Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

SCHOOL OF MECHANICAL ENGINEERING
CONTINUOUS ASSESSMENT TEST – I
WINTER SEMESTER 2023-2024

Reg. No.
(To be filled by the student)

Programme Name & Branch	**: B.Tech. Mechanical Engineering, B.Tech. Mechanical with Specialization in Automotive Engineering & B.Tech. Mechanical with Specialization in Manufacturing Engineering**
Course Code	**: BMEE215L**
Course Name	**: ENGINEERING OPTIMIZATION**
Faculty Name(s)	**: Dr. John Rajan A, Dr. Soumen Pal, Dr. Jeeva P A, Dr. Sundaramali G**
Class Number(s)	**: VL2023240504655, VL2023240504654, VL2023240504647, VL2023240504656**
Slot	**: C2+TC2+TCC2**
Date of the Exam	**: 13-Feb-2024**
Exam Duration	**: 90 minutes** **Maximum Marks: 50**

General instructions:

- ***Use of non-programmable calculator is permitted.***
- ***Use of graph sheet is compulsory for solving appropriate problem.***

ANSWER ALL QUESTIONS

1. a) A firm can produce three types of cloth, say: A, B and C. Three kinds of wool are required for it, say: red, green and blue wool. One unit length of type A cloth needs 2 meters of red wool and 3 meters of blue wool; one unit length of type B cloth needs 3 meters of red wool, 2 meters of green wool and 2 meters of blue wool; and one unit of type C cloth needs 5 meters of green wool and 4 meters of blue wool. The firm has only a stock of 8 meters of red wool, 10 meters of green wool and 15 meters of blue wool. It is assumed that the income obtained from one unit length of type A cloth is Rs.3.00, of type B cloth is Rs.5.00, and of type C cloth is Rs.4.00.
   Develop a LPP to determine how the firm should use the available material, so as to maximize the income from the finished cloth.

   (5 marks)

   b) A television company operates 2 assembly sections, section A and section B. Each section is used to assemble the components of 3 types of televisions: Colour, standard and Economy. The expected daily production on each section is as follows :

T.V Model	Section A	Section B
Colour	3	2
Standard	2	1
Economy	2	6

   The daily running costs for 2 sections are Rs.4500 for section A and Rs.5000 for section B. It is given that the company must produce at least 24 colours, 18 standard and 40 Economy TV sets for which an order is pending.
   Formulate this as a LPP so as to minimize the total cost.

   (5 marks)

2. Solve the following LPP using the graphical method.
   Minimize $z = 20x_1 + 10x_2$
   subject to
   $x_1 + 2x_2 \leq 40$
   $3x_1 + x_2 \geq 30$
   $4x_1 + 3x_2 \geq 60$
   $x_1, x_2 \geq 0$

   (10 marks)

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3. Apply the Big-M method to solve the following LPP.
Maximize $z = x_1 + 5x_2$
subject to
$3x_1 + 4x_2 \leq 6$
$x_1 + 3x_2 \geq 2$
$x_1, x_2 \geq 0$

(10 marks)

4. A company has four warehouses, P, Q, R and S. It is required to deliver a product from these warehouses to three customers A, B and C. The warehouses have the following amounts in stock:

Warehouse	:	P	Q	R	S
No. of units	:	5	8	7	14

and the customer's requirements are

Customer	:	A	B	C
No. of units	:	7	9	18

The table below shows the costs of transporting one unit from warehouse to the customer.

	P	**Q**	**R**	**S**
A	**19**	**30**	**50**	**10**
B	**70**	**30**	**40**	**60**
C	**40**	**8**	**70**	**20**

Find initial basic feasible solution for given problem by using North-West Corner Rule method and Vogel's Approximation Method.

(10 marks)

5. A department has five employees with five jobs to be performed. The time (in hours) each men will take to perform each job is given in the effectiveness matrix.

		Employees				
		I	**II**	**III**	**IV**	**V**
Jobs	**A**	**20**	**22**	**35**	**14**	**18**
	B	**4**	**26**	**20**	**24**	**7**
	C	**23**	**14**	**17**	**19**	**19**
	D	**17**	**15**	**16**	**18**	**15**
	E	**16**	**19**	**21**	**19**	**28**

How should the jobs be allocated, one per employee, so as to minimize the total man-hours?

