SLOT: G1 + TG1

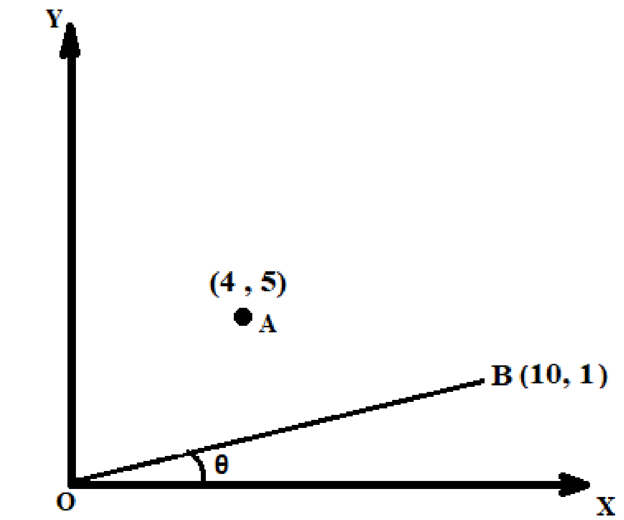
REG.NO.:

SCHOOL OF MECHANICAL ENGINEERING
CONTINUOUS ASSESSMENT TEST (CAT) -I
WINTER SEMESTER 2024-2025

Programme Name & Branch	**: B. Tech & Mechanical Engineering**
Course Code	**: BMEE306L**
Course Name	**: Computer Aided Design and Finite Element Analysis**
Faculty Name(s)	**: Dr. P. Kuppan, Dr. M. Murugan, Dr. R. Manoharan, Dr. A. Vinoth Jebaraj, Dr. A. Deepa,**
Class Number(s)	**: VL2024250503569, 3570, 3571, 3572, 3573**
Date of Examination	**: 02-Feb-2025**
Exam Duration	**: 90 minutes Maximum Marks: 50**

General Instruction(s):

- Answer **all** the questions.
- M - Max mark; CO – Course Outcome; BL – Blooms Taxonomy Level (1 – Remember, 2 – Understand, 3 – Apply, 4 – Analyse, 5 – Evaluate, 6 – Create)
- Course Outcomes Statements:
  CO. 1: Develop concept model into CAD model using geometric modelling techniques.
  CO. 2: Apply suitable product data exchange techniques to convert geometric model into numerical model.
  CO. 3: Generate mathematical representation of curves, surfaces and solids using interpolation and approximation concepts.

Q. No	Question	M	CO	BL
1.	Consider the mirroring (reflection) of the given point 'A' (4, 5) through a line 'OB' with its starting point at origin and its end point at (10, 1) as shown in Fig.1. Determine the concatenated matrix required for the combined transformation.  Fig.1. Reflection	10	1	3

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$\theta = \tan^{-1}\left(\frac{1}{10}\right) = 5.71^\circ$

$$\text{Rotation matrix } [R] = \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$\text{Mirror (or) matrix } [M] = \begin{bmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$\boxed{\text{Sequence of Transformation}}$

Rotation (clock wise) about z-axis → Reflection → Rotation (CCW) about z-axis

$$[T] = \begin{bmatrix} \cos 5.71 & -\sin 5.71 & 0 \\ \sin 5.71 & \cos 5.71 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos(-5.71) & -\sin(-5.71) & 0 \\ \sin(-5.71) & \cos(-5.71) & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$[T] = \begin{bmatrix} 0.995 & -0.0995 & 0 \\ 0.0995 & 0.995 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0.995 & 0.0995 & 0 \\ -0.0995 & 0.995 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$\boxed{[T] = \begin{bmatrix} 0.98 & 0.198 & 0 \\ 0.198 & -0.98 & 0 \\ 0 & 0 & 1 \end{bmatrix}}$$

2.	Find the transformed position of a 2D lamina lying in xy – plane having vertices A(1, 2), B(3, 2), C(4, 3) and D(2, 4) subjected to the following successive transformations: (i) Reflection about the y – axis (ii) Translation by – 1 unit in x and y directions (iii) Rotation by 180° counter clockwise direction about the z – axis.	10	1	3

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Reflection matrix, $$[R]=\begin{bmatrix}-1&0&0\\0&1&0\\0&0&1\end{bmatrix}$$

