1	0	-1/4	3/8		
			Z _j	3	4	5/4	1/8		
			N.F.R.	0	0	-5/4	-1/8		

Working notesNote no. (i) $S_2 \rightarrow$ Other than K.F. row - ($\frac{\text{Fixed}}{\text{ratio}} \times \text{Key factor row}$)

$$16 - \left(\frac{2}{3} \times 16 \right) = \frac{16}{3}$$

$$4 - \left(\frac{2}{3} \times 2 \right) = \frac{8}{3}$$

$$2 - \left(\frac{2}{3} \times 3 \right) = 0$$

$$0 - \left(\frac{2}{3} \times 1 \right) = -\frac{2}{3}$$

$$1 - \left(\frac{2}{3} \times 0 \right) = 1$$

Note no. 2 X_2 Other than K.F. row - ($\frac{\text{Fixed}}{\text{ratio}} \times \text{K.F. row}$)

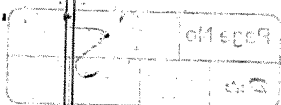
$$\frac{16}{3} - \left(\frac{1}{4} \times \frac{16}{3} \right) = \frac{16}{3} - \frac{16}{12} = 4$$

$$\frac{2}{3} - \left(\frac{1}{4} \times \frac{8}{3} \right) = \frac{2}{3} - \frac{8}{12} = 0$$

$$1 - \left(\frac{1}{4} \times 0 \right) = 1 - 0 = 1$$

$$\frac{1}{3} - \left(\frac{1}{4} \times \frac{2}{3} \right) = \frac{1}{3} - \frac{2}{12} = \frac{1}{4}$$

$$0 - \left(\frac{1}{4} \times 1 \right) = -\frac{1}{4}$$



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* Concept of Primal v/s Dual

Q.41

$$\begin{aligned} \text{Max. (z)} &= 3x_1 + 4x_2 \\ \text{s.t. } 2x_1 + 3x_2 &\leq 16 \\ 4x_1 + 2x_2 &\leq 16 \\ x_1, x_2 &\geq 0 \end{aligned} \quad \left. \vphantom{\begin{aligned} \text{Max. (z)} &= 3x_1 + 4x_2 \\ \text{s.t. } 2x_1 + 3x_2 &\leq 16 \\ 4x_1 + 2x_2 &\leq 16 \\ x_1, x_2 &\geq 0 \end{aligned}} \right\} \text{Primal}$$

$$\begin{aligned} \text{Min. (z)} &= 16y_1 + 16y_2 \\ \text{s.t. } 2y_1 + 4y_2 &\geq 3 \\ 3y_1 + 2y_2 &\geq 4 \\ y_1, y_2 &\geq 0 \end{aligned} \quad \left. \vphantom{\begin{aligned} \text{Min. (z)} &= 16y_1 + 16y_2 \\ \text{s.t. } 2y_1 + 4y_2 &\geq 3 \\ 3y_1 + 2y_2 &\geq 4 \\ y_1, y_2 &\geq 0 \end{aligned}} \right\} \text{Dual}$$

Q.42

$$\begin{aligned} \text{Max. (z)} &= 100x_1 + 90x_2 + 40x_3 + 60x_4 \\ \text{s.t. } 6x_1 + 4x_2 + 8x_3 + 4x_4 &\leq 140 \\ 10x_1 + 10x_2 + 2x_3 + 6x_4 &\leq 120 \\ 10x_1 + 12x_2 + 6x_3 + 2x_4 &\leq 50 \\ x_1, x_2, x_3 &\geq 0 \end{aligned} \quad \left. \vphantom{\begin{aligned} \text{Max. (z)} &= 100x_1 + 90x_2 + 40x_3 + 60x_4 \\ \text{s.t. } 6x_1 + 4x_2 + 8x_3 + 4x_4 &\leq 140 \\ 10x_1 + 10x_2 + 2x_3 + 6x_4 &\leq 120 \\ 10x_1 + 12x_2 + 6x_3 + 2x_4 &\leq 50 \\ x_1, x_2, x_3 &\geq 0 \end{aligned}} \right\} \text{Primal}$$

Soln

$$\begin{aligned} \text{Min. (z)} &= 140y_1 + 120y_2 + 50y_3 \\ \text{s.t. } 6y_1 + 10y_2 + 10y_3 &\geq 100 \\ 4y_1 + 10y_2 + 12y_3 &\geq 90 \end{aligned}$$

(95)

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Final ans.