(10 marks)

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ANSWER ALL QUESTIONS

1. a) A firm can produce three types of cloth, say: A, B and C. Three kinds of wool are required for it, say: red, green and blue wool. One unit length of type A cloth needs 2 meters of red wool and 3 meters of blue wool; one unit length of type B cloth needs 3 meters of red wool, 2 meters of green wool and 2 meters of blue wool; and one unit of type C cloth needs 5 meters of green wool and 4 meters of blue wool. The firm has only a stock of 8 meters of red wool, 10 meters of green wool and 15 meters of blue wool. It is assumed that the income obtained from one unit length of type A cloth is Rs.3.00, of type B cloth is Rs.5.00, and of type C cloth is Rs.4.00.
Develop a LPP to determine how the firm should use the available material, so as to maximize the income from the finished cloth.

(5 marks)

$$\text{Max.} Z = 3x_1 + 5x_2 + 4x_3$$
$$\text{Sub to } 2x_1 + 3x_2 \le 8$$
$$3x_1 + 2x_2 + 2x_3 \le 15$$
$$5x_2 + 4x_3 \le 10$$
$$x_1, x_2, x_3 \ge 0$$

* One mark per line

b) A television company operates 2 assembly sections, section A and section B. Each section is used to assemble the components of 3 types of televisions: Colour, standard and Economy. The expected daily production on each section is as follows :

T.V Model	Section A	Section B
Colour	3	2
Standard	2	1
Economy	2	6

The daily running costs for 2 sections are Rs.4500 for section A and Rs.5000 for section B. It is given that the company must produce at least 24 colours, 18 standard and 40 Economy TV sets for which an order is pending.
Formulate this as a LPP so as to minimize the total cost.

(5 marks)

