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TEST PAPER – 04

**(Chapters Covered – Linear Programming, Transportation,
Assignment, Game Theory, Simulation & PERT + CPM)**

STRATEGIC COST MANAGEMENT

Time Allowed: 3 Hours

Full Marks: 100

Section A contains Question Number 1. All parts of this question are compulsory.
Working notes should form part of the relevant answer.

SECTION-A

1. Choose the correct answer from the given alternatives (you may write only the Roman number and the alphabet chosen for your answer) (2×15 = 30 Marks)

- (i) In a transportation matrix (where R_i are rows and C_j are columns), the second allocation under the North West Corner Rule can be
- (a) R_1C_2
 - (b) R_1C_3
 - (c) R_2C_3
 - (d) None of these

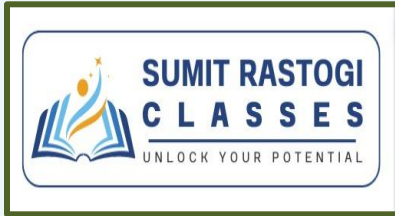
- (ii) When fewer than $m + n - 1$ shipment exist in a feasible solution
- (a) The problem is capacitated
 - (b) An occupied cell must be created artificially
 - (c) A dummy source must be created
 - (d) The problem is unbalanced

(iii) The pay-off matrix of a game for the Company S and Company T is given below:

	Company T			
Company S	25	12	10	30
	15	13	6	8
	30	5	8	6

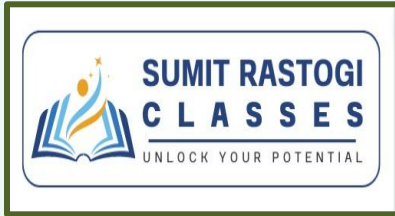
Using Maximin-Minimax principle, what will be the value of the game?

- (a) 15
- (b) 12
- (c) 10
- (d) None of the above



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- (iv) The highest negative opportunity cost value in an unused cell of a Transportation Matrix is chosen to improve the current solution because:
- (a) It represents maximum possible cost reduction per unit
 - (b) It ensures no violation of Rim Condition
 - (c) It represents per unit cost improvement
 - (d) Either one of the above
- (v) When a maximisation assignment problem is converted to minimisation problem, the resultant matrix is called:
- (a) Profit Matrix
 - (b) Regret Matrix
 - (c) Cost Matrix
 - (d) Dummy Matrix
- (vi) In marking assignments which of the following should be preferred?
- (a) Only row having single zero
 - (b) Only column having single zero
 - (c) Column having more than one zero
 - (d) Only row/column having single zero
- (vii) The Pay-off Matrix of a game is given below:
- | | Player B | | |
|----------|----------|----|---|
| Player A | 3 | -1 | 4 |
| | -1 | 8 | 2 |
| | 16 | 8 | 6 |
- What is the value of Game to Player A (using Maximin-Minimax Principle)?
- (a) 6
 - (b) 8
 - (c) 16
 - (d) None of the above
- (viii) The important step(s) required for simulation approach in solving a problem is/are:
- (a) Test and validate the Model
 - (b) Design the experiment
 - (c) Conduct the experiment
 - (d) All of the above



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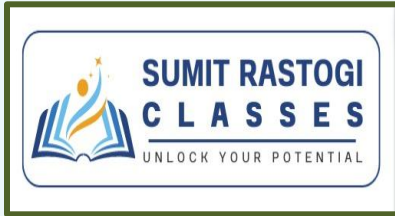
- (ix) The expected time for an activity of Project LM is 20 days. If the most likely and pessimistic time are 19 days and 28 days, what will be the variance of the activity?
- (a) 1.36
 (b) 1.78
 (c) 4
 (d) 0

- (x) The drive-up window of a fast-food operation was being studied using simulation for a variety of operating characteristics. As part of the study, data was collected on Order Processing Time as given in the following table. Using the first two digits of the Random Numbers, determine the processing time that would be used to simulate the fifth sample.

Processing Time (Minutes)	1	2	3	4
Probability	0.30	0.45	0.20	0.05

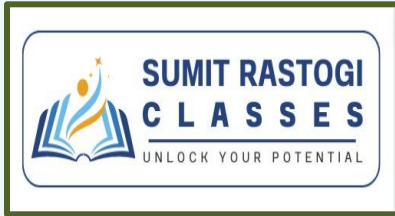
Customer	1	2	3	4	5	6	7	8	9
Random No.	1048	2236	2413	4216	3757	1501	4657	4836	9309

- (a) 2 minutes
 (b) 4 minutes
 (c) 1 minute
 (d) 3 minutes
- (xi) Optimistic and pessimistic time of an activity respectively are 4 days and 16 days. Variance of the duration of the activity will be:
- (a) 4 days
 (b) 2 days
 (c) 3 days
 (d) None of the above
- (xii) The normal duration and normal cost of an activity of project BOZ are 12 days and ₹400 respectively. The cost slope is ₹80 per day, if the crash cost of the activity is ₹560, what will be the crash duration of the activity?
- (a) 12 Days
 (b) 10 Days
 (c) 8 Days
 (d) 6 Days



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- (xiii) A PERT Network has four activities on its Critical Path. The Standard Deviation of each activity on the Critical path is 4 days. What will be the standard deviation of the Critical Path?
- (a) 8 days
 - (b) 4 days
 - (c) 2 days
 - (d) None of the above
- (xiv) Which of the following is a valid constraint for a linear programming problem?
- (a) $3x^2 + 4x + 1 = 0$
 - (b) $5x_1 + 2x_2 \leq 10$
 - (c) $4x_1 + 3x_2 > 7$
 - (d) $(12x_1 + 4x_2)/3x_2 \leq 8x_1$
- (xv) If (50, 0), (50, 14), (25, 50) and (13, 50) are the Corner Points of the feasible region of the Linear Programming problem, Maximize $Z = 2x_1 + 3x_2$, then maximum value of the objective function will be
- (a) ₹200
 - (b) ₹270
 - (c) ₹240
 - (d) ₹120



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SECTION-B

2. (a) A computer service centre services laptop. It is proposed to study the arrival and servicing pattern of the service centre. The following information was collected over 100 days.