Products Units x Pft p.u. = Total Pft
X₁ 2 x 3 = 6

X₂ 4 x 4 = 16

22

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$$8y_1 + 2y_2 + 6y_3 \geq 40$$

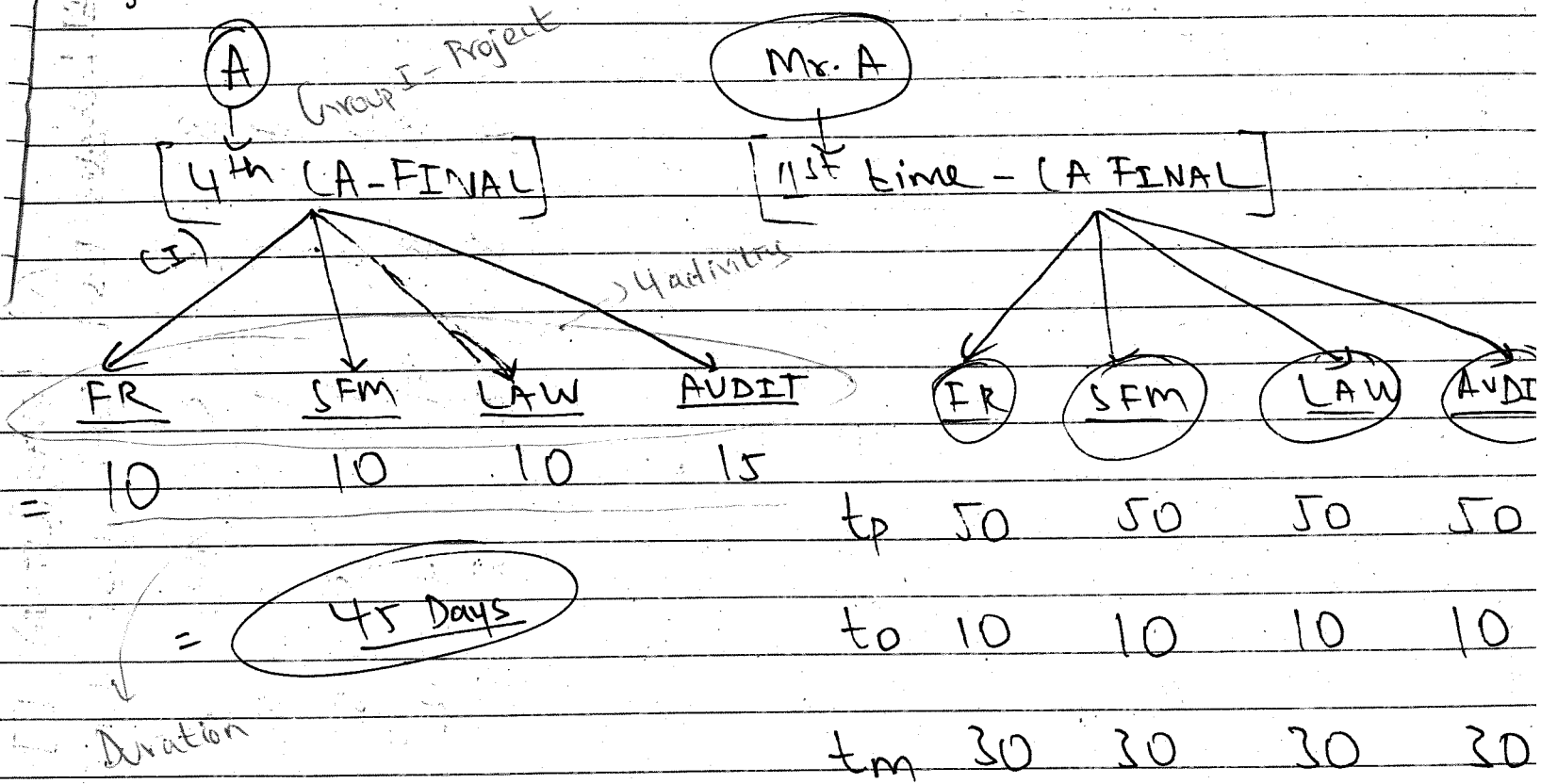
$$4y_1 + 6y_2 + 2y_3 \geq 60$$

$$y_1, y_2, y_3 \geq 0$$

Meaning of C.P.M. (Critical Path method)

A path is having a longest duration - known as critical path. It is also known as project completion time.

e.g.

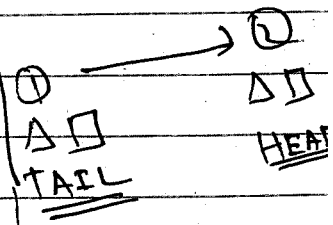


C.P.M :- You know the duration

P.E.R.T :- You have to find out the duration

△ :- Earliest Start Time (EST) → (maximum)

□ :- Latest Finish Time (LFT) → (minimum)