Minimize $Z = 4500x_1 + 5000x_2$

Sub to

$3x_1 + 2x_2 \geq 24$

$2x_1 + x_2 \geq 18$

$2x_1 + 6x_2 \geq 40$

$x_1, x_2 \geq 0$

* One mark per line

2. Solve the following LPP using the graphical method.

Minimize $z = 20x_1 + 10x_2$

subject to

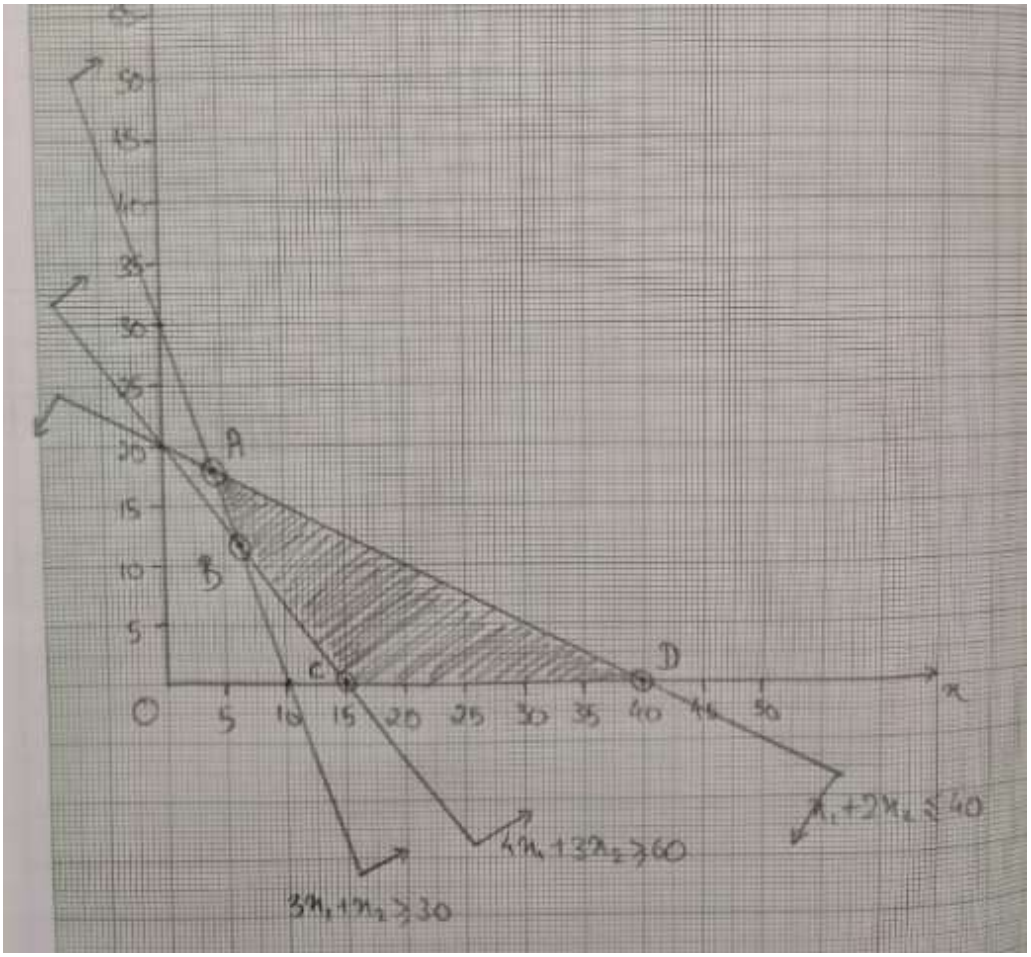
$x_1 + 2x_2 \leq 40$

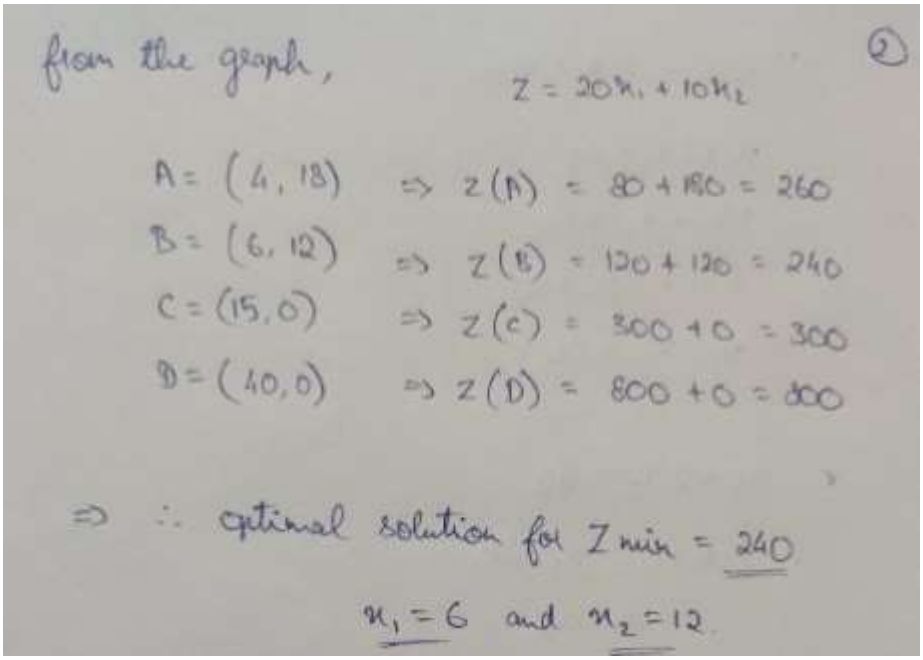
$3x_1 + x_2 \geq 30$

$4x_1 + 3x_2 \geq 60$

$x_1, x_2 \geq 0$

(10 marks)





* 10 marks if all are correct.
* If graph is correct and wrong solution = 5 marks
* If graph also wrong and some portions are correct = 3 marks
* Rest decided by the faulty based on the answer

3. Apply the Big-M method to solve the following LPP.
Maximize $z = x_1 + 5x_2$
subject to
$3x_1 + 4x_2 \leq 6$
$x_1 + 3x_2 \geq 2$
$x_1, x_2 \geq 0$

(10 marks)

Maximize $x_1 + 5x_2 + 0x_3 + 0x_4 - MA_1$

subject to

$3x_1 + 4x_2 + x_3 = 6$
$x_1 + 3x_2 - x_4 + A_1 = 2$

$x_1 \geq 0, x_2 \geq 0, x_3 \geq 0, x_4 \geq 0, A_1 \geq 0$

Where:
x_3 is a slack variable
x_4 is a surplus variable.
A_1 is an artificial variable.

Initial basic feasible solution

$x_1 = x_2 = x_4 = 0$
$A_1 = 2, x_3 = 6$

The Big M Method: Table 1

	c_j	1	5	0	0	–M	
c_B	Basic variables B	x_1	x_2	x_3	x_4	A_1	Solution values b (= X_B)
0	x_3	3	4	1	0	0	6
–M	A_1	1	3	0	–1	1	2
$z_j – c_j$		–M–1	–3M–5	0	M	0	

Calculating values for index row ($z_j – c_j$)

$z_1 – c_1 = 0 \text{ X } 3 + (–M) \text{ X } 1 – 1 = –M – 1$
$z_2 – c_2 = 0 \text{ X } 4 + (–M) \text{ X } 3 – 5 = –3M – 5$
$z_3 – c_3 = 0 \text{ X } 1 + (–M) \text{ X } 0 – 0 = 0$
$z_4 – c_4 = 0 \text{ X } 0 + (–M) \text{ X } (–1) – 0 = M$
$z_5 – c_5 = 0 \text{ X } 0 + (–M) \text{ X } 1 – (–M) = 0$

As M is a large positive number, the coefficient of M in the $z_j–c_j$ row would decide the incoming basic variable.
As -3M < -M, x_2 becomes a basic variable in the next iteration.
Key column = x_2 column.
Minimum (6/4, 2/3) = 2/3
Key row = A1 row
Pivot element = 3.
A1 departs and x_2 enters.