No. of Laptops	Frequency of Arrival	Frequency of Service
8	10	15
9	25	20
10	20	25
11	15	16
12	18	14
13	12	10

Simulate the arrival and servicing pattern for 7 days and analyze and assess the average number of laptops held for more than one day for service. Assume FIFO method is followed for service and there is one laptop held from previous day for service at the beginning of the first day.

Use the following series of random numbers:

Arrivals	69	45	46	10	82	16	35
Service	52	36	62	49	68	77	55

(7 Marks)

2. (b) A State Municipal Corporation has decided to carry out road repairs on four main roads in the city and you have been asked to advise them the least cost allocation. It is learnt that the State Government has agreed to make a special grant of ₹114 lakhs towards the cost with the condition that the repairs should be carried at the lowest cost. Five contractors have sent their bids. Only one road will be awarded to one contractor. The bids are given below:

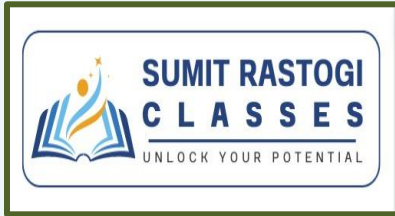
Cost of Repairs (₹ in Lakhs)

Contractor	Road			
	R1	R2	R3	R4
C1	18	28	38	30
C2	14	34	40	39
C3	18	36	42	38
C4	20	24	36	36
C5	20	30	42	32

You are also informed that contractor C1 should get R1 and C5 should get R2 to minimise costs.

- (i) By applying the principles of Assignment, assess the minimum cost of allocation.
- (ii) Calculate the minimum discount that the eliminated contractor should offer for meriting a contract.

(7 Marks)



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3. (a) RONTECH (I) Ltd., an engineering firm won a contract to install an instrument landing device at the local airport. The complete installation can be broken down into seven separate activities. Each activity (Labelled A through G), its predecessor activities, normal time (days) and cost and crash time (days) and cost are given below (in table):

Activity and Identification	Predecessor Activity	Normal duration (Days)	Crash duration (Days)	Normal Cost (₹)	Crash Cost (₹)
A (1 - 2)	-	7	5	500	900
B (2 - 4)	A	4	5	400	600
C (2 - 3)	A	5	5	500	500
D (2 - 5)	A	6	4	800	1,000
E (4 - 6)	B, C	7	4	700	1,000
F (5 - 6)	C, D	5	2	800	1,400
G (6 - 7)	E, F	6	4	800	1,600

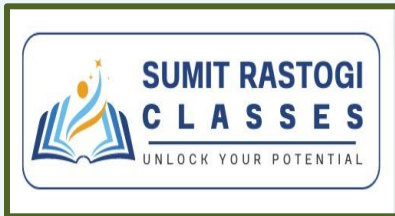
Required:

- Design the project network and indicate all paths through it.
 - Assess the critical path and the normal duration.
 - Evaluate the percentage increase in cost to complete the project in 21 days. (7 marks)
3. (b) CNG Ltd. (CNGL), a compressed natural gas (CNG) company, has three plants producing gas and four outlets. The cost of transporting gas from different production plants to the outlets, production capacity of each plant and requirement at different outlets is shown in the following cost-matrix table:

Plants	Outlets				Capacity of Production (Units)
	A	B	C	D	
X	4	6	8	6	700
Y	3	5	2	5	400
Z	3	9	6	5	600
Requirement (Units)	400	450	350	500	

Required:

- Analyze and show the production and distribution schedule in a way which minimizes the transportation costs of the company using Vogel's Approximation Method (VAM).
- Assess the total costs of transporting gas of the company. (7 marks)



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4. (a) The following information are given:

Arrival of patients		Services	
Inter-Arrival Time (minutes)	Probability	Inter-Service Time (minutes)	Probability
2	0.20	4	0.25
4	0.24	6	0.34
6	0.28	8	0.26
8	0.18	10	Balance
10	Balance		

The following random numbers are to be used for the simulation of arrival and service patterns:

Arrival	740	225	906	048	421
Service	402	183	706	923	638

Required:

- Find out the average time spent by the patient in the queue by simulation. Assume that the time starts at 6:00 am and there is only one counter and there is no time gap between finishing with one patient and starting the next patient if the next patient is already in the queue.
- As second counter is to be set up if the probability of waiting beyond 3 minutes exceeds 40% or if the average waiting time of a patient exceeds 5 minutes if there is a wait. Should the second counter be set up? Substantiate based on the simulation results. **(7 marks)**

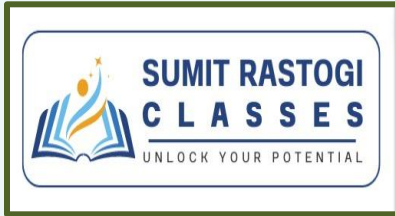
4. (b) A travelling salesman has to visit five cities. S, T, X, Y and Z. The inter-city distances are tabulated below. Note the distance between two cities need not be same both ways.

From	To				
	S	T	X	Y	Z
S	-	14	26	27	17
T	8	-	18	20	9
X	12	13	-	20	14
Y	16	19	24	-	18
Z	14	15	25	27	-

The distance are in Km.

Required:

If the travelling salesman starts from City S and has to come back to city S, by applying the principle of quantitative technique, which route would you advise him to take so that total distance travelled by him is minimized? **(7 marks)**



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5. (a) SIMCON, a construction company, has an opportunity to submit a bid for the construction of Administrative Building of LNP Ltd. From the specifications provided, project manager has estimated most likely, optimistic and pessimistic completion time (in days) for each activity of the project as under:

Activity	Immediate Predecessor	Time (days)		
		Most likely	Optimistic	Pessimistic
A	-	5	4	6
B	-	12	8	16
C	-	5	4	12
D	A, B	3	1	5
E	B	2	2	2
F	C	5	4	6
G	B, C	14	10	18
H	D, E, G	20	18	34

Required:

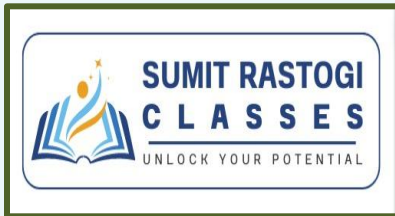
- (i) Assess the expected duration for each activity.
- (ii) Design the PERT Network and indicate all paths through it.
- (iii) Identify the Critical path and assess the expected completion time (in days) and its standard deviation.
- (iv) Assess the probability that the project will be completed in 54 days.
- (v) There is evidence that managers are poor in estimating extreme values. It is suspected that in this project the times for tasks A, B, C and F underestimate the pessimistic times by 1 day and overestimate the optimistic time by 1 day. In the case of tasks G & H, the under/over estimation is put at 2 days.