* Meaning of Network

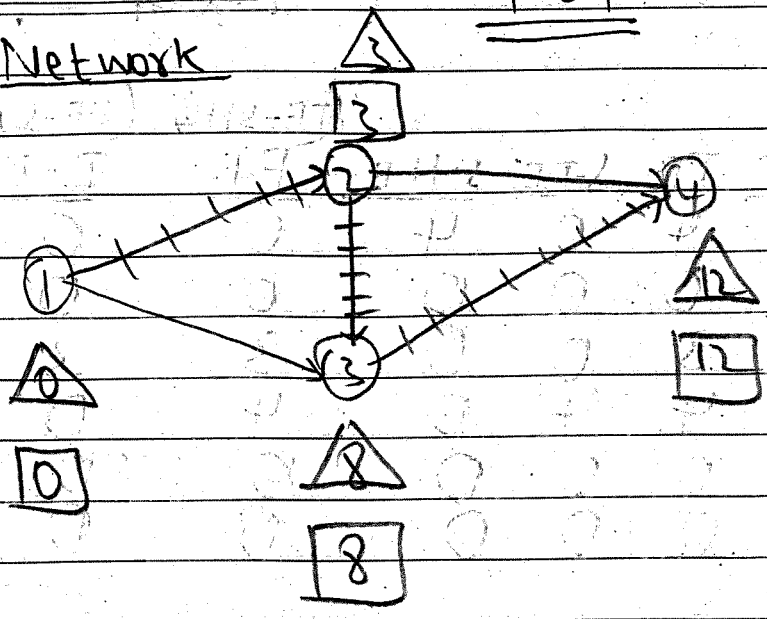
It is a graphical presentation which starts from left & goes to right.

ACTIVITY	Duration	Δ E.S.T	(EST+D) E.F.T	(LFT-D) L.S.T	$\square$ L.F.T	(LST-EST) Total Float	S.T.E	S.H.E.T.F.S.H.E.F.F.S.T.E	Free Float	Indep Float
1-2	3	0	3	0	3	0	0	0	0	0
1-3	7	0	7	1	8	1	0	0	1	0
2-3	5	3	8	3	8	0	0	0	0	0
2-4	8	3	11	4	12	1	0	0	1	0
3-4	4	8	12	8	12	0	0	0	0	0

Q. 51

Pg 3

* Network



Critical path

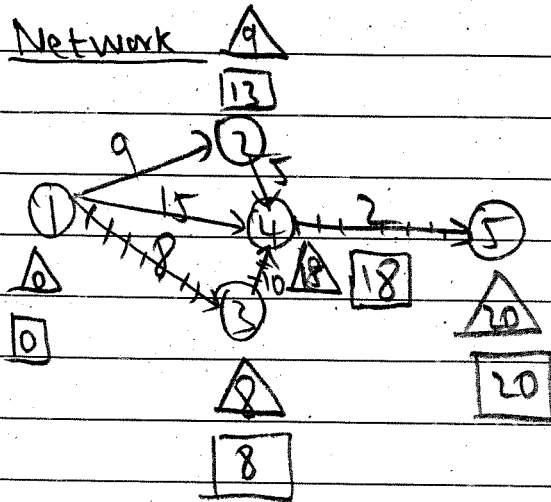
1-2-4 = 11

1-2-3-4 = 12

1-3-4 = 11

Q.52

Activity	D	Δ EST	EFT	LST	$\square$ LFT	TF	C.T.E.	S.H.E.	(TF-SHE) F.F.	(FF-LTE) I.F.
1-2	9	0	9	4	13	4	0	4	0	0
<u>1-3</u>	8	0	8	0	8	<u>0</u>	0	0	0	0
1-4	15	0	15	3	18	3	0	0	3	3
2-4	5	9	14	13	18	4	4	0	4	0
<u>3-4</u>	10	8	18	8	18	<u>0</u>	0	0	0	0
<u>4-5</u>	2	18	20	18	20	<u>0</u>	0	0	0	0



