Duration: 2 ½ Hours **Max. Marks: 75**

Note:

1. **All questions are compulsory. (Subject to internal Choice)**
2. **Figures to the right indicate full marks.**
3. **The normal distribution table is printed on the last page for reference.**
4. **Support your answers with diagrams/illustrations wherever necessary.**
5. **Graph paper will be supplied on request.**

Q1 A) State whether following Statements are True or False (Any Eight) **08**

1. Linear Programming Problems consist of decision variables, an objective function, and constraints.
2. In the Graphical Method of Linear Programming, the feasible region is always a polygon.
3. The Assignment Problem can have multiple optimal solutions.
4. In a balanced transportation problem, the total supply must be equal to the total demand.
5. Dummy activities are used in network diagrams to maintain logical dependencies.
6. The Program Evaluation and Review Technique (PERT) considers three time estimates for activity duration.
7. Crashing a project reduces both time and cost simultaneously.
8. In job sequencing, idle time refers to the time a machine remains unutilized.
9. A two-person zero-sum game means that one player's gain is exactly equal to the other player's loss.
10. In the Simplex Method, slack variables are introduced to convert inequalities into equations.

Q1 B) Match the Column Questions: (Any SEVEN) **07**

Column A	*Column B*
1. Feasible Region	a) Method to solve transportation problems
2. Redundant Constraint	b) Project scheduling technique
3. Decision Variables	c) Represents unused or excessive restrictions in LPP
4. Unbounded Solution	d) Graphical area satisfying all constraints in LPP
5. Duality in Linear Programming	e) Used in Linear Programming Formulation
6. MODI Method	f) When there is no finite optimal solution
7. Slack Variable	g) Difference between primal and dual problems
8. Network Diagram	h) Extra variable added to convert "≤" constraint into equality
9. Zero-Sum Game	i) One player's gain is equal to the other player's loss
10. Least Cost Method (LCM)	j) Heuristic approach for transportation problems

Q2 A) Vitamins B_1 and B_2 are found in two foods F_1 and F_2. 1 unit of F_1 contains 3 units of B_1 and 4 units of B_2. 1 unit of F_2 contains 5 units of B_1 and 3 units of B_2. The minimum daily prescribed consumption of B_1 & B_2 is 50 and 60 units, respectively. The cost per unit of F_1 & F_2 is Rs.6 & Rs.3, respectively. **08**

Formulate as LPP (Linear Programming Problem).

Q2 B) **Solve the following Linear Programming problem by simplex method.** **07**

Max. Z $= 3x_1 + 5x_2$

Subject to the constraints:

$x_1 + x_3 = 4$

$x_2 + x_4 = 6$

$3x_1 + 2x_2 + x_5 = 12$

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

Does degeneracy occur in this problem?

OR

Q2 C) During the modification of a factory layout at BMS Auto Parts, four newly acquired machines—M_1, M_2, M_3, and M_4—need to be installed in a machine shop. The shop has five available locations: A, B, C, D, and E, which are suitable for installation. **08**

However, due to size constraints:

- M_2 cannot be placed at C, and
- M_3 cannot be placed at A.

The installation cost (in hundreds of rupees) for each machine at different locations is given in the following table:

Machines	**Location**				
	A	**B**	**C**	**D**	**E**
M_1	9	11	15	10	11
M_2	12	9	**X**	10	9
M_3	**X**	11	14	11	7
M_4	14	8	12	7	8

Find the optimal assignment that minimizes the total installation cost.

Q2 D) Solve the following LPP by the graphical Method **07**

Maximize $Z=50x_1+20x_2$

Constraints:

$x_1+x_2 \leq 600$

$x_1+x_2 \geq 300$

$6x_1+2x_2 \geq 1200$

$x_1x_2 \geq 0$

Q3 A) For a project, different activities along with time and cost estimates are given below: **08**

Activity	Normal Time (Days)	Crash Time (Days)	Cost Slope (ΔC/ΔT) (Rs)	Normal Cost (Rs)
1 - 2	4	3	30	100
1 - 3	6	4	50	250
1 - 4	2	1	20	45
2 - 4	5	3	50	100
3 - 4	2	2	NIL	150
2 - 5	7	5	35	120
4 - 5	4	2	60	115

Indirect cost is Rs. 100 per day.

(a) Construct the project network and identify the critical path. What is the normal duration and corresponding total cost of the project?