Note that in the iteration just completed, artificial variable A_1 was eliminated from the basis. The new solution is shown in the following table.

Table 2

	c_j	1	5	0	0	
c_B	**Basic variables B**	x_1	x_2	x_3	x_4	**Solution valu b (= X_B)**

0	x_3	5/3	0	1	4/3	10/3
5	x_2	1/3	1	0	−1/3	2/3
$z_j - c_j$		2/3	0	0	−5/3	

Final Optimal Table: The Big M Method

	c_j	**1**	**5**	**0**	**0**	
c_B	**Basic variables B**	x_1	x_2	x_3	x_4	**Solution valu b (= X_B)**
0	x_4	5/4	0	3/4	1	5/2
5	x_2	3/4	1	1/4	0	3/2
$z_j - c_j$		11/4	0	5/4	0	

The optimal solution is:

$x_1 = 0, x_2 = 3/2$
$z = 0 + 5 \text{ X } 3/2 = 15/2$

* 10 marks if all are correct.
* Up to starting table is correct = 5 marks
* Up to table-1 is correct = 7 marks
* Rest decided by the faulty based on the answer

4. A company has four warehouses, P, Q, R and S. It is required to deliver a product from these warehouses to three customers A, B and C. The warehouses have the following amounts in stock:

Warehouse : P Q R S
No. of units : 5 8 7 14

and the customer's requirements are

Customer : A B C
No. of units : 7 9 18

The table below shows the costs of transporting one unit from warehouse to the customer.

	P	**Q**	**R**	**S**
A	**19**	**30**	**50**	**10**
B	**70**	**30**	**40**	**60**
C	**40**	**8**	**70**	**20**

Find initial basic feasible solution for given problem by using North-West Corner Rule method and Vogel's Approximation Method.

(10 marks)

NWCR

Initial feasible solution is

	D_1	D_2	D_3	D_4	Supply
S_1	19 **(5)**	30 **(2)**	50	10	7
S_2	70	30 **(6)**	40 **(3)**	60	9
S_3	40	8	70 **(4)**	20 **(14)**	18
Demand	5	8	7	14	

The minimum total transportation cost $= 19 \times 5 + 30 \times 2 + 30 \times 6 + 40 \times 3 + 70 \times 4 + 20 \times 14 = 1015$

* 5 marks if all are correct.
* More than half values are correct = 2.5 or 3 marks
* Rest decided by the faulty based on the answer

VAM

Initial feasible solution is

	D_1	D_2	D_3	D_4	Supply	Row Penalty
S_1	19**(5)**	30	50	10**(2)**	7	9 | 9 | 40 | 40 | -- | -- |
S_2	70	30	40**(7)**	60**(2)**	9	10 | 20 | 20 | 20 | 20 | 40 |
S_3	40	8**(8)**	70	20**(10)**	18	12 | 20 | 50 | -- | -- | -- |
Demand	5	8	7	14		
Column Penalty	21 21 -- -- -- --	22 -- -- -- -- --	10 10 10 10 40 40	10 10 10 50 60 --		

The minimum total transportation cost $= 19 \times 5 + 10 \times 2 + 40 \times 7 + 60 \times 2 + 8 \times 8 + 20 \times 10 = 779$

* 5 marks if all are correct.
* More than half values are correct = 2.5 or 3 marks
* Rest decided by the faulty based on the answer

*Add both the marks and provide

5. A department has five employees with five jobs to be performed. The time (in hours) each men will take to perform each job is given in the effectiveness matrix.

		Employees				
		I	**II**	**III**	**IV**	**V**
Jobs	**A**	**20**	**22**	**35**	**14**	**18**
	B	**4**	**26**	**20**	**24**	**7**
	C	**23**	**14**	**17**	**19**	**19**
	D	**17**	**15**	**16**	**18**	**15**
	E	**16**	**19**	**21**	**19**	**28**

How should the jobs be allocated, one per employee, so as to minimize the total man-hours?
(10 marks)

After 2 Iterations,

Optimal solution is

Work	Job	Cost
A	4	14
B	5	7
C	2	14
D	3	16
E	1	16
	Total	67

* 10 marks if all are correct.
* Up to first iteration is correct = 5 marks
* Rest decided by the faulty based on the answer

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