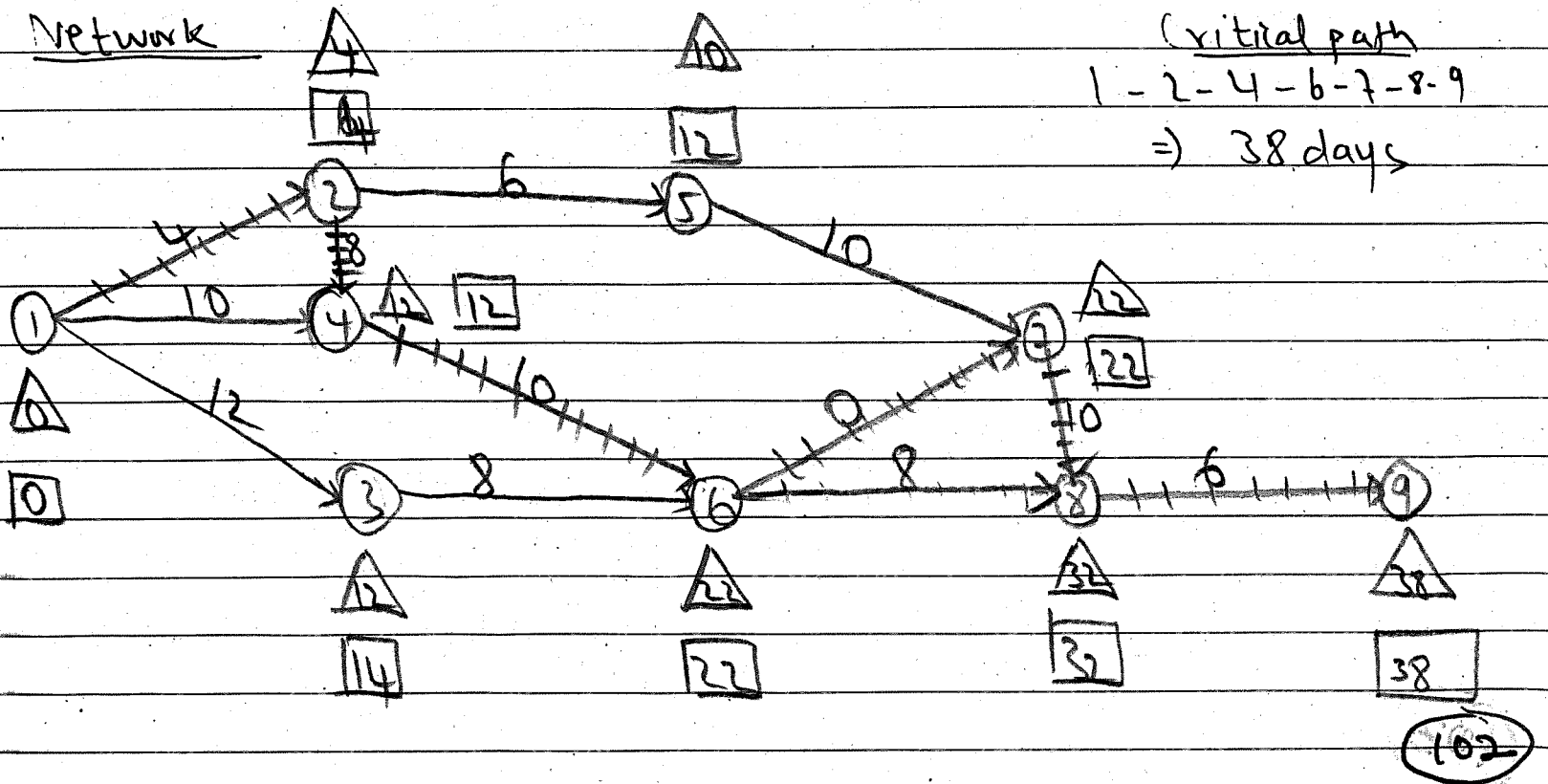
Critical path

$$1-3-4-5 = 20$$

Q.53

Activity	D	<u>EFT</u>	<u>EST</u>	<u>LST</u>	<u>LFT</u>	<u>TF</u>	<u>LT</u>	<u>SH</u>	<u>FF</u>	<u>IF</u>
1-2	4	4	0	0	4	0	0	0	0	0
1-3	12	12	0	2	14	2	0	2	0	0
1-4	10	10	0	2	12	2	0	0	2	2
2-4	8	12	4	4	12	0	0	0	0	0
2-5	6	10	4	6	12	2	0	2	0	0
3-6	8	20	12	14	22	2	2	0	2	0
4-6	10	22	12	12	22	0	0	0	0	0
5-7	10	20	10	12	22	2	2	0	2	0
6-7	0	22	22	22	22	0	0	0	0	0
6-8	8	30	22	24	32	2	0	0	2	2
7-8	10	32	22	22	32	0	0	0	0	0
8-9	6	38	32	32	38	0	0	0	0	0

Network



g(6)

* P.E.R.T.

$$\text{Exp. Duration} = \left(\frac{t_o + 4t_m + t_p}{6} \right)$$

$$\text{Variance} = \left(\frac{t_p - t_o}{6} \right)^2$$

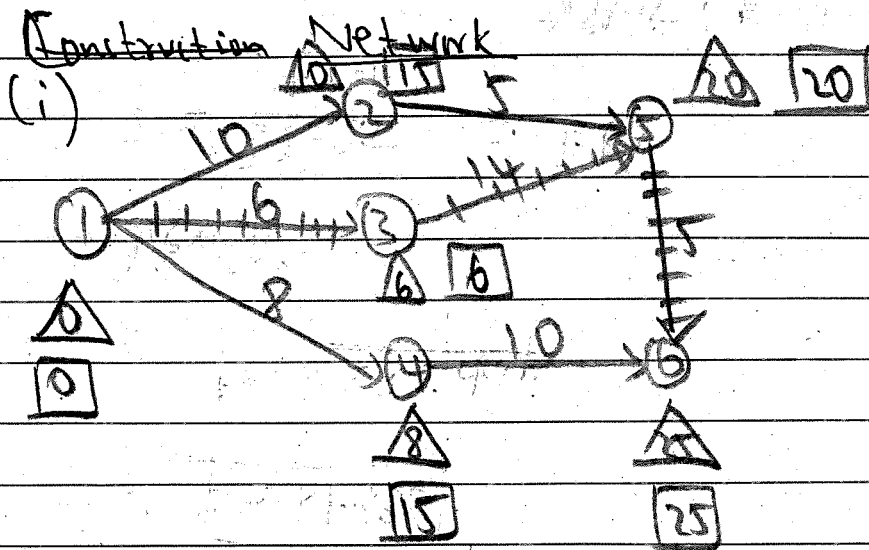
$$\text{S.D.} = \sqrt{\text{Variance}}$$

