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UPSC CSE Mathematics: Previous Year Questions: LPP

2025

1) How many basic solutions are there for the following system of equations?

$$2x_1 - x_2 + 3x_3 + x_4 = 6$$
$$4x_1 - 2x_2 - x_3 + 2x_4 = 10$$

Find all of them. Furthermore, find the number of basic solutions, which are feasible/non-feasible/non-degenerate.

2) Apply the principle of duality to solve the following linear programming problem:

Maximize $Z = 3x_1 + 4x_2$

subject to the constraints
$$x_1 - x_2 \leq 1$$
$$x_1 + x_2 \geq 4$$
$$x_1 - 3x_2 \leq 3$$
$$x_1, x_2 \geq 0$$

3) The following table shows all the necessary information on the available supply to each

		Market				
		I	*II*	*III*	*IV*	*Supply*
Warehouse	*A*	5	2	4	3	22
	B	4	8	1	6	15
	C	4	6	7	5	8
	Requirement	7	12	17	9	

warehouse, the requirement of each market and the unit transportation cost from each warehouse to each market :

The shipping clerk has worked out the following schedule from experience:

12 units from A to II, 1 unit from A to III, 9 units from A to IV, 15 units from B to III, 7 units from C to I and 1 unit from C to III.

Find the optimal schedule and minimum total shipping cost.

2024

1) Use two phase method to solve the following linear programming problem :

$$\begin{aligned} \text{Maximize} \quad & z = x_1 + 2x_2 \\ \text{Minimize} \quad & z = 4x_1 + 3x_2 + x_3 \\ \text{subject to} \quad & x_1 + 2x_2 + 4x_3 \geq 12 \\ & 3x_1 + 2x_2 + x_3 \geq 8 \\ & x_1, x_2, x_3 \geq 0 \end{aligned}$$

2) Using duality principle, solve the following linear programming problem :

3) The personnel manager of a company wants to assign officers A, B and C to the regional offices at Delhi, Mumbai, Kolkata and Chennai. The cost of relocation (in thousand Rupees) of the three officers at the four regional offices are given below :

Find the assignment which minimizes the total cost of relocation and also determine the minimum cost.

	Office			
Officer	Delhi	Mumbai	Kolkata	Chennai
A	16	22	24	20
B	10	32	26	16
C	10	20	46	30

2023

1) A person requires 24,24 and 20 units of chemicals A, B and C respectively for his garden. Product P contains 2,4 and 1 units of chemicals A, B and C respectively per jar and product Q contains 2,1 and 5 units of chemicals A, B and C respectively per jar. If a jar of P costs ₹30 and a jar of Q costs ₹50, then how many jars of each should be purchased in order to minimize the cost and meet the requirements?

2) Solve the following linear programming problem by Big M method

$$\text{Minimize} \quad Z = 2x_1 + 3x_2$$

subject to

$$x_1 + x_2 \geq 9$$
$$x_1 + 2x_2 \geq 15$$
$$2x_1 - 3x_2 \leq 9$$
$$x_1, x_2 \geq 0$$

Is the optimal solution unique? Justify your answer.

3) A department head has 5 subordinates and 5 jobs to be performed. The time (in hours) that

		Jobs				
		A	*B*	*C*	*D*	*E*
Subordinates	*I*	4	9	4	12	4
	II	15	11	20	5	8
	III	17	7	15	12	18
	IV	9	13	11	9	14
	V	6	11	12	9	14

each subordinate will take to perform each job is given in the matrix below:

How should the jobs be assigned, one to each subordinate, so as to minimize the total time?

Also, obtain the total minimum time to perform all the jobs if the subordinate IV cannot be assigned job C.