(b) Systematically Crash the project and find the minimum cost and optimal time. Also, find out the additional costs required to reach the optimal time.

(c) Find the total cost required to reach the minimum time.

Q3 B) A company is transporting its units from three factories F_1, F_2, and F_3 to four warehouses W_1, W_2, W_3, and W_4. The transportation cost per unit (in Rs.), along with supply and demand details, is provided below. The total demand for warehouses is as follows: W_1: 400 units W_2: 500 units W_3: 700 units W_4: 800 units. The total supply available from the factories is: F_1: 800 units F_2: 600 units F_3: 1000 units **07**

A feasible solution, including allocations and unit cost data, is presented in the table below.

From → To	W_1	W_2	W_3	W_4	Supply
F_1	12 (300)	6 (500)	20	25	**800**
F_2	6 (100)	11	15 (500)	12	**600**
F_3	9	15	17 (200)	7 (800)	**1000**
Demand	**400**	**500**	**700**	**800**	**2400**

(i) Test the given solution for optimality using the Modified Distribution Method (MODI Method).

(ii) If the solution is not optimal, modify it to obtain the best possible solution.

(iii) Determine the minimum transportation cost.

OR

Q3 C) M/s Motwani Limited have taken up a special project consisting of 10 activities whose three point time estimates are listed in the table below. Activities are marked with their node numbers. **15**

Activity	Time Estimates in Weeks		
	Optimistic	Most Likely	Pessimistic
1-2	1	2	3
1-3	1	2	3
1-4	1	2	3
2-5	4	9	20
3-5	2	5	14
3-7	3	6	15
5-7	1	2	9
4-6	2	4	6
6-7	3	3	3
7-8	4	4	4

(a) Draw network diagram and find expected completion time of project.
(b) Identity critical path.
(c) Find the probability that the project is completed in 17 weeks.
(d) What is the probability that the project will not be completed in 20 weeks?
(e) If the project includes a penalty clause of Rs.1,000 per week for any delay beyond 19 weeks. What is the probability of paying a penalty of more than Rs. 5,000.

Q4 A) Six jobs **P, Q, R, S, T, and U** are to be processed on two machines **M and N** in the order **MN**. The processing time (in minutes) for each job on the respective machines is given below: **08**

Jobs	Machine M	Machine N
P	28	50
Q	20	35
R	42	25
S	16	30
T	33	22
U	26	45

Find:

a) The optimal sequence of jobs to minimize total elapsed time.
b) The total elapsed time.
c) Idle time for each machine.

Q4 B) Alpha Corp (Firm A) and Beta Ltd (Firm B) are two competing firms in a market. Each firm has three possible strategic choices to maximize their payoffs. The following **payoff matrix** represents the outcomes for Alpha Corp based on the strategic interactions with Beta Ltd. **07**

	Beta I	**Beta II**	**Beta III**
Alpha I	220	150	170
Alpha II	-50	40	-20
Alpha III	140	120	100

Find:

1. Identify the **optimal maximin strategy** for Alpha Corp.
2. Determine the **optimal minimax strategy** for Beta Ltd.
3. Compute the **value of the game** and check if a **saddle point** exists.

OR

Q4 C) A company has 3 plants P1, P2 and P3. It supplies to 4 warehouses W1, W2, W3 and W4. Cost per unit and demand – supply data is as given below. Find the Initial Feasible Solution (IFS) using the Least Cost Method (LCM). **08**

Plant	W1	W2	W3	W4	Capacity
P1	10	12	18	22	400
P2	22	18	28	26	300
P3	30	36	52	40	300
Demand	50	150	350	450	

Q4 D) Six jobs **G, H, I, J, K, L** are to be processed on three machines **A, B, C** in the order **A → B → C**. The processing times (in hours) are: **07**

Machine	G	H	I	J	K	L
A	8	9	7	10	6	11
B	2	4	5	3	2	6
C	5	7	4	6	3	8

Find:

1. The optimal job sequence that minimizes total elapsed time.
2. The total elapsed time.
3. Idle time on Machine A, Machine B, and Machine C.

