Ref. No.: **Ex/PG/ETC/PE/T/124I/2025**

M.E. ELECTRONICS AND TELE-COMMUNICATION ENGINEERING FIRST YEAR
SECOND SEMESTER - 2025

Subject: **BEHAVIORAL AND COGNITIVE ROBOTICS** Time: 3 Hours Full Marks: 100

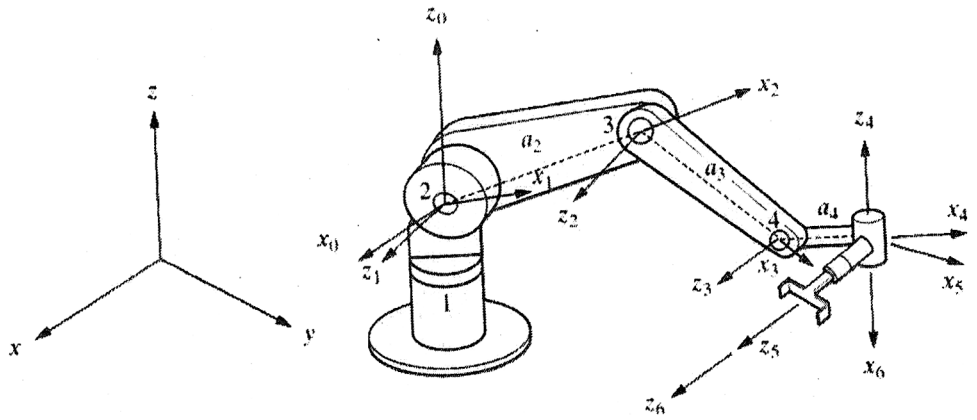
All parts of the same question must be answered at one place only.

Answer any FOUR

1. (a) A frame is rotated about the x-axis by 90^0; it is then translated about the current a-axis by 3 inches before being rotated about the z-axis by 90^0. Finally, it is translated about the current o-axis by 5 inches. Find the final location of a point P (1, 5, 4) attached to the frame relative to the reference frame. 15

   (b) Derive the expression of inverse of a homogeneous transformation matrix. 10

2. Find the total transformation between the base and the hand of the following robot using D-H scheme. 25



3. (a) The order of multiplication of rotational matrices for differential motion is not important. Justify. 7

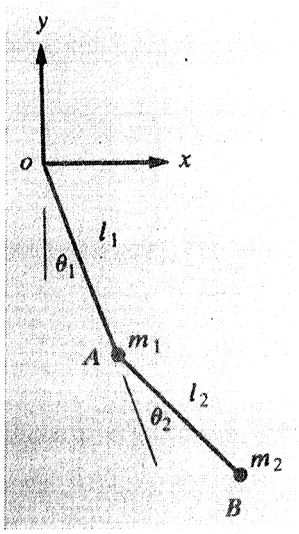
   (b) Justify why differential operator is not a transformation matrix. 6

   (c) The hand frame of a robot with five degrees of freedom, its numerical Jacobian for this instant, and a set of differential motions are given below. Find the new location of the hand after the differential motion. 12

$$\mathbf{T}_6 = \begin{bmatrix} 1 & 0 & 0 & 5 \\ 0 & 0 & -1 & 3 \\ 0 & 1 & 0 & 2 \\ 0 & 0 & 0 & 1 \end{bmatrix}, \quad \mathbf{J} = \begin{bmatrix} 3 & 0 & 0 & 0 & 0 \\ -2 & 0 & 1 & 0 & 0 \\ 0 & 4 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 \\ -1 & 0 & 0 & 0 & 1 \end{bmatrix}, \quad \begin{bmatrix} d\theta_1 \\ d\theta_2 \\ d\theta_3 \\ d\theta_4 \\ d\theta_5 \end{bmatrix} = \begin{bmatrix} 0.1 \\ -0.1 \\ 0.05 \\ 0.1 \\ 0 \end{bmatrix}$$

[Turn over

4. Derive the equations of motion for the two degree of freedom system shown next. 25



5. (a) Differentiate between joint-space and Cartesian space trajectory. 7

(b) Derive the expression of the necessary blending time for joint space trajectory planning with linear segments with parabolic blends. 10

(c) Joint 1 of a 6-axis robot is to go from initial angle of 30^0 to a final angle of 70^0 in 5 seconds with a cruising velocity of 10 degrees/second. Find the necessary time for blending and plot the joint positions, velocities and acceleration. 8

6. (a) Prove that $\frac{d\vec{r}}{dt} = \frac{d^*\vec{r}}{dt} + \vec{\omega} \times \vec{r}$ 12

and hence derive $\frac{d^2\vec{r}}{dt^2}$ where parameters have their usual meanings.

(b) For a n-link robot determine $\dot{\vec{v}}_i$ and $\dot{\vec{\omega}}_i$ for link i. 13