Use of 'z' table

Pg 7

Q.55

Activity	Exp. Duration $\frac{t_o + 4t_m + t_p}{6}$	Variance $\left(\frac{t_p - t_o}{6}\right)^2$	S.D.
1-2	$[4 + (4 \times 10) + 16] \div 6 = 10$	4	
1-3	6	1	1
1-4	8	4	
2-5	5	0	
3-5	14	16	4
4-6	10	4	
5-6	5	1	1



S.D. of C.P.

$$= \sqrt{1 + 16 + 1}$$

$$= \sqrt{18}$$

$$= 4.24$$

(ii) Critical path :- 1-3-5-6 :- 25 days

(iii) Probability that project will be completed 5 days earlier than C.P. duration

$$Z = \frac{t_{cp}(\text{new}) - t_{cp}(\text{old})}{\text{S.D. of C.P.}} = \frac{20 - 25}{4.24} = -1.18$$

(104) $\therefore Z = 0.1190$

Pg 8

(iv)

$$z = \frac{t(p(\text{new})) - t(p(\text{old}))}{\text{SD of (P)}}$$

If prob = 95%; $z = 1.65$

$$\therefore 1.65 = \frac{x - 25}{4.24}$$

$$\therefore 6.996 = x - 25$$

$$\therefore x = 31.996$$

i.e. $x = 32$ days

Verification

$$z = \frac{32 - 25}{4.24} = 1.65$$

$\Rightarrow 0.9505$ (F. value)

Note

- If 'z' value is +ve, then probability of meeting the demand is always more than 0.5
- If 'z' value is negative, then Prob < 0.5

pg 9

Ans no.

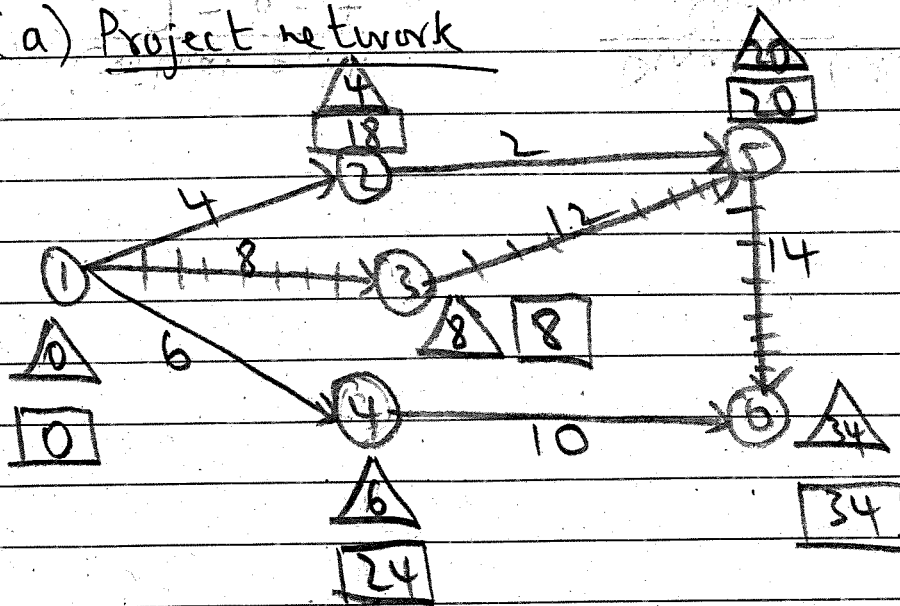
Q.59

(b)

Activity	Exp. Duration = $\frac{t_o + 4t_m + t_p}{6}$	Variance = $\left(\frac{t_p - t_o}{6}\right)^2$
1-2	4	4
1-3	8	4
1-4	6	4
2-5	2	0
3-5	12	16
4-6	10	4
5-6	14	16

Ans no.