Q5 A) Explain Forward pass and Backward Pass calculation of Network Analysis **08**

Q5 B) Explain Different techniques of Operation Research. **07**

OR

Q5 C) Write Short Notes (ANY THREE) **15**

1. Vogel's Approximation Method (VAM) in Transportation Problems
2. North-West Corner Rule for Initial Feasible Solution
3. Differences Between Balanced and Unbalanced Transportation Problems
4. Concept of Free Float, Total Float, and Independent Float in CPM
5. Saddle Point and Its Significance in Game Theory

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Normal Probability Table

Areas under the Standard Normal Curve from 0 to z

z	0	1	2	3	4	5	6	7	8	9
0.0	.0000	.0040	.0080	.0120	.0160	.0199	.0239	.0279	.0319	.0359
0.1	.0398	.0438	.0478	.0517	.0557	.0596	.0636	.0675	.0714	.0753
0.2	.0793	.0832	.0871	.0910	.0948	.0987	.1026	.1064	.1103	.1141
0.3	.1179	.1217	.1255	.1293	.1331	.1368	.1406	.1443	.1480	.1517
0.4	.1554	.1591	.1628	.1664	.1700	.1736	.1772	.1808	.1844	.1879
0.5	.1915	.1950	.1985	.2019	.2054	.2088	.2123	.2157	.2190	.2224
0.6	.2258	.2291	.2324	.2357	.2389	.2422	.2454	.2486	.2518	.2549
0.7	.2580	.2612	.2642	.2673	.2704	.2734	.2764	.2794	.2823	.2852
0.8	.2881	.2910	.2939	.2967	.2996	.3023	.3051	.3078	.3106	.3133
0.9	.3159	.3186	.3212	.3238	.3264	.3289	.3315	.3340	.3365	.3389
1.0	.3413	.3438	.3461	.3485	.3508	.3531	.3554	.3577	.3599	.3621
1.1	.3643	.3665	.3686	.3708	.3729	.3749	.3770	.3790	.3810	.3830
1.2	.3849	.3869	.3888	.3907	.3925	.3944	.3962	.3980	.3997	.4015
1.3	.4032	.4049	.4066	.4082	.4099	.4115	.4131	.4147	.4162	.4177
1.4	.4192	.4207	.4222	.4236	.4251	.4265	.4279	.4292	.4306	.4319
1.5	.4332	.4345	.4357	.4370	.4382	.4394	.4406	.4418	.4429	.4441
1.6	.4452	.4463	.4474	.4484	.4495	.4505	.4515	.4525	.4535	.4545
1.7	.4554	.4564	.4573	.4582	.4591	.4599	.4608	.4616	.4625	.4633
1.8	.4641	.4649	.4656	.4664	.4671	.4678	.4686	.4693	.4699	.4706
1.9	.4713	.4719	.4726	.4732	.4738	.4744	.4750	.4756	.4761	.4767
2.0	.4772	.4778	.4783	.4788	.4793	.4798	.4803	.4808	.4812	.4817
2.1	.4821	.4826	.4830	.4834	.4838	.4842	.4846	.4850	.4854	.4857
2.2	.4861	.4864	.4868	.4871	.4875	.4878	.4881	.4884	.4887	.4890
2.3	.4893	.4896	.4898	.4901	.4904	.4906	.4909	.4911	.4913	.4916
2.4	.4918	.4920	.4922	.4925	.4927	.4929	.4931	.4932	.4934	.4936
2.5	.4938	.4940	.4941	.4943	.4945	.4946	.4948	.4949	.4951	.4952
2.6	.4953	.4955	.4956	.4957	.4959	.4960	.4961	.4962	.4963	.4964
2.7	.4965	.4966	.4967	.4968	.4969	.4970	.4971	.4972	.4973	.4974
2.8	.4974	.4975	.4976	.4977	.4977	.4978	.4979	.4979	.4980	.4981
2.9	.4981	.4982	.4982	.4983	.4984	.4984	.4985	.4985	.4986	.4986
3.0	.4987	.4987	.4987	.4988	.4988	.4989	.4989	.4989	.4990	.4990
3.1	.4990	.4991	.4991	.4991	.4992	.4992	.4992	.4992	.4993	.4993
3.2	.4993	.4993	.4994	.4994	.4994	.4994	.4994	.4995	.4995	.4995
3.3	.4995	.4995	.4995	.4996	.4996	.4996	.4996	.4996	.4996	.4997
3.4	.4997	.4997	.4997	.4997	.4997	.4997	.4997	.4997	.4997	.4998
3.5	.4998	.4998	.4998	.4998	.4998	.4998	.4998	.4998	.4998	.4998
3.6	.4998	.4998	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999
3.7	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999
3.8	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999
3.9	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000