2022

1) Use two-phase method to solve the following linear programming problem:

$$\text{Minimize} \quad Z = x_1 + x_2$$

subject to

$$2x_1 + x_2 \geq 4$$
$$x_1 + 7x_2 \geq 7$$
$$x_1, x_2 \geq 0$$

2) Solve the following linear programming problem by the simplex method. Write its dual. Also, write the optimal solution of the dual from the optimal table of the given problem:

$$\text{Maximize} \quad Z = x_1 + x_2 + x_3$$

subject to

$$2x_1 + x_2 + x_3 \leq 2$$
$$4x_1 + 2x_2 + x_3 \leq 2$$
$$x_1, x_2, x_3 \geq 0$$

3) Find the initial basic feasible solution of the following transportation problem by Vogel's approximation method and use to find the optimal solution and transportation cost of problem

		Destination				
		A	B	C	D	
Source	S_1	21	16	25	13	11
	S_2	17	18	14	23	13
	S_3	32	27	18	41	19
Requirement		6	10	12	15	43

Availability

2021

1) A department of a company has five employees with five jobs to be performed. The time (in hours) that each man takes to perform each job is given in the effectiveness matrix. Assign all the jobs to these five employees to minimize the total processing time :

		Employees				
		I	II	III	IV	V
Jobs	A	10	5	13	15	16
	B	3	9	18	13	6
	C	10	7	2	2	2
	D	7	11	9	7	12
	E	7	9	10	4	12

2) Convert the following LPP into dual LPP :

$$\text{Minimize} \quad Z = x_1 - 3x_2 - 2x_3$$

subject to

$$3x_1 - x_2 + 2x_3 \le 7$$
$$2x_1 - 4x_2 \ge 12$$
$$-4x_1 + 3x_2 + 8x_3 = 10$$

where $x_1, x_2 \ge 0$ and x_3 is unrestricted in sign.

3) Solve the following linear programming problem using Big M method :

$$\text{Maximize} \quad Z = 4x_1 + 5x_2 + 2x_3$$

subject to

$$2x_1 + x_2 + x_3 \ge 10$$
$$x_1 + 3x_2 + x_3 \le 12$$
$$x_1 + x_2 + x_3 = 6$$
$$x_1, x_2, x_3 \ge 0$$

2020

1. UPSC maintenance section has purchased sufficient number of curtain cloth pieces to meet the curtain requirement of its building. The length of each piece is 17 feet. The requirement according to curtain length is as follows:

Curtain length (in feet)	Number required
5	700
9	400
7	300

The width of all curtains is same as that of available pieces. Form a linear programming problem in standard from that decided the number of pieces cut in different ways so that the total trim loss is minimum. Also give a basic feasible solution to it.

2. Solve the linear programming problem using simple method:

$$\begin{aligned} \text{Minimize } z &= -6x_1 - 2x_2 - 5x_3 \\ \text{subject to } & 2x_1 - 3x_2 + x_3 \leq 14 \\ & -4x_1 + 4x_2 + 10x_3 \leq 46 \\ & 2x_1 + 2x_2 - 4x_3 \leq 37 \\ & x_1 \geq 2,\ x_2 \geq 1,\ x_3 \geq 3 \end{aligned}$$

3. Find the initial basic feasible solution of the following transportation problem by Vogel's approximation method and use it to find the optimal solution and the transportation cost of the problem.

		Destinations				
		D_1	D_2	D_3	D_4	Demand
Sources	S_1	10	0	20	11	15
	S_2	12	8	9	20	25
	S_3	0	14	16	18	10
	Supply	5	20	15	10	

2019

1) Use graphical method to solve the linear programming problem.

$$\begin{aligned} \text{Maximize } Z &= 3x_1 + 2x_2 \\ \text{subject to} & \\ & x_1 - x_2 \geq 1, \\ & x_1 + x_3 \geq 3 \\ \text{and} \quad & x_1, x_2, x_3 \geq 0 \end{aligned}$$

2) Solve the linear programming problem using Simplex Method.

Minimize $Z = x_1 + 2x_2 - 3x_3 - 2x_4$
subject to
$x_1 + 2x_2 - 3x_3 + x_4 = 4$
$x_1 + 2x_2 + x_3 + 2x_4 = 4$
and $x_1, x_2, x_3, x_4 \geq 0$

3) Consider the following LPP,

Maximize $Z = 2x_1 + 4x_2 + 4x_3 - 3x_4$
subject to
$x_1 + x_2 + x_3 = 4$
$x_1 + 4x_2 + x_4 = 8$
and $x_1, x_2, x_3, x_4 \geq 0$

Use the dual problems to verify that the basic solution (x_1, x_2) is not optimal

2018

1) An agricultural firm has 180 tons of nitrogen fertilizer, 250 tons of phosphate and 220 tons of potash. It will be able to sell a mixture of these substances in their respective ratio $3:3:4$ at a profit of Rs.1500 Per ton and a mixture in the ratio 2: 4: 2 at a profit of Rs. 1200 per ton. Pose a linear programming problem to show how many tons of these two mixtures should be prepared to obtain the maximum profit.