(a) Project network

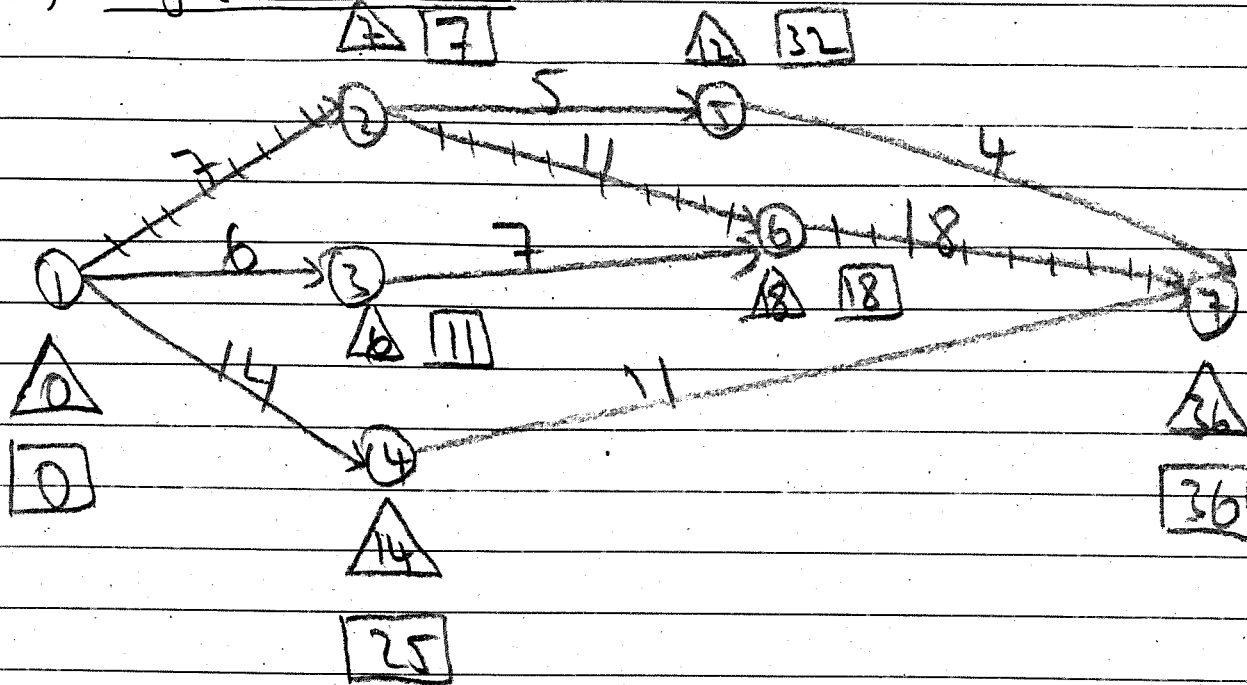


Critical path

1-3-5-6 :- 34 days

Q.57

(i) Project network



(iii) Critical path
1-2-6-7

Duration (days)
36 days

(ii) Activity	Exp. Duration $\left(\frac{t_o + 4t_m + t_p}{6}\right)$	Variance $= \left(\frac{t_p - t_o}{6}\right)^2$
1-2	7	4
1-3	6	4
1-4	14	16
2-5	5	1
2-6	11	4
3-6	7	4
4-2	11	16
5-7	4	1
6-7	18	16

Pg (11)

