Reg. No. | | | | | | | | | |

MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
(A constituent unit of MAHE, Manipal)

SEVENTH SEMESTER B.TECH. (INSTRUMENTATION AND CONTROL ENGG.)

END SEMESTER DEGREE EXAMINATIONS, NOVEMBER - 2019

SUBJECT: ROBOTIC SYSTEMS AND CONTROL [ICE 4030]

TIME: 3 HOURS MAX. MARKS: 50

Instructions to candidates :*Answer ALL questions and missing data may be suitably assumed.*

1A. Determine the degrees of freedom for the mechanism shown in Fig. Q1A.

1B. The end-point of a link of a manipulator is at $P_1 = [2\ 2\ 6]^T$ w.r.t a global frame of reference O_1XYZ. Assume the reference-frame of the link to be O_2 UVW. The link is rotated by 90^0 about X-axis, -90^0 about the –W axis, translated by a distance of 2 units about the Y-axis and finally, rotated by 90^0 about the U axis. Find the resultant homogeneous transformation matrix and the final position (P_2) of the given end-point.

1C. Find the Euler-I and Euler-II angles for the rotation matrix given below; assuming each angle $\theta \in (0,\pi)$

$$^0R_E = \begin{bmatrix} 0.1 & 0.23 & 0.5 \\ 0.5 & 0.866 & 0.5 \\ 0.866 & 0.5 & 1 \end{bmatrix}$$

(2+4+4)

2A. With a relevant schematic diagram, explain Impedance Control for robot manipulators.

2B. Obtain the forward kinematics equation of the 4 DoF SCARA robot shown in Fig. Q2B.

2C. Derive the dynamic model of a planar 2dof R‖R arm using Lagrangian algorithm. Assume that the mass of each link is a point-mass located at the centre of mass of each link, and the links are assumed to be rigid, slender structures.

(2+3+5)

3A. Give a brief description on any FOUR types of mechanical grippers (with relevant diagrams) based on the type of kinematic device used to actuate finger-movements.

3B. Prove that the overall differential transformation of a rigid body in 3-D space due to three differential rotations δ_x, δ_y and δ_z about X, Y and Z axes (respectively) is independent of the sequence in which these rotations are made.

3C. The DH table for an R-P-R arm is given as follows:

Table Q3C.

θ	d	a	α	Comment
θ_1	--	--	π/2	$^0T_1$
--	d_2	1	--	$^1T_2$
θ_3	--	1	π/2	^2T_E

(i) Obtain the Jacobian matrix, J

(ii) Determine the possible joint configuration(s) corresponding to kinematic singularity (iii)If the respective joint-configuration is given by the joint-space, $q = \begin{bmatrix} \frac{\pi}{6} & 0.5 & \frac{-\pi}{3} \end{bmatrix}^T$ and the joint velocities by $\dot{q} = \begin{bmatrix} \frac{\pi}{3} & 0.3 & \frac{-\pi}{6} \end{bmatrix}^T$, determine the translational and angular Cartesian velocities.

(2+3+5)

4A. Give a brief note on each of the following control scheme (with relevant diagrams):
  (i) Computed Torque/Force Control
  (ii) Hybrid Position/Force Control

4B. For the 3DoF manipulator arm shown in Fig. Q4C, design a trapezoidal velocity profile for the second revoluting joint. The initial and final positions of the end effector (E) are expressed by the given homogeneous transformation matrices T_S and T_G respectively. The time taken for traversal is 4 seconds.

$$T_S = \begin{bmatrix} 0.354 & 0.866 & -0.354 & -0.106 \\ -0.612 & 0.5 & 0.612 & 0.184 \\ 0.707 & 0 & 0.707 & 0.212 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad T_G = \begin{bmatrix} 0.583 & -0.766 & 0.272 & 0.027 \\ 0.694 & 0.643 & 0.324 & 0.032 \\ -0.423 & 0 & 0.906 & 0.091 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

(4+6)

5A. The code for a MATLAB function 'inverse' given below is found to be erraneous. This function is supposed to find the inverse of a 4×4 homogeneous transformation matrix T. Identify the bug(s) in the code and correct the same.

```
function [T1]=inverse(T)
    R1=T(1:3,1:3);
    R2=R1';
    D1=T(:,4);
    D2=R2*D1;
    T1=[R2 D2;0 1];
```

5B. List the various types of position and velocity sensors used in robots.

5C. Derive the expressions for designing Discrete Kalman Filter for the linear stochastic discrete-time process given below:

$$X_k = A_{k-1}X_{k-1} + w_{k-1}$$
$$Y_k = H_k X_k + v_k$$

where w_{k-1} and v_k are assumed to be the process and measurement noises respectively.

(1+3+6)

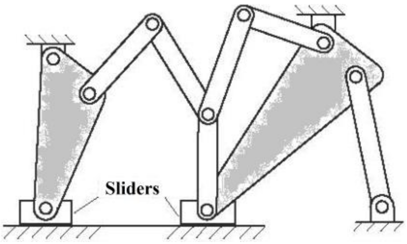

Fig. Q1A

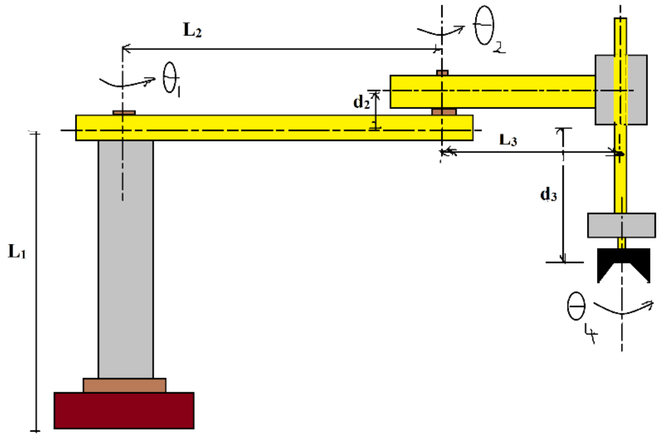

Fig.Q2B

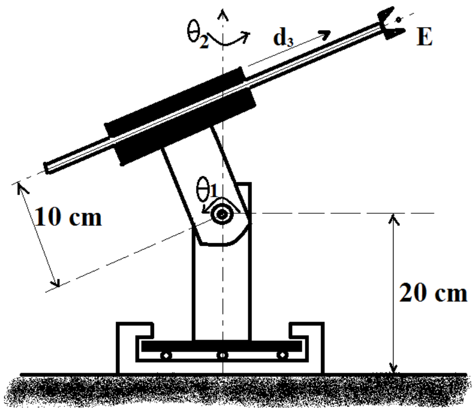

Fig.Q4C

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