In consideration of above aspects, assess the new probability of completing the project in 54 days.

Given: Table for areas under Normal Curve from 0 to Z.

Z = 0 to Z	0.50	1	1.3	1.42	1.84	2.00
Table Value	0.0915	0.3413	0.4032	0.4222	0.4667	0.4772

(7 marks)



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5. (b) FAMC Ltd., a manufacturing company produces three products A, B and C. It uses two types of raw materials I and II of which 5,000 and 7,500 units respectively are available. The raw material requirements per unit of the products are given below:

Raw Material	Requirement per unit of Product		
	A	B	C
I	3	4	5
II	5	3	5

The labour time for each unit of product A is twice that of product B and three times that of product C. The entire labour force of the firm can produce the equivalent of 3,000 units. The minimum demand of the three products is 600, 650 and 500 units respectively. Also, the ratios of the number of units produced must be equal to 2:3:4. The profits per unit of A, B and C are ₹50, ₹50 and ₹80 respectively.

Required:

Analyze and Formulate the problem as a linear programming model in order to determine the number of units of each product which will maximize the profit. **(7 marks)**

6. (a) S-MART, a retailer deals in a perishable commodity. The daily demand and supply are variable. The data for the past 500 days show the following demand and supply.

Supply:

Availability (kgs)	No. of Days
10	40
20	50
30	190
40	150
50	70

Demand:

Availability (kgs)	No. of Days
10	50
20	110
30	200
40	100
50	40

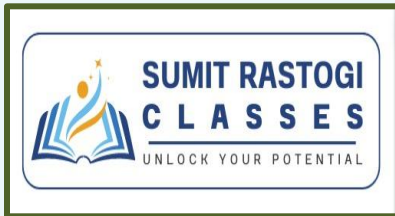
S-MART buys the commodity at ₹40 per kg and sells at ₹60 per kg. Any commodity remains at the end of the day has no saleable value. Moreover, the loss (unearned profit) on any unsatisfied demand is ₹16 per kg.

Required:

Given the following pair of random numbers, simulate 6 days sales, demand and Profit:

(31, 18) (63, 84) (15, 79) (07, 32) (43, 75) (81, 27)

The first random number in the pair is for supply and the second random number is for demand viz. in the first pair (31, 18), use 31 to simulate supply and 18 to simulate demand. **(7 Marks)**



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6. (b) In a textile sales emporium of SONTEX Ltd. four salesmen A, B, C and D are available to four counters W, X, Y and Z. Each salesman can handle any counter. Their services (in hour) of each counter, when manned by each salesman is given below:

Counter	Salesman			
	A	B	C	D
W	41	72	39	52
X	22	29	49	65
Y	27	39	60	51
Z	45	50	48	52

Required:

How should the salesmen be allocated appropriate counters so as to minimize the service time? Each salesman must handle only one counter. (7 marks)

7. (a) JOBSON Ltd., a manufacturer of plant and machinery is in the process of quoting a tender called by ZOYB Ltd. Delivery date once promised is crucial and penalty clause is applicable. The Project Manager of JOBSON Ltd. has listed down the activities of the project as under:

ACTIVITY (i - j)	Estimated Duration (in weeks)		
	Optimistic (a)	Most Likely (m)	Pessimistic (b)
1 - 2	1	1	7
1 - 3	1	4	7
1 - 4	2	2	8
2 - 5	1	1	1
3 - 5	2	5	14
4 - 6	2	5	8
5 - 6	3	6	15

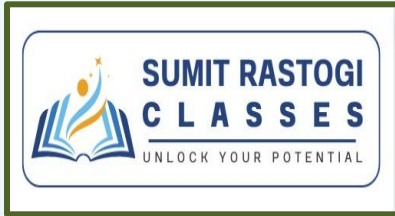
Required:

- Design the project network and indicate all the paths through it.
- Analyze the expected duration and variances for each activity and Assess project length.
- Calculate the standard deviation of the project length and critically assess the probability that the project will be completed:
 - At least 3 weeks earlier than expected time.
 - No more than 3 weeks later than expected time.
- If the project due date is 18 weeks, assess the probability of not meeting the due date.

Given: Table for areas under normal curve for O to Z.

Z = O to Z	0.10	0.33	0.67	1.00	1.33	2.00
Table value	0.0398	0.1293	0.2486	0.3413	0.4082	0.4772

(7 marks)



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7. (b) Two Firms P and Q are competing for business under the conditions so that one firm's gain is another firm's loss. Firm P's pay-off matrix is given below:

Firm P	Firm Q			
		No Advertising	Medium Advertising	Heavy Advertising
	No Advertising	10	5	-2
	Medium Advertising	13	12	15
	Heavy Advertising	16	14	10

Required:

- (i) Suggest optimal strategies for the two firms.
(ii) Assess the value of Game. (7 marks)

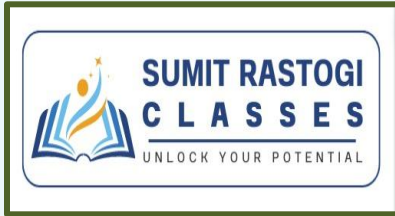
8. (a) An automobile company manufactures around 150 scooters. The daily production varies from 146 to 154 depending upon the availability of raw materials and other working conditions. The probability for the number of units produced daily is given as under:

Production Per Day	146	147	148	149	150	151	152	153	154
Probability	0.04	0.09	0.12	0.14	0.11	0.10	0.20	0.12	0.08

The finished scooters are transported in a specially arranged lorry accommodating 150 scooters.