(iv) Prob. that project will be completed in 38 weeks

$$Z = \frac{t_{cp}(\text{new}) - t_{cp}(\text{old})}{\text{S.D of C.P}}$$

$$= \frac{38 - 36}{\sqrt{7 + 11 + 18}} \\ \sqrt{4 + 4 + 16}$$

$$= \frac{2}{4.90}$$

$$= 0.41$$

Θ value

↓
Z value is +ve
✓

↓
Z value is -ve
X

$$\Theta = 0.1591$$

$$+ 0.5000$$

$$0.6591$$

Prob

(v) If prob is 0.95 ; $z = 1.65$

$$Z = \frac{x - 36}{4.90}$$

$$\therefore 1.65 \times 4.90 = x - 36$$

$$x = 44 \text{ days}$$

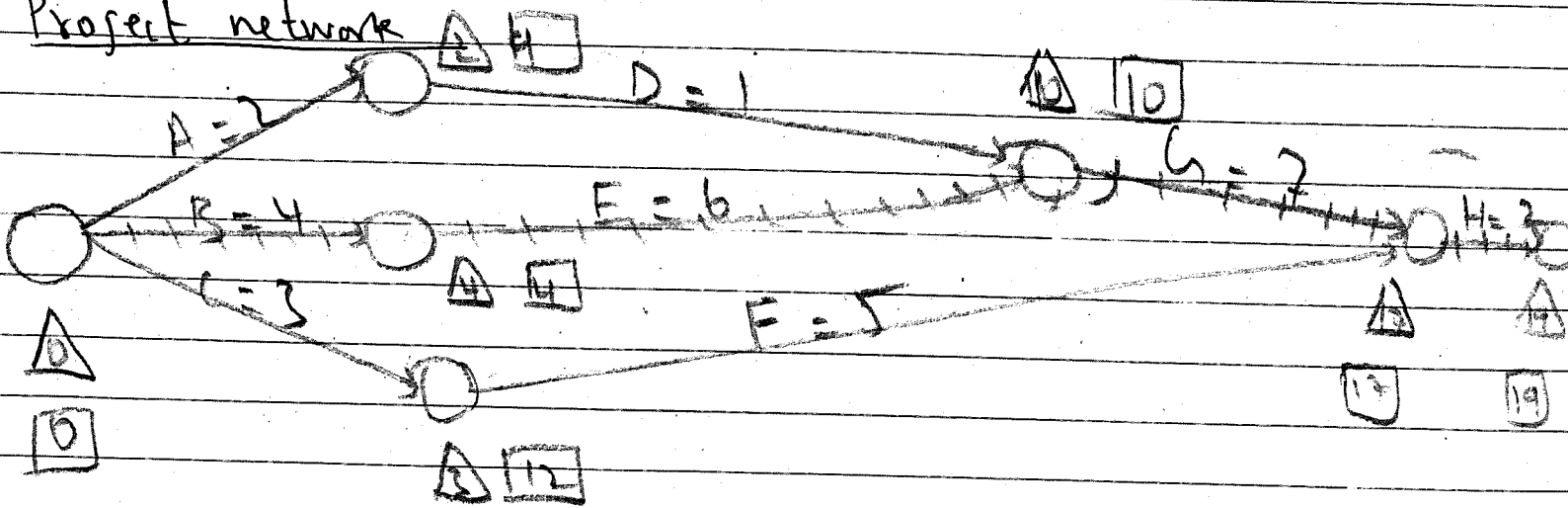
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Pg. (12)

Q. 54

Activity	Pre-Activity	Exp. Duration = $\frac{t_o + 4t_m + t_p}{6}$	$\left(\frac{t_p - t_o}{6}\right)^2 = \text{Variance}$
A	-	2	1
B	-	4	1
C	-	3	1
D	A	1	0
E	B	6	4
F	C	5	1
G	D, E	7	4
H	F, G	2	0

Project network



C.P.
B-E-G-H

Duration
19 days

Pg 13

$$S.D \text{ of } I.P = \sqrt{1+4+1} = \underline{\underline{3}}$$

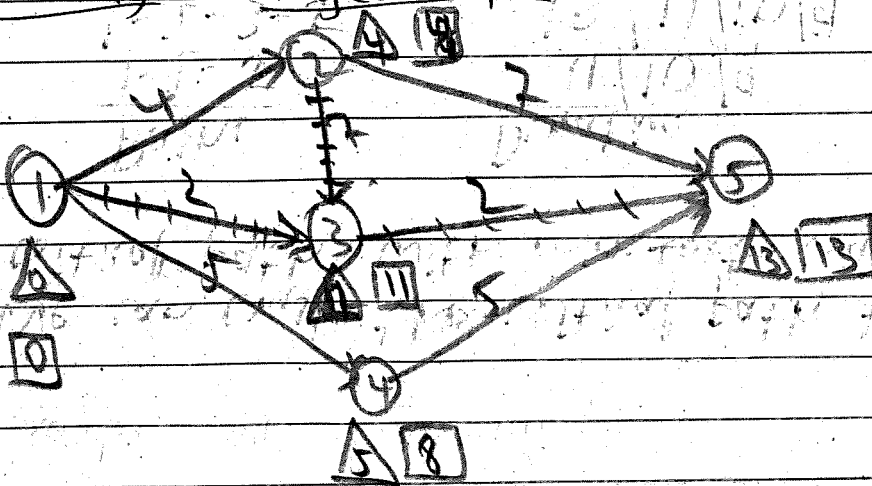
Crashing Concept

Project Crashing

Regular	Fees	Crash time	Possible crash	Fees	Extra fees	Per mth
4 mths	30000	2 mths	(4-2)	60000	30000	15000
					(60k-30k)	(30000-15000)

Activity	Normal time (day)	Crash time (days)	Possible crash	Normal cost	Crash cost	Extra cost	Cost per day
1-2	4	3	1/0	1500	2000	500	500
1-3	2	2	0	1000	1000	-	0
1-4	5	4	1/0	1875	2250	375	375
2-3	7	5	2/0	1000	1500	500	250
2-5	7	6	1/0	2000	2500	500	500
3-5	2	1	1/0	1250	1625	375	375
4-5	5	4	1	1500	2125	625	625

Ans no. (i) :- Project M/W



Critical path
1-2-3-5

Duration
13 days

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* Golden rules of Crashing

- We can crash the critical path to the extent of next critical path with min. ~~cost~~ crash cost.