2) Solve the following liner programming problem by Big M-method and show that the problem has finite optional has finite optimal solutions. Also Find the value of the objective Function:

Minimize $z = 3x_1 + 5x_2$ subject to

$$x_1 + 2x_2 \geq 8$$
$$3x_1 + 2x_2 \geq 12$$
$$5x_1 + 6x_2 \leq 60$$
$$x_1, x_2 \geq 0.$$

3) In a factory there are five operators O_1, O_2, O_3, O_4, O_5, and five machines M_1, M_2, M_3, M_4, M_5 The operating costs are given when the O_i operator. Operates the M_j machine $(i, j = 1,2, \dots ,5)$. .But there is a restriction that 0_3 cannot be allowed to operate the third machine M_3 and 0_2 cannot be allowed to operate the fifth machine M_5 The cost matrix is given below. Find the optimal assignment and the optimal Machines assignment cost also.

		Machines				
		M_1	M_2	M_3	M_4	M_5
Operator	O_1	24	29	18	32	19
	O_2	17	26	34	22	21
	O_3	27	16	28	17	25
	O_4	22	18	28	30	24
	O_5	28	16	31	24	27

4) How many basic solutions are there in the following linearly independent set of equations? Find all of them.

$$2x_1 - x_2 + 3x_3 + x_4 = 6$$
$$4x_1 - 2x_2 - x_3 + 2x_4 = 10.$$

2017

1) Using graphical method, find the maximum values of $2x + y$

Subject to

$$4x + 3y \leq 12$$
$$4x + y \leq 8$$
$$4x - y \leq 8$$
$$x, y \geq 0$$

2) Solve the following linear programming problem by simplex method:

Maximize $z = 3x_1 + 5x_2 + 4x_3$ Subject to

$$2x_1 + 3x_2 \leq 8$$
$$2x_2 + 5x_3 \leq 10$$
$$3x_1 + 2x_2 + 4x_3 \leq 15x_3$$
and $x_1, x_2, x_3 \geq 0$.

3) Find the initial basic feasible solution of the following transportation problem using Vogel's approximation methods and find the cost.

		Destinations					
		D_1	D_2	D_3	D_4	D_5	
Origins	O_1	4	7	0	3	6	14
	O_2	1	2	−3	3	8	9
	O_3	3	−1	4	0	5	17
		8	3	8	13	8	
		Demand					

Supply

2016

1) Find the maximum value of $5x + 2y$ with constraints $x + 2y \geq 1, 2x + y \leq 1, x \geq 0$ by $y \geq 0$ graphically method.

2) Maximize $z = 2x_1 + 3x_2 + 6x_3$

Subjected to

$$2x_1 + x_2 + x_3 \leq 5$$
$$3x_2 + 2x_3 + \leq 6$$
and $x_1 \geq 0, x_2 \geq 0, x_3 \geq 0$

Is the optimal solution unique? Justify your answer.

2015

1) Solve the following assignment problem to maximize the sales

		Territoreis				
		I	II	III	IV	V
Salesmen	A	3	4	5	6	7
	B	4	15	13	7	6
	C	6	13	12	5	11
	D	7	12	15	8	5
	E	8	13	10	6	9

2) Consider the following linear programming problem

Maximize $Z = x_1 + 2x_2 - 3x_3 + 4x_4$ subject to

$$x_1 + x_2 + 2x_3 + 3x_4 = 12$$
$$x_2 + 2x_3 + x_4 = 8$$
$$x_1, x_2, x_3, x_4 \geq 0$$

(i)Using the definition, find its all-basic solutions. Which of these are degenerate basic feasible solutions and which are non-degenerate basic feasible solutions?

(ii) Without solving the problem, show that it has an optimal solution and which of the basic feasible solution(s) is/are optimal?

