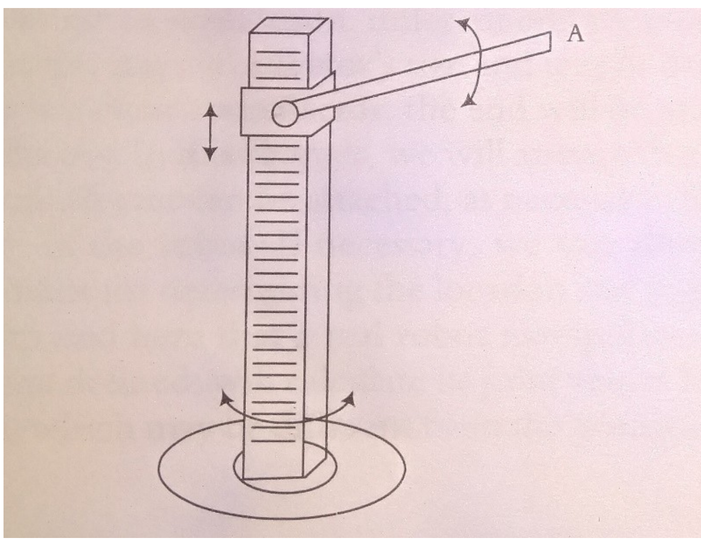
Name: **Enrolment No:**	

UNIVERSITY OF PETROLEUM AND ENERGY STUDIES
End Semester Examination, May 2022

Course: Robotics and Control — **Semester: IV**
Program: B.Tech. Mechatronics Engineering — **Time : 03 hrs.**
Course Code: ECEG2040 — **Max. Marks: 100**

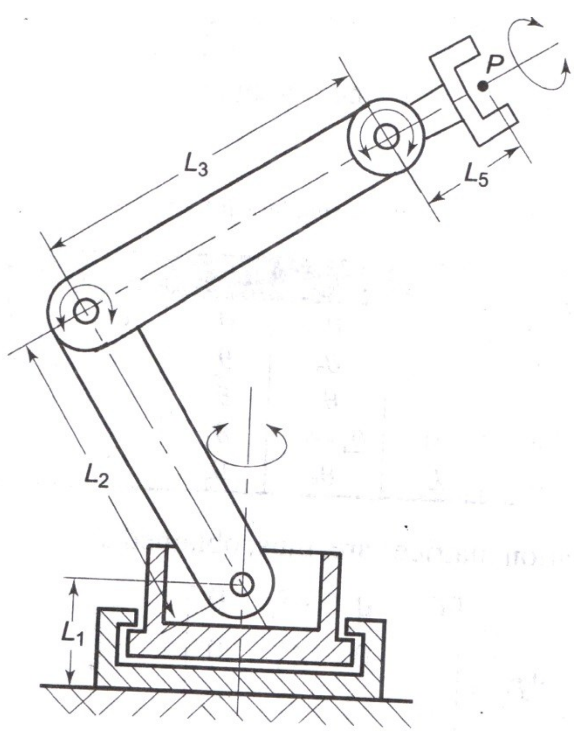
Instructions: Assume any missing data

SECTION A
(5Qx4M=20Marks)

S. No.		Marks	CO
Q 1	Sketch the approximate workspace of the robot shown in Fig. 1 below.  Fig. 1: A robot	**4**	**CO1**
Q 2	Define robot.	**4**	**CO1**
Q 3	Differentiate between forward and inverse kinematics.	**4**	**CO2**
Q 4	State various robot characteristics.	**4**	**CO1**
Q 5	Discuss the various robot coordinates.	**4**	**CO1**

SECTION B
(4Qx10M= 40 Marks)

Q 6	Suppose we desire to place the origin of the hand frame of a cylindrical robot at $[2,3,5]^T$. Calculate the joint variables of the robot.	**10**	**CO4**
Q 7	In a robotic set-up, a camera is attached to the fifth link of a 6-DOF	**10**	**CO3**

	robot. It observes an object and determines its frame relative to the camera's frame. Using the following information, determine the necessary motion the end-effector must make to get to the object: $^{5}T_{cam} = \begin{bmatrix} 0 & 0 & -1 & 3 \\ 0 & -1 & 0 & 0 \\ -1 & 0 & 0 & 5 \\ 0 & 0 & 0 & 1 \end{bmatrix}$; $^{5}T_{H} = \begin{bmatrix} 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 4 \\ 0 & 0 & 0 & 1 \end{bmatrix}$; $^{cam}T_{obj} = \begin{bmatrix} 0 & 0 & 1 & 2 \\ 1 & 0 & 0 & 2 \\ 0 & 1 & 0 & 4 \\ 0 & 0 & 0 & 1 \end{bmatrix}$; $^{H}T_{E} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$ Note: (i) $^{i}T_{j}$ refers to transformation from frame $\{i\}$ to frame $\{j\}$. (ii) '5' stands for 'local frame attached to link 5 of the robot'; 'cam' stands for 'camera'; 'H' stands for 'hand frame'; 'obj' stands for 'object', and 'E' stands for 'end-effector'. (iii) $^{0}T_{3} = {}^{0}T_{1} \times {}^{1}T_{2} \times {}^{2}T_{3}$		
Q 8	A 5-DOF robot is shown in figure 2. Find the DH parameters for the robot.  Figure 2: A 5-DOF robot.	**10**	**CO2**

Q 9	Derive the relationship between the differential motions of hand frame and differential motions of joints of a two-link articulated planar robot. **OR** A frame B is rotated 90º about the a-axis, 90º about the y-axis, then translated 2 and 4 units relative to the x- and y-axes respectively, then rotated another 90º about the n-axis. Find the new location and orientation of the frame. $B=\begin{bmatrix} 0 & 1 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 0 & -1 & 1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$	**10**	**CO2**
	SECTION-C **(2Qx20M=40 Marks)**		
Q 10	It is desired to have the third joint of a 6-axis robot go from an initial angle of 20° to a final angle of 80° in 4 seconds. Calculate the coefficients for a third-order polynomial joint-space trajectory and plot the joint angles, velocities, and accelerations. The robot starts from rest but should have a final velocity of 5°/sec.	**20**	**CO3**
Q 11	The position and orientation of the end-effector of a spherical manipulator is given by the following transformation matrix. $T=\begin{bmatrix} 0.354 & 0.866 & 0.354 & 0.106 \\ -0.612 & 0.5 & -0.612 & -0.184 \\ 0.707 & 0 & 0.707 & 0.212 \\ 0 & 0 & 0 & 1 \end{bmatrix}$ Find the feasible joint solutions if the joint limits are as follows. $-100^{\circ}<\theta_1<100^{\circ}$ $-30^{\circ}<\theta_2<70^{\circ}$ $0.05\,m<d_3<0.5\,m$ **OR** Perform the inverse kinematics of a 2-DoF planar robot having two revolute joints. If the length of each link L_1 and L_2 is 1 ft. and the position and orientation of the end effector is given by matrix ${}^0T_H$, calculate the values of joint variables. Check for multiple solutions, if any. ${}^0T_H=\begin{bmatrix} -0.2924 & -0.9563 & 0 & 0.6978 \\ 0.9563 & -0.2924 & 0 & 0.8172 \\ 0 & 0 & 1 & 0.0000 \\ 0 & 0 & 0 & 1 \end{bmatrix}$	**20**	**CO4**