Paths	Duration
1-2-5	11/10/9
1-2-3-5	13/11/10/9
1-4-5	10/9
1-3-5	4

Step I :-	Activity	Possible crash	Cost per day
	1-2	1	500
	2-3	2	250 (Min. cost)
	3-5	1	375

Crash 2-3 by 2 days

$$\text{Cost} = 2 \times 250 = 500$$

Step II :-

Activity	Possible crash	Cost per day
1-2	1	500
2-5	1	500
3-5	1	375

Optim I :-	Crash 3-5 (1 X 375)	375
	2-5 (1 X 500)	500
		875

(111)

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Option II : Crash 3-5 (1×375) 375
1-2 (1×500) 500
875

Option III (Crash 1-2 by 1 day (common) (1×500) 500 ✓ $\Rightarrow$ Lowest Cost

Step III :-

Activity	Possible crash	Cost per day
2-5	1	500
3-5	1	500 375
1-4	1	375
4-5	1	625

Crash		
1-4	1	375
3-5	1	375
2-5	1	500
		<u>1250</u>

Final ans (iii)

Statement showing optimum duration

	13	12	11	10	9
Crash cost	-	250	250+250 =500	1000 (500+500)	2250 (1000+1250)
Indirect cost	6500 (5000/13)	6000	5500	5000	4500
T. cost	<u>6500</u>	<u>6250</u>	<u>6000</u>	<u>6000</u>	<u>6750</u>

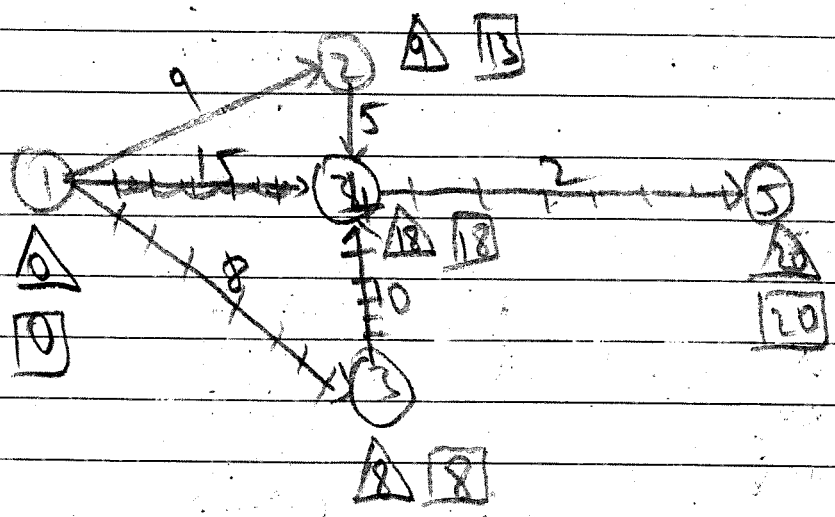
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Q.56

Activity	Normal dur ⁿ	Crash dur ⁿ	Possible Crash	Crash cost Normal per day
1-2	9	6	3/2	20
1-3	8	5	3/2/1/0	25
1-4	15	10	5/4/3/2/1	30
2-4	5	3	2/1/0	10
3-4	10	6	4/1/0	15
4-5	2	1	1/0	40

Note no. 1
Project N/w



C.P.
1-3-4-5
Normal Duration
20
Min. = ?
Duration

Paths	Duration
1-2-4-5	16/15/14/13/12
1-4-5	17/16/15/14/13/12
1-3-4-5	20/17/16/15/14/13/12

Step I:-

Activity	Possible crash	Cost/day
1-3	3	25
3-4	4	15 (min. cost)
4-5	1	40

Crash 3-4 (3x15) = 45

Step II:-

1-4	5	30
4-5	1	40
1-3	3	25
3-4	1	15

Option I:-

3-4	(1x15)	= 15
1-4	(1x30)	= 30
3-4	(1x15)	= 15
		<u>45</u>

Option II:- (common activity)

4-5 (1x40) = 40 ✓

Step III :-

Activity

1-2	5	30
1-3	3	25
3-4	1	15 ✓

Crash 3-4 (1x15) 15

1-4 (1x30) 30
45

Step IV :-

1-2	3	20
2-4	2	10
1-4	4	30
1-3	3	25

Crash 2-4 (1x10) ₹ 10

1-3 (1x25) ₹ 25

1-4 (1x30) ₹ 30
₹ 65

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Step(5)

1-2	3	20 x
2-4	1	10 ✓
1-4	3	30
1-3	2	25

Crash 2-4 (1x10) ₹10

1-3 (1x25) ₹25

1-4 (1x30) ₹30
₹65

Step(6)

1-2	3	20
1-4	2	30
1-3	1	25

Crash 1-3 (1x20) ₹20

1-3 (1x25) ₹25

1-4 (1x30) ₹30

₹75

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	1	L-1	L-2	L-3	L-4	L-5	L-6	L-7	L-8
	20	19	18	17	16	15	14	13	12
Crash Cost		15	30 (15+15)	45 (30+15)	85 (45+40)	130 (85+45)	195 (130+65)	260 (195+65)	335 (260+75)
Extra Cost	1200 (60x20)	1140 (60x19)	1080 (60x18)	1020 (60x17)	960 (60x16)	900 (60x15)	840 (60x14)	780 (60x13)	720 (60x12)
Total Cost	1200	1155 1140	1110	1065	1045	1030	1035	1040	1055

Optimum duration
(min. cost)