3) Solve the following linear programming problem by the simplex method. Write its dual. Also, write the optimal solution of the dual from the optimal table of the given problem:

Maximize $Z = 2x_1 - 4x_2 + 5x_3$
subject to
$$x_1 + 4x_2 - 2x_3 \leq 2$$
$$-x_1 + 2x_2 + 3x_3 \leq 1$$
$$x_1, x_2, x_3 \geq 0$$

2014

1) Solve graphically: Maximize $Z = 6x_1 + 5x_2$ Subject to

$$2x_1 + x_2 \leq 16$$
$$x_1 + x_2 \leq 11$$
$$x_1 + 2x_2 \geq 6$$
$$5x_1 + 6x_2 \leq 90$$

2) Find the initial basic feasible solution to the following transportation problem by Vogel's approximation method. Also, find its optimal solution and the minimum transportation cost

		D_1	D_2	D_3	D_4	Supply
Origins	O_1	6	4	1	5	14
	O_2	8	9	2	7	16
	O_3	4	3	6	2	5
Demand		6	10	15	4	

3) Find all optimal solutions of the following linear programming problem by the simplex method: Maximize $Z = 30x_1 + 24x_2$ Subject to

$$5x_1 + 4x_2 \leq 200$$
$$x_1 \leq 32$$
$$x_2 \leq 40$$
$$x_1 x_2 \geq 0$$

2013

1) Solve the following linear programming problem

Maximize $Z = 2x_1 + 3x_2 - 5x_3$ Subject to

$$x_1 + x_2 + x_3 = 7$$
$$2x_1 - 5x_2 + x_3 \geq 10$$
$$x_1, x_2, x_3 \geq 0$$

2) Solve the minimum time assignment problem

		Machines			
		M_1	M_2	M_3	M_4
Jobs	J_1	3	12	5	14
	J_2	7	9	8	12
	J_3	5	11	10	12
	J_4	6	14	4	11

3) Solve the following linear programming problem Minimize $Z = 5x_1 - 4x_2 + 6x_3 - 8x_4$ Subject to the constraints

$$x_1 + 2x_2 - 2x_3 + 4x_4 \leq 40$$
$$2x_1 - x_2 + x_3 + 2x_4 \leq 8$$
$$4x_1 - 2x_2 + x_3 - x_4 \leq 10$$
$$\text{and } x_1, x_2, x_3, x_4 \geq 0$$

2012

1) For each hour per day that Ashok studies mathematics, it yields him 10 marks and for each hour that he studies physics, it yields him 5 marks. He can study at most 14 hours a day and he must get at least 40 marks in each. Determine graphically how many hours a day he should study mathematics and physics each, in order to maximize his marks?

2) By the method of Vogel, determine an initial basic feasible solution for the following transportation problem: Products $P_1, P_2, P_3, \& P_4$ have to be sent of destinations $D_1, D_2 \& D_3$. The cost of sending product P_i to destinations D_j is C_{ij}, where the matrix

$$[C_{ij}] = \begin{bmatrix} 10 & 0 & 15 & 5 \\ 7 & 3 & 6 & 15 \\ 0 & 11 & 9 & 13 \end{bmatrix}$$

The total requirements of destinations $D_1, D_2 \& D_3$ are given by 45, 45, 95 respectively and the availability of the products $P_1, P_2, P_3, \& P_4$ are respectively 25,35,55 and 70 .

2011

1) Solve by simplex method, the following LP Problem: Maximize, $Z = 5x_1 + x_2$ Subject to constraints,

$$3x_1 + 5x_2 \leq 15$$
$$5x_1 + 2x_2 \leq 10$$
$$x_1, x_2 \geq 0$$

2) Write down the dual of the following LP problem and hence solve it by graphical method: Minimize $Z = 6x_1 + 4x_2$ Subject to constraints

$$2x_1 + x_2 \geq 1$$
$$3x_1 + 4x_2 \geq 1.5$$
$$x_1, x_2 \geq 0$$

2010

1) Construct the dual of the primal problem: Maximize $Z = 2x_1 + x_2 + x_3$ Subject to the constraints

$$x_1 + x_2 + x_3 \geq 6$$
$$3x_1 - 2x_2 + 3x_3 = 3$$
$$-4x_1 + 3x_2 - 6x_3 = 1$$
$$x_1, x_2, x_3 \geq 0$$