Use the following random numbers i.e., 80, 81, 76, 75, 64, 43, 18, 26, 10, 12, 65, 68, 69, 61 and 57, simulate the process to find out:

- (i) What will be the average number of scooters waiting in the factory?
(ii) What will be the average number of empty spaces on the lorry? (7 marks)



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8. (b) LM Company has the option of producing two products in its plant. The costs and selling prices per unit of two products are detailed below:

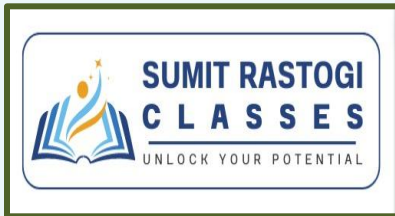
Product	Alfa (₹)	Beta (₹)
Selling Price	1,000	900
Direct Materials @₹50 per kg.	200	200
Direct Labour @₹40 per hour	160	80
Painting @₹60 per hour	60	120
Variable Overheads	380	350
Fixed Costs @₹35/D.L. hour	140	70
Total Costs	940	820
Profit	60	80

In any month the maximum availability of inputs is limited to the following:

Direct Materials	:	960 kgs
Direct Labour hours	:	800 hours
Painting hours	:	400 hours

Required:

- Formulate a Linear Programming Problem to determine the production plan which maximizes the contributions. (You are not required to solve the LPP)
- Prepare the DUAL to the problem formulated in (i).



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ANSWERS OF TEST PAPER – 04

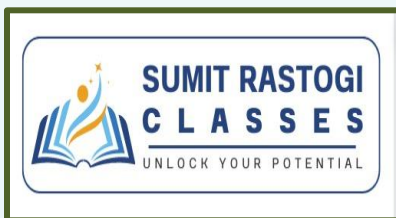
(Chapters Covered –Linear Programming, Transportation, Assignment, Game Theory, Simulation & Network Analysis – PERT, CPM)

STRATEGIC COST MANAGEMENT

SECTION-A

ANS.1

- (i) (a) R1C2
- (ii) (b) An occupied cell must be created artificially
- (iii) (c) 10
- (iv) (a) It represents maximum possible cost reduction per unit
- (v) (b) Regret Matrix
- (vi) (d) Only row/column having single zero
- (vii) (a) 6
- (viii) (d) All of the above
- (ix) (x) 4
- (x) (a) 2 minutes
- (xi) (a) 4 days
- (xii) (b) 10 Days
- (xiii) (a) 8 Days
- (xiv) (b) $5x_1 + 2x_2 \leq 10$
- (xv) (a) ₹200



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SECTION-B

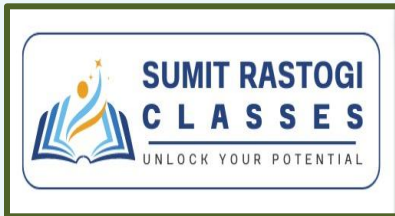
ANS. 2 (a)

Arrivals				
No. of Laptops	Frequency	Probability	Cumulative Probability	Random No. Interval
8	10	0.10	0.10	00-09
9	25	0.25	0.35	10-34
10	20	0.20	0.55	35-54
11	15	0.15	0.70	55-69
12	18	0.18	0.88	70-87
13	12	0.12	1.00	88-99
	100			

Service				
No. of Laptops	Frequency	Probability	Cumulative Probability	Random No. Interval
8	15	0.15	0.15	00-14
9	20	0.20	0.35	15-34
10	25	0.25	0.60	35-59
11	16	0.16	0.76	60-75
12	14	0.14	0.90	76-89
13	10	0.10	1.00	90-99
	100			

SI No.	Random No. Arrival	No. of Laptops	Random No. for Service	No. of Laptops (Service Capacity)	Laptops held from Previous day	Laptops arrived	Laptops serviced	Laptops held overnight
1	69	11	52	10	1	11	10	2
2	45	10	36	10	2	10	10	2
3	46	10	62	11	2	10	11	1
4	10	9	49	10	1	9	10	0
5	82	12	68	11	0	12	11	1
6	16	9	77	12	1	9	10	0
7	35	10	55	10	0	10	10	0
Total								6

Average no. of laptops held for more than one day for service = $6/7 = 0.857$



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ANS. 2 (b)

- (i) Since it is already given that Contractor C1 should get R1 and C5 should get R2. The respective row and column gets eliminated. And now we have two roads R3 and R4 to be allocated between C2, C3 and C4, making it an unbalanced problem. So dummy column needs to be added. Accordingly, the revised matrix is as below:

Contractors	Roads		
	R3	R4	Dummy
C2	40	39	0
C3	42	38	0
C4	36	36	0

Row Operation:

Contractors	Roads		
	R3	R4	Dummy
C2	40	39	0
C3	42	38	0
C4	36	36	0

Column Operation:

Contractors	Roads		
	R3	R4	Dummy
C2	4	3	0
C3	6	2	0
C4	0	0	0

Here minimum number of horizontal and vertical straight lines to cover all the zeros = 2 $\neq$ Order (3) of the matrix. So, the solution is non-optimal. An improvement over this one is done by subtracting the minimum of the uncovered elements i.e. 2 from all the uncovered elements and adding that to the elements at the junction of lines.

Improved Matrix:

Contractors	Roads		
	R3	R4	Dummy
C2	2	1	0
C3	4	0	0
C4	0	0	2

In this case we find that the minimum number of lines to cover the zeros = 3 = Order of the matrix. Hence the solution is optimal.

We start assignment by choosing the 3rd cell with zero in the 1st row i.e. **cell C2-Dummy** and other zeros in the third Column are crossed out. Next Assignment is in 2nd row at **cell C3-R4** and other zeros in the 2nd column are crossed out. And the final assignment is done at cell **C4-R3**.

Optimal Assignments and Cost:

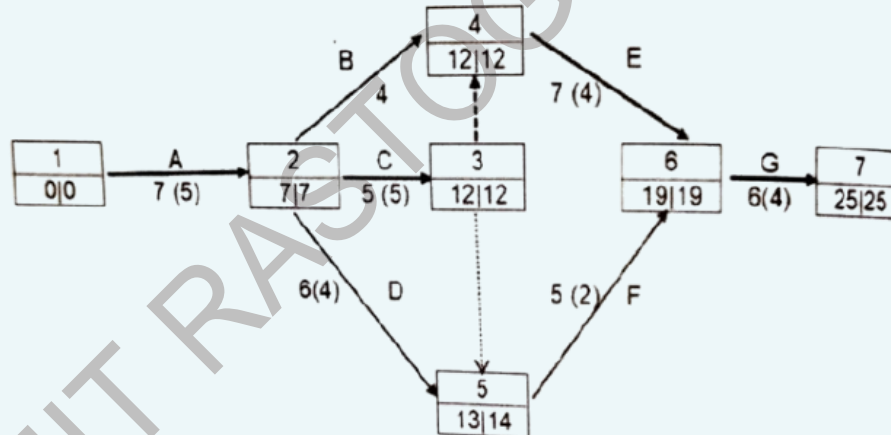
Contractors	Roads	Cost (₹ in lakhs)
C1	R1	18
C3	R4	38
C4	R3	36
C5	R2	30
Total		122

Minimum Cost = ₹122 Lakhs

- (ii) Eliminated contractor C2 should offer a minimum discount of ₹1 Lakh (39 – 38) to match the quote of Contractor C3 for the contract of Road R4.