Translation matrix, $$[T_t]=\begin{bmatrix}1&0&-1\\0&1&-1\\0&0&1\end{bmatrix}$$

Rotation matrix, $$[T_r]=\begin{bmatrix}\cos 180^\circ&-\sin 180^\circ&0\\ \sin 180^\circ&\cos 180^\circ&0\\0&0&1\end{bmatrix}=\begin{bmatrix}-1&0&0\\0&-1&0\\0&0&1\end{bmatrix}$$

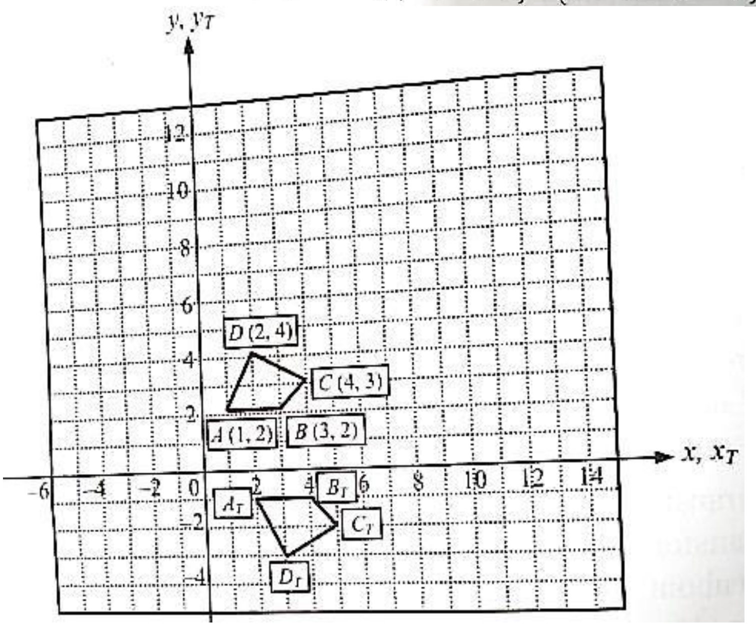
The resulting concatenated matrix is

$$[T]=[T_r].[T_t].[R]$$

$$[T]=\begin{bmatrix}-1&0&0\\0&-1&0\\0&0&1\end{bmatrix}.\begin{bmatrix}1&0&-1\\0&1&-1\\0&0&1\end{bmatrix}.\begin{bmatrix}-1&0&0\\0&1&0\\0&0&1\end{bmatrix}=\begin{bmatrix}1&0&1\\0&-1&1\\0&0&1\end{bmatrix}$$

Hence, transformed position vectors of the lamina *ABCD* are

$$\begin{Bmatrix}x_{T1}&x_{T2}&x_{T3}&x_{T4}\\y_{T1}&y_{T2}&y_{T3}&y_{T4}\\1&1&1&1\end{Bmatrix}=\begin{bmatrix}1&0&1\\0&-1&1\\0&0&1\end{bmatrix}.\begin{Bmatrix}1&3&4&2\\2&2&3&4\\1&1&1&1\end{Bmatrix}=\begin{Bmatrix}2&4&5&3\\-1&-1&-2&-3\\1&1&1&1\end{Bmatrix}$$



3.	Calculate the parametric midpoint of the Hermite curve that fits the point $P_0 = (1, 1)$, $P_1 = (6, 5)$ and tangent vectors $P_0' = (0, 4)$, and $P_1' = (4, 0)$.	10	3	4

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$$x(0.5) = 1[1 - 3(0.5^2) + 2(0.5^3)] + 6[3(0.5^2) - 2(0.5^3)] + 0[0.5 - 2(0.5^2) + (0.5^3)] + 4[-(0.5^2) + (0.5^3)]$$
$$= 1 \times 0.5 + 6 \times 0.5 + 0 \times 0.125 - 4 \times 0.125$$

and:

$$y(0.5) = 1[1 - 3(0.5^2) + 2(0.5^3)] + 5[3(0.5^2) - 2(0.5^3)] + 4[0.5 - 2(0.5^2) + (0.5^3)] + 0[-(0.5^2) + (0.5^3)]$$
$$= 1 \times 0.5 + 5 \times 0.5 + 4 \times 0.125 - 0 \times 0.125$$

which give $\mathbf{p}(0.5) = (3, 3.5)$.