2) Determine an optimal transportation programme so that the transportation cost of 340 tons of a certain type of material from three factories to five warehouses W_1, W_2, W_3, W_4, W_5 is minimized. The five warehouses must receive 40 tons, 50 tons, 70 tons, . 90 tons and 90 tons respectively. The availability of the material at F_1, F_2, F_3 is 100 tons, 120 tons, 120 tons respectively. The transportation costs per ton from factories to warehouses are given in the table below:

	W_1	W_2	W_3	W_4	W_5
F_1	4	1	2	6	9
F_2	6	4	3	5	7
F_3	5	2	6	4	8

Use Vogel's approximation method to obtain the initial basic feasible solution.

2009

1) A paint factory produces both interior and exterior paint from two raw materials M_1 and M_2. The basic data is as follows:

	Tons of raw material per ton of		Maximum daily availability
	Exterior paint	Interior paint	
Raw Material M_1	6	4	24
Raw Material M_2	1	2	6
Profit per ton (Rs. 1000)	5	4	

A market survey indicates that the daily demand interior paint cannot exceed that of exterior paint by more than 1 ton. The maximum daily demand of interior paint is 2 tons. The factory wants to determine the optimum product mix of interior and exterior paint that maximizes daily profits. Formulate the LP problem for this situation

2) Solve the following linear programming problem:

Maximize $Z = 3x_1 + 5x_2 + 4x_3$ Subjet to

$$2x_1 + 3x_2 \leq 8$$
$$3x_1 + 2x_2 + 4x_3 \leq 15$$
$$2x_2 + 5x_3 \leq 10$$
$$x_1, x_2, x_3 \geq 0$$

2008

1) Find the dual of the following linear programming problem:

Max $Z = 2x_1 - x_2 + x_3$

Subject to

$$x_1 + x_2 - 3x_3 \leq 8$$
$$4x_1 - x_2 + x_3 = 2$$
$$2x_1 + 3x_2 - x_3 \geq 5$$
$$x_1, x_2, x_3 \geq 0$$

2) Solve the following transportation problem:

		Destinations						
		D_1	D_2	D_3	D_4	D_5	D_6	Availability
Factories	F_1	2	1	3	3	2	5	50
	F_2	3	2	2	4	3	4	40
	F_3	3	5	4	2	4	1	60
	F_4	4	2	2	1	2	2	30
	Demand	30	50	20	40	30	10	180

by finding the initial solution by Matrix Minima Method

2007

1) Put the following in slack form and describe which of the variables are 0 at each of the vertices of the constraint set and hence determine the vertices algebraically:

Maximize $Z = 4x + 3y$ Subject to

$$x + y \leq 4$$
$$-x + y \leq 2$$
$$x, y \geq 0$$

2) Solve the following by Simplex method:

Maximize $u = x + y$ Subject to

$$-x + y \leq 1$$
$$x - 2y \leq 4$$
$$x, y \geq 0$$

2006

1) Given the programme Maximize $u = 5x + 2y$ Subject to

$$x + 3y \leq 12$$
$$3x - 4y \leq 9$$
$$7x + 8y \leq 20$$
$$x, y \geq 0$$

2) Use the simplex method to solve the problem

Maximize $u = 2x + 3y$ Subject to

$$-2x + 3y \leq 2$$
$$3x + 2y \leq 5$$
$$x, y \geq 0$$

2005

1) Put the following program in standard form:

Minimize $Z = 25x_1 + 30x_2$ Subject to

$$4x_1 + 7x_2 \geq 1$$
$$8x_1 + 5x_2 \geq 3$$
$$6x_1 + 9x_2 \geq -2$$
$$x_1, x_2 \geq 0$$

2) Use the simplex method to solve the problem

Maximize $Z = 5x_1 + 2x_2$ Subject to

$$6x_1 + x_2 \geq 6$$
$$4x_1 + 3x_2 \geq 12$$
$$x_1 + 2x_2 \geq 4$$

and $x_1, x_2 \geq 0$

2004

1) Use simplex method to solve the linear programming problem:

Max $Z = 3x_1 + 2x_2$ Subject to

$$x_1 + x_2 \leq 4$$
$$x_1 - x_2 \leq 2$$
$$x_1, x_2 \geq 0$$

2) A travelling salesman has to visit 5 cities. He wishes to start from a particular city, visit each city once and then return to his starting point. Cost of going from one city to another is given below: You are required to find the least cost route

	A	B	C	D	E
A	∞	4	10	14	2
B	12	∞	6	10	4
C	16	14	∞	8	14
D	24	8	12	∞	10
E	2	6	4	16	∞

3) A department has 4 technicians and 4 tasks are to be performed. The technicians differ in efficiency and tasks differ in their intrinsic difficulty. The estimate of time (in hours), each technician would take to perform a task is given below. How should the task be allotted, one to a technician, so as to minimize the total work hours?

Task / Technician	I	II	III	IV
A	8	26	17	11
B	13	28	4	26
C	38	19	18	15
D	19	26	24	10

2003

1) For the following system of equations

$x_1 + x_2 + x_3 = 3$

$2x_1 - x_2 + 3x_3 = 4$

Determine:

i. All basic solutions

ii. All basic feasible solutions

iii. A feasible solution which is not a basic feasible solution.

2) An animal feed company must produce 200 kg of a mixture consisting of ingredients X_1 and X_2 daily. X_1 costs Rs. 3 per Kg and X_2 costs Rs. 8 per Kg. No more than 80Kg of X_1 can be used, and at least 60Kg of X_2 must be used. Formulate a linear programming model of the problem and use Simplex method to determine the ingredients X_1 and X_2 to be used to minimize cost

3) Find the optimal solution for the assignment problem with the following cost matrix:

$$\begin{bmatrix} 6 & 1 & 9 & 11 & 12 \\ 2 & 8 & 17 & 2 & 5 \\ 11 & 8 & 3 & 3 & 3 \\ 4 & 10 & 8 & 6 & 11 \\ 8 & 10 & 11 & 5 & 13 \end{bmatrix}$$

Indicate clearly the rule you apply to arrive at the complete assignment.

2002

1) Using Simplex method

Maximize $Z = 45x_1 + 80x_2$

Subject to

$$5x_1 + 20x_2 \leq 400$$
$$10x_1 + 15x_2 \leq 450$$
$$x_1, x_2 \geq 0$$

2) Using simplex method maximize

Maximize $Z = 5x_1 + 3x_2$

Subject to

$$x_1 + x_2 \leq 2$$
$$5x_1 + 2x_2 \leq 10$$
$$3x_1 + 8x_2 \leq 12$$
$$x_1, x_2 \geq 0$$

3) A company has 3 factories A, B and C which supply units to warehouses X, Y and Z. Every month the capacities of the factories per month are 60, 70 and 80 units A, B and C respectively. The requirements of X, Y and Z are 50, 80 and 80 respectively. The necessary data in terms of unit transportation cost in rupees, factory capacities and warehouse requirements are given below:

	X	Y	Z	
A	8	7	5	60
B	6	8	9	70
C	9	6	5	80
	50	80	80	210

Find the minimum distribution cost.

2001

1) Compute all basic feasible solutions of the linear programming problem

Maximize $Z = 2x_1 + 3x_2 + 2x_3$ Subject to

$$2x_1 + 3x_2 - x_3 = 8$$
$$x_1 - 2x_2 + 6x_3 = -3$$
$$x_1, x_2, x_3 \geq 0$$

And hence indicate the optimal solution.

2) Using duality or otherwise solve the linear programming problem

Minimize $Z = 18x_1 + 12x_2$ Subject to

$$2x_1 - 2x_2 \geq -3$$
$$3x_1 + 2x_2 \geq 3$$
$$x_1, x_2 \geq 0$$

3) A manufacturer has distribution centers at Delhi, Kolkata and Chennai. These centers have available 30, 50 and 70 units of his product. His four retail outlets require the following number of units: A, 30: B, 20; C, 60; D, 40. The transportation cost per unit in rupees between each center and outlet is given in the following table:

Distribution Centers	Retail outlets			
	A	B	C	D
Delhi	10	7	3	6
Kolkata	1	6	7	3
Chennai	7	4	5	3

Determine the minimum transportation cost.