ANS. 3 (a)

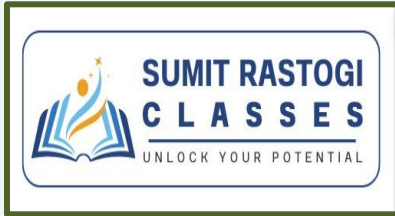
(i) Network Diagram



Various paths of the network are given below:

- | | |
|-----------------------|-------------------------|
| 1 – 2 – 3 – 4 – 6 – 7 | with duration = 25 days |
| 1 – 2 – 4 – 6 – 7 | with duration = 24 days |
| 1 – 2 – 3 – 5 – 6 – 7 | with duration = 23 days |
| 1 – 2 – 5 – 6 – 7 | with duration = 24 days |

- (ii) The critical path of the project is A → C → E → G or 1 – 2 – 3 – 4 – 6 – 7 with normal duration of 25 days.



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(iii) Calculation of Cost Slope for various activities

Activity	Normal duration	Crash duration	Normal Cost (₹)	Crash Cost (₹)	Cost Slope (₹)
A (1 - 2)	7	5	500	900	200
B (2 - 4)	4	5	400	600	-200
C (2 - 3)	5	5	500	500	N.A
D (2 - 5)	6	4	800	1,000	100
E (4 - 6)	7	4	700	1,000	100
F (5 - 6)	5	2	800	1,400	200
G (6 - 7)	6	4	800	1,600	400
		Total	4,500		

Step-1:

In order to decide the cost of completing the project in 21 days, let us crash that activity on the critical path which has minimum cost slope.

It can be seen that the minimum cost slope of ₹100 corresponds to activity E (4 - 6) and it lies on the critical path.

Note: Therefore, we crash activity E (4 - 6) by 1 day at an additional cost of ₹100.

Step-2:

Different paths now are

- 1 - 2 - 3 - 4 - 6 - 7 with duration = 24 days
- 1 - 2 - 4 - 6 - 7 with duration = 23 days
- 1 - 2 - 3 - 5 - 6 - 7 with duration = 23 days
- 1 - 2 - 5 - 6 - 7 with duration = 24 days

An examination of the above four paths clearly points out that there are two critical paths namely 1 - 2 - 3 - 4 - 6 - 7 and 1 - 2 - 5 - 6 - 7 each with duration = 24 days.

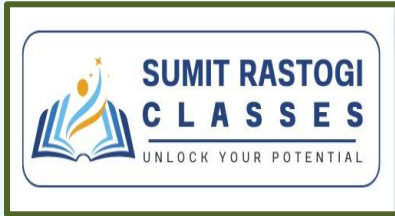
To reduce the project duration by three days more, there are following possible combination of activities:

- Crash activities 4 - 6 on the path 1 - 2 - 3 - 4 - 6 - 7 and 5 - 6 on the path 1 - 2 - 5 - 6 - 7 by one day each at an additional cost of ₹100 + ₹200 = ₹300
- Crash activities 4 - 6 on path 1 - 2 - 3 - 4 - 6 - 7 and 2 - 5 on path 1 - 2 - 5 - 6 - 7 by one day each at an additional cost of ₹100 + ₹100 = ₹200.
- Crash activity 1 - 2 by one day at an additional cost of ₹200.

It can be observed that the additional cost of reducing the project duration by one day in combination 2 as well as combination 3 is ₹200.

Conclusion: Therefore, any of these two can be selected for crashing.

Although, since crashing activity 1 - 2 by 1 day reduces the duration of all the paths by 1 day, we will crash it by 1 day. The project duration becomes 23 days at an additional cost of ₹200



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Step-3:

Crash activity 1 – 2 by 1 day further, it would reduce the project duration to 22 days at an additional cost = ₹200.

Step-4:

Activity 1 – 2 cannot be crashed further. So, we now select the combination 2 stated above for crashing. Crash activities 4 – 6 and 2 – 5 by one day each at an additional cost of ₹100 + ₹100 = ₹200.

The project duration now becomes equal to 21 days.

Therefore, in order to complete the project in 21 days, an additional cost of ₹100 + ₹200 + ₹200 + ₹200 = ₹700 will be incurred.

The normal cost of completing the project in 25 days = ₹4,500.

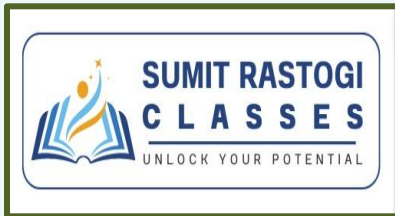
Conclusion: Therefore, the percentage increase in cost to complete the project in 21 days = $\frac{₹700}{₹4,500} \times 100 = 15.55\%$

ANS. 3 (b)

Plants		Outlets				Capacity (Units)	Row Penalties			
		A	B	C	D		1 st	2 nd	3 rd	4 th
X		4	6 ⁴⁵⁰	8	6 ²⁵⁰	700/250/0	1	2	0	0
Y		3	5	2 ³⁵⁰	5 ⁵⁰	400/50/0	1	2	0	0
Z		3 ⁴⁰⁰	9	6	5 ²⁰⁰	600/200/0	2	2*	4*	-
Requirement (Units)		400/0	450/0	350/0	500/300/250/0					
Column Penalties	1 st	0	1	4*	0					
	2 nd	0	1	-	0					
	3 rd	-	1	-	0					
	4 th	-	1	-	1*					

Statement of Allocation and Transportation Cost:

Cell	Allocation	Transportation Cost (₹)
X - B	450	450 × 6 = 2,700
X - D	250	250 × 6 = 1,500
Y - C	350	350 × 2 = 250
Y - D	50	50 × 5 = 250
Z - A	400	400 × 3 = 1,200
Z - D	200	200 × 5 = 1,000
Total		7,350