Q. No.	Question	Marks	CO	BL
4.	Calculate the points on the Bézier curve at u = 0.25, u=0.5 and u = 0.75 and draw the schematic diagram of a curve defined by the four control points P_o (1, 2), P_1 (3, 4), P_2 (6, –6) and P_3 (9, 7).	10	3	3

$$P(t) = \sum_{i=0}^{3} P_i . B_{n,i}(t) = P_0 B_{3,0}(t) + P_1 B_{3,1}(t) + P_2 B_{3,2}(t) + P_3 B_{3,3}(t)$$

$$P(t) = P_0(1-t)^3 + P_1 3t(1-t)^2 + P_2 3t^2(1-t) + P_3 t^3$$

Therefore, any point $P(t)$ on Bézier curve is given by

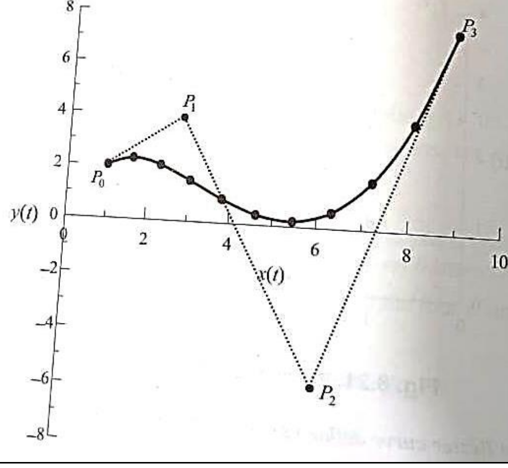
$$P(t) = \begin{Bmatrix} x(t) \\ y(t) \end{Bmatrix} = \begin{Bmatrix} 1 \\ 2 \end{Bmatrix}.(1-t)^3 + \begin{Bmatrix} 3 \\ 4 \end{Bmatrix}.3t(1-t)^2 + \begin{Bmatrix} 6 \\ -6 \end{Bmatrix}.3t^2(1-t) + \begin{Bmatrix} 9 \\ 7 \end{Bmatrix}.t^3$$

On simplification, $x(t)$ and $y(t)$ coordinates are given as

$$x(t) = (1-t)^3 + 9t(1-t)^2 + 18t^2(1-t) + 9t^3$$

$$y(t) = 2(1-t)^3 + 12t(1-t)^2 - 18t^2(1-t) + 7t^3$$

t	$x(t)$	$y(t)$	t	$x(t)$	$y(t)$
0.0	1.000	2.000	0.6	5.464	0.200
0.1	1.629	2.275	0.7	6.327	0.565
0.2	2.312	2.040	0.8	7.208	1.680
0.3	3.043	1.505	0.9	8.101	3.755
0.4	3.816	0.880	1.0	9.000	7.000
0.5	4.625	0.375	–	–	–



Q. No.	Question	Marks	CO	BL
5.	a) List out the input conditions required to generate the following	(5+5)	2	2

	surfaces. Also, write the parametric equations of the following surfaces. (i) Hermite Bi-cubic surface (ii) Bezier Bi-cubic surface **Hermite bicubic surface patch** $P\ (u,v) = \sum_{i=0}^{3}\sum_{j=0}^{3} C_{ij}u^i v^j$ $where\ 0 \le u \le 1\ and\ 0 \le v \le 1$ $P\ (u,v) = U^T[C]V$ $P\ (u,v) = U^T[M_H][B][M_H]^T\ V$ M_H → Matrix of coefficients of blending functions [B] → Geometric Coefficients $M_H = \begin{bmatrix} 2 & -2 & 1 & 1 \\ -3 & 3 & -2 & -1 \\ 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 \end{bmatrix}$ **Bicubic Bézier surface** $P(u,v) = \sum_{i=0}^{3}\sum_{j=0}^{3} P_{ij}B_{i,3}(u)B_{j,3}(v)$ $Where\ 0 \le u \le 1\ \&\ 0 \le v \le 1$ $P(u,v)$ → Any point on the surface P_{ij} → control points form the vertices of the control or characteristic polyhedron	10		
	b) Expand the following terms of CAD file exchange formats and briefly explain their usage in various stages of design applications. (i) IGES (ii) STEP **IGES** ➢ It stands for Initial Graphics Exchange Specification. ➢ Topology and geometry of the object is stored separately in this format. ➢ IGES has certain limitations such as absence of assembly data, product information etc. ➢ Data storage in both binary and ASCII formats are possible.			

	STEP ➢ It stands for Standard for Exchange of Product Data ➢ In addition to CAD data, it stores data related to product information. ➢ STEP format has many types (exchange of drawing files, design data, data of FEM analysis etc. ➢ STEP offers storage of assembly information of parts.			

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