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ANS. 4 (a)

(i)

Arrivals			
Minutes	Probability	Cumulative Probability	Random No. Interval
2	0.20	0.20	000-199
4	0.24	0.44	200-439
6	0.28	0.72	440-719
8	0.18	0.90	720-899
10	0.10	1.00	900-999

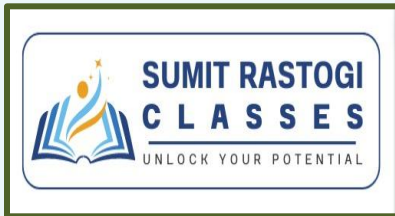
Service			
Minutes	Probability	Cumulative Probability	Random No. Interval
4	0.25	0.25	000-249
6	0.34	0.59	250-589
8	0.26	0.85	590-849
10	0.15	1.00	850-999

SI No.	Random No. Arrival	Time	Entry time in queue	Service Start Time	Random no. for Service	Service Time	Service End time	Waiting Time of Patient	Idle Time of Centre
1	740	8	6:08	6:08	402	6	6:14	-	08
2	225	4	6:12	6:14	183	4	6:18	2	-
3	906	10	6:22	6:22	706	8	6:30	-	4
4	048	2	6:24	6:30	923	10	6:40	06	-
5	421	4	6:28	6:40	638	8	6:48	12	
Total								20	12

(ii) Probability of waiting time is more than 3 minutes = $2/5 = 40\%$. Hence is not exceeding 40%.

Average waiting time of a patient = Total of waiting time/Instances of waiting = $20/3 = 6.67$

Hence the second counter should be set up based on simulated results.



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ANS. 4 (b)

Row Operation:

From	To				
	S	T	X	Y	Z
S	-	0	12	13	3
T	0	-	10	12	1
X	0	1	-	8	2
Y	0	3	8	-	2
Z	0	1	11	13	-

Column Operation:

From	To				
	S	T	X	Y	Z
S	1	0	4	5	2
T	0	1	2	4	0
X	0	1	1	0	1
Y	0	3	0	1	1
Z	0	1	3	5	1

In this case we find that the minimum number of lines to cover the zeros = 5 = Order of the matrix. Hence the solution is optimal.

We start assignment by choosing the 2nd cell with zero in the 1st row i.e. cell S-T. Now 2nd, 3rd and 4th row each has more than one zero so we assign in 1st cell in 5th row i.e. Z-S and cancel all other zeros in 1st column.

Now, we assign column wise. We have only one zero in each of 2nd, 3rd and 4th column so we assign values to cell T-Z, X-Y and Y-X.

Optimal Assignments and Distance:

From	To	Distance (Kms)
S	T	14
T	Z	9
X	Y	20
Y	X	24
Z	S	14
Total		81

Now, according to optimal assignment it is not possible to reach back to S as Assignment is from X to Y and Y to X. So, we have two options to travel S-T-Z-X-Y-S or S-T-Z-Y-X-S.

S-T-Z-X-Y-S = 14 + 9 + 25 + 20 + 16 = **84 Kms.**

S-T-Z-Y-X-S = 14 + 9 + 27 + 24 + 12 = **86 Kms.**

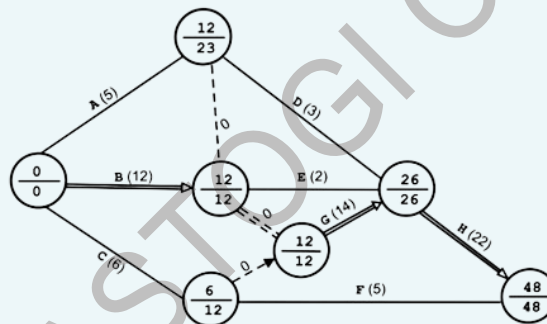
So, Optimal Route is S-T-Z-X-Y-S with total distance of 84 kms.

ANS. 5 (a)

(i) Calculation of Expected Project Duration:

Activity	Most Likely (M)	Optimistic (O)	Pessimistic (P)	Expected Duration (O+4M+P)/6(Days)
A	5	4	6	5
B	12	8	16	12
C	5	4	12	6
D	3	1	5	3
E	2	2	2	2
F	5	4	6	5
G	14	10	18	14
H	20	18	34	22

(ii) Project Network Diagram



(iii) Critical Path, Expected project duration & Std. Deviation:

From the EST and LST calculated above, it is clear that, tasks B, G and H are in critical path. The overall project duration is 48 days.

Calculation of Standard Deviation of the activities in Critical Path

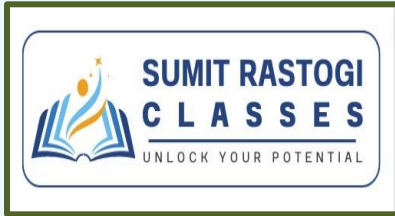
Activity	Pessimistic time	Optimistic Time	Standard Deviation
B	16	8	1.33
G	18	10	1.33
H	34	18	2.67

Standard Deviation of the Project = $\sqrt{1.33^2 + 1.33^2 + 2.67^2} = 3.27$

(iv) Calculation of probability that the project will be completed in 54 days:

Using Z value, we have $Z = (54 - 48)/3.27 = 1.84$

Using area under standard normal curve, the probability of finishing the project in 54 days is $0.5 + 0.4667 = 0.9667 = 96.67\%$



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(v) Calculation of new probability:

The revised estimates do not affect the average task times as the reduction in optimistic time equals the increase in pessimistic times. Therefore, tasks B, G & H are still in critical path and the expected project duration is still 48 days.

However, increase in variability will affect the standard deviation of the project.

Calculation of Revised Standard Deviation of the project:

Activity	Pessimistic time	Optimistic Time	Standard Deviation
B	17	7	3.78
G	20	8	4.00
H	36	16	11.10

Standard Deviation of the project = $\sqrt{(2.78 + 4 + 11.10)} = 4.23$

Using Z value, we have $Z = (54 - 48)/4.23 = 1.42$

Using area under standard normal curve, the probability of finishing the project in 54 days is $0.5 + 0.4222 = 0.9222 = 92.22\%$.

ANS. 5 (b)

Let the firm produce X_1 units of product A, X_2 units of product B and X_3 units of product C. The profit per unit of products A, B and C is ₹50, ₹50 and ₹80 respectively.

The objective function is:

Maximise, $Z = 50X_1 + 50X_2 + 80X_3$

Raw material constraints are: $3X_1 + 4X_2 + 5X_3 \leq 5,000$ & $5X_1 + 3X_2 + 5X_3 \leq 7,500$

The labour time for each unit of product A is twice that of product B and three times that of product C. Also, the entire labour force can produce the equivalent of 3,000 units.

$$X_1 + X_2/2 + X_3/3 \leq 3,000$$

$$6X_1 + 3X_2 + 2X_3 \leq 18,000$$

Demand constraints are: $X_1 \geq 600$ $X_2 \geq 650$ and $X_3 \geq 500$

Since the ratios of the number of units produced must be equal to 2: 3: 4, therefore,

$$1/2 (X_1) = 1/3 (X_2) \text{ and } 1/3 (X_2) = 1/4 (X_3)$$

$$\text{Or, } 3X_1 = 2X_2 \text{ and } 4X_2 = 3X_3$$

The linear programming model can be formulated as follows:

Maximise, $Z = 50X_1 + 50X_2 + 80X_3$

Subject to the Constraints:

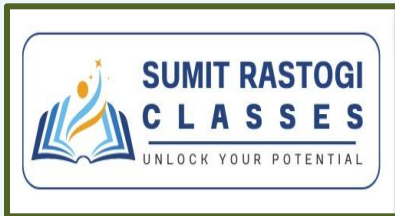
$$3X_1 + 4X_2 + 5X_3 \leq 5,000$$

$$5X_1 + 3X_2 + 5X_3 \leq 7,500$$

$$6X_1 + 3X_2 + 2X_3 \leq 18,000$$

$$3X_1 = 2X_2 \text{ and } 4X_2 = 3X_3$$

$$X_1 \geq 600 \text{ } X_2 \geq 650 \text{ and } X_3 \geq 500$$



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ANS. 6 (a)

Supply				
Availability (kgs.)	No. of Days	Probability	Cumulative Probability	Random No. Interval
10	40	0.08	0.08	00-07
20	50	0.10	0.18	08-17
30	190	0.38	0.56	18-55
40	150	0.30	0.86	56-85
50	70	0.14	1.00	86-99
Total	500	1.00		

Demand				
Demand (kgs.)	No. of Days	Probability	Cumulative Probability	Random No. Interval
10	50	0.10	0.10	00-09
20	110	0.22	0.32	10-31
30	200	0.40	0.72	32-71
40	100	0.20	0.92	72-91
50	40	0.08	1.00	92-99
Total	500	1.00		

Simulation Table:

Day	Random Nos.	Supply	Random Nos.	Demand	Buying Cost	Selling Price	Loss for Unsatisfied Demand	Profit (₹)
1	31	30	18	20	1,200	1,200	-	-
2	63	40	84	40	1,600	2,400	-	800
3	15	20	79	40	800	1,200	320	80
4	07	10	32	30	400	600	320	-120
5	43	30	75	40	1,200	1,800	160	440
6	81	40	27	20	1,600	1,200	-	-400
Total								800

During the simulated period of six days, the net profit of S-MART = ₹800.

ANS. 6 (b)

Row Operation:

Counter	Salesman			
	A	B	C	D
W	2	33	0	13
X	0	7	27	43
Y	0	12	33	24
Z	0	5	3	7

Column Operation:

Counter	Salesman			
	A	B	C	D
W	2	28	0	6
X	0	2	27	36
Y	0	7	33	17
Z	0	0	3	0

Here minimum number of horizontal and vertical straight lines to cover all the zeros = 3 $\neq$ Order (4) of the matrix. So, the solution is non-optimal. An improvement over this one is done by subtracting the minimum of the uncovered elements i.e. 2 from all the uncovered elements and adding that to the elements at the junction of lines.

Improved Matrix:

Counter	Salesman			
	A	B	C	D
W	4	28	0	6
X	0	0	25	34
Y	0	5	31	15
Z	2	0	3	0

In this case we find that the minimum number of lines to cover the zeros = 4 = Order of the matrix. Hence the solution is optimal.

We start assignment by choosing the 3rd cell with zero in the 1st row i.e. **cell W-C** and other zeros in the third Column are crossed out.

2nd row has more than one zero, so we assign 1st cell in 3rd row with zero, i.e. **cell Y-A** and cancel other zeros in 1st column.

Now, again 4th row has more than one zero so, we assign column wise, again column 2 have more than one zero so we assign the cell **D-Z** in 4th column and cross other zeros in the 4th row.

Now only one zero is left in the 2nd row and that is at the **cell X-B** where the last assignment is done.

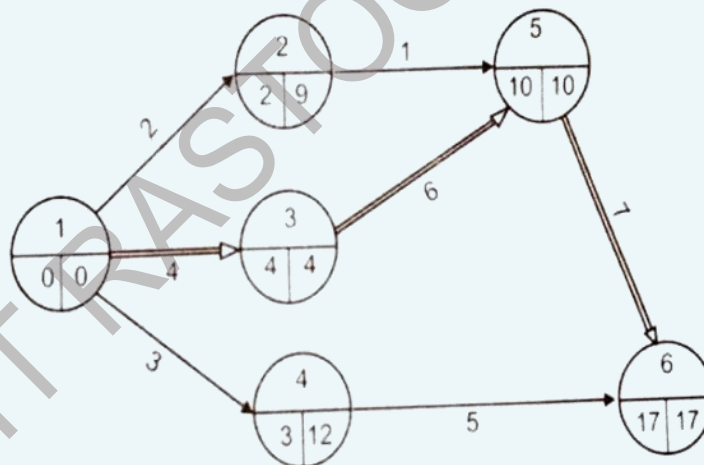
Optimal Assignments and Time:

Counter	Salesman	Time (Hours)
W	C	39
X	B	29
Y	A	27
Z	D	52
Total		147

Maximum profit = 147 Hours.

ANS. 7 (a)

(i) The network as below:



(ii) Critical path is 1-3-5-6

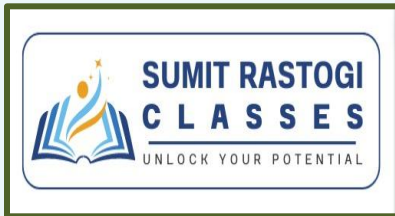
The total project duration is sum of the duration of each critical activity, i.e.

$$4 + 6 + 7 = 17 \text{ Weeks.}$$

(iii) Variance of the critical path is sum of the variance of each critical activity, i.e.

$$1 + 4 + 4 = 9 \text{ Weeks.}$$

$$\text{OR, (S.D.) } \sqrt{\text{Variance of the Project}} = 3$$



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(a) At least 3 weeks earlier than expected:

The Standard normal equation can be applied as follows:

$$Z = \frac{\text{Due Date} - \text{Expected Date of Completion}}{\text{S.D.}} = \frac{-3}{3} = -1$$

Referring to the normal table, we find a probability of = 0.1587 i.e. 15.87%

(b) No more than 3 weeks later than expected:

$$Z = \frac{20-17}{3} = 1$$

Probability = (0.50 + 0.3413) = 0.8413 i.e. 84.13%

(iv) $Z = \frac{18 - 17}{3} = 0.33$

Therefore, Probability of meeting the due date = 0.50 + 0.1293 = 0.6293 i.e. 62.93%

Probability of not meeting the due date = (1 - 0.6293) = 0.3707 = 0.3707 i.e. 37.07%

ANS. 7 (b)

Clearly, the first column is dominated by the second column as all the elements of the first column are greater than elements of second column. Thus eliminating first column, we get

		Firm Q	
		Medium Advertising	Heavy Advertising
Firm P	No. Advertising	5	-2
	Medium Advertising	12	15
	Heavy Advertising	14	10

Again, first row is dominated by second and third row as all the elements of first row are less than the respective elements of second and third row.

Hence eliminating first row, we obtain the following 2 × 2 pay-off matrix.

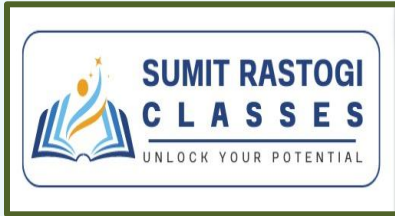
		Firm Q	
		Medium Advertising	Heavy Advertising
Firm P	Medium Advertising	12	15
	Heavy Advertising	14	10

As the pay-off matrix does not possess any saddle point, the firms will use mixed strategies. The optimum mixed strategy for firm P is determined by:

$$p_1 = \frac{10 - 14}{12 + 10 - (14 + 15)} = \frac{4}{7} \text{ and } p_2 = 1 - p_1 = 1 - 4/7 = \frac{3}{7}$$

and for the firm Q is given by:

$$q_1 = \frac{10 - 15}{12 + 10 - (14 + 15)} = \frac{5}{7} \text{ and } q_2 = 1 - q_1 = 1 - 5/7 = \frac{2}{7}$$



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Hence, the optimum strategies for the two firms are:

No Advertising Medium Advertising Heavy Advertising
 $S_A = [0 \qquad 4/7 \qquad 3/7]$

No Advertising Medium Advertising Heavy Advertising
 $S_B = [0 \qquad 5/7 \qquad 2/7]$

The Value of the game (corresponding to the above strategies) is given by:

$$V = \frac{12 \times 10 - 14 \times 15}{12 + 10 - (14 + 15)} = \frac{90}{7}$$

Hence, the Value of the Game is $V = 90/7$

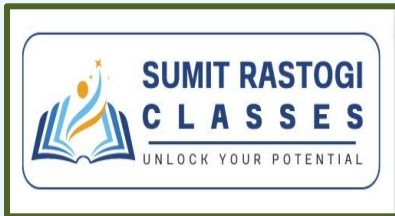
ANS. 8 (a)

Simulation Table:

Production Per Day	Probability	Cumulative Probability	Random No. Interval	Random No.	Demand	Scooters Waiting	Empty Space on Lorry
146	0.04	0.04	00-03	80	153	3	-
147	0.09	0.13	04-12	81	153	3	-
148	0.12	0.25	13-24	76	152	2	-
149	0.14	0.39	25-38	75	152	2	-
150	0.11	0.50	39-49	64	152	2	-
151	0.10	0.60	50-59	43	150	-	-
152	0.20	0.80	60-79	18	148	-	2
153	0.12	0.92	80-91	26	149	-	1
154	0.08	1.00	92-99	10	147	-	3
				12	147	-	3
				65	152	2	-
				68	152	2	-
				69	152	2	-
				61	152	2	-
				57	151	1	-
						21	9

(i) Average number of scooters waiting in the factory = $21/15 = 1.4$ per day.

(ii) Average number of empty space on the lorry = $9/15 = 0.6$ per day



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ANS. 8 (b)

(i) **Calculation of Contribution per unit:**

Particulars	Alfa (₹)	Beta (₹)
Selling Price	1,000	900
Less: Direct Material	(200)	(200)
Direct Labour	(160)	(80)
Painting	(60)	(120)
Variable OH	(380)	(350)
Contribution	200	150

Raw Material Required per unit for Alfa = $200/50 = 4$ kg & Beta = $200/50 = 4$ Kg

Labour hours required per unit of Alfa = $160/40 = 4$ hours & Beta = $80/40 = 2$ hours

Painting hours required per unit of Alfa = $60/60 = 1$ hour & Beta = $120/60 = 2$ hours

Let x_1 be the no. of units of Alfa

Let x_2 be the no. of units of Beta

Objective Function:

Maximize $Z = 200x_1 + 150x_2$

Subject to constraints:

$$\begin{aligned}
 4x_1 + 4x_2 &\leq 960 && \text{[Raw Material Constraints]} \\
 4x_1 + 2x_2 &\leq 800 && \text{[Labour Hours Constraints]} \\
 1x_1 + 2x_2 &\leq 400 && \text{[Painting Hours Constraints]} \\
 x_1, x_2 &> 0 && \text{[Non-negative Constraints]}
 \end{aligned}$$

(ii) **Dual of the problem:**

Minimize $Z = 960y_1 + 800y_2 + 400y_3$

Subject to constraints:

$$\begin{aligned}
 4y_1 + 4y_2 + 1y_3 &\geq 200 \\
 4y_1 + 2y_2 + 2y_3 &\geq 150 \\
 y_1, y_2, y_3 &\geq 0.
 \end{aligned}$$