Reg. No.										

MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL

A Constituent Institution of Manipal University

V SEMESTER B.TECH. (MECHATRONICS ENGINEERING)

END SEMESTER EXAMINATIONS, DEC 2017

SUBJECT: MECHANICS OF ROBOT SYSTEMS [MTE 3102]

REVISED CREDIT SYSTEM

Time: 3 Hours | MAX. MARKS: 50

Instructions to Candidates:

- Answer **ALL** the questions.
- Data not provided may be suitably assumed

1A. Determine the homogeneous transformation matrix to represent the following sequence of operations. **03**

a) Rotation of 60˚ about OX axis.
b) Translation of 4 units along OX axis.
c) Translation of -6units along OC axis.
d) Rotation of 30˚ about OB axis.

1B. Write down the general form of EoF (equation of motion) for multi body system. What does each of the components represents? Derive the equation of motion for the following system (Figure Q.1B) by Lagrangian formulation. **07**

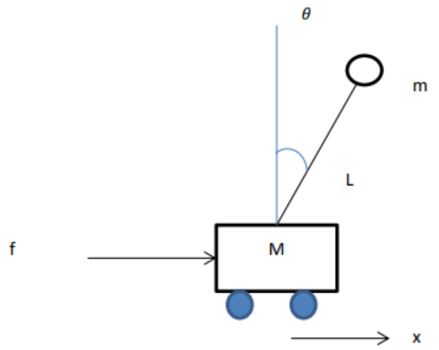

Figure Q.1B

2A. Differentiate between: **03**

1. Joint space Trajectory and Cartesian Space Trajectory
2. Reachable Workspace and Dexterous Workspace

Sketch RWS and DWS for a two link planar manipulator where both the links are of same size.

2B. Write down the properties of rotation matrix. **02**

2C. A fifth order polynomial is used to control the motions of the joints of a robot. Find the coefficients of the fifth order polynomial that allow a joint to go from 0^o to 120^o **05**

in 5 seconds, while the initial and final velocities are zero the initial acceleration and deceleration are 10 degrees/sec^2

3A. The hand frame of a robot with five degree of freedom, its numerical Jacobian for this instance, and a set of differential motion are given. The robot has a 2RP2R configuration. Find the new location of the hand after the differential motion **03**

$$T_6 = \begin{bmatrix} 1 & 0 & 0.1 & 5 \\ 0 & 0 & -1 & 3 \\ 0 & 1 & 0 & 2 \\ 0 & 0 & 0 & 1 \end{bmatrix}, \quad J = \begin{bmatrix} 3 & 0 & 0 & 0 & 0 \\ -2 & 0 & 1 & 0 & 0 \\ 0 & 4 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 \\ -1 & 0 & 0 & 0 & 1 \end{bmatrix}, \quad \begin{bmatrix} d\theta_1 \\ d\theta_2 \\ ds_1 \\ d\theta_4 \\ d\theta_5 \end{bmatrix} = \begin{bmatrix} 0.1 \\ -0.1 \\ 0.05 \\ 0.1 \\ 0 \end{bmatrix}$$

3B. Derive the equations of motion for the two link mechanism with distributed mass as shown in figure Q.3B. **07**

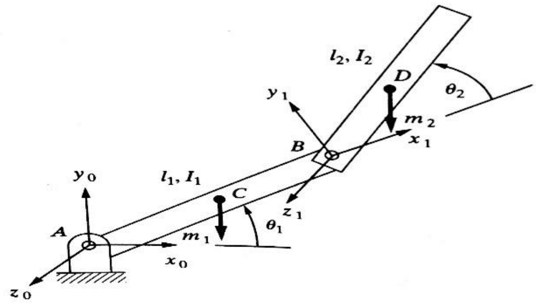

Figure Q.3B

Also define the various terms involved.

4A. A manipulator with an articulated arm is shown in figure Q.4A. All the five joints of the manipulator are revolute. Obtain the kinematic model of the manipulator and test it for home position. For this home position the joint variable vector will be **06**

$q_{home} = [\ 0\ \ 0\ \ 0\ \ 0\ 0\ ]^T$. *(Matrix A_{n+1} for reference)*

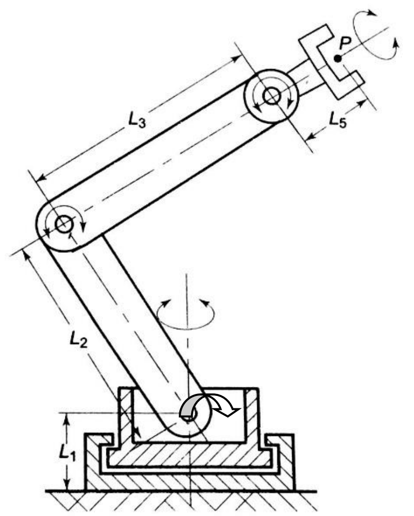

Figure Q.4A: A five degree of freedom industrial manipulator

4B. A six joint robotic manipulator equipped with a digital TV camera is capable of continuously monitoring the position and the orientation of an object. The position and the orientation of the object with respect to the camera is expressed by a matrix [T1], the origin of the robot base coordinate with respect to the camera is given by [T2], and the position and the orientation of the gripper with respect to the base coordinate frame is given by [T3]. **04**

$$[T1]=\begin{bmatrix}0 & 1 & 0 & 5\\ 1 & 0 & 0 & 6\\ 0 & 0 & -1 & 10\\ 0 & 0 & 0 & 1\end{bmatrix}\quad [T2]=\begin{bmatrix}1 & 0 & 0 & -20\\ 0 & -1 & 0 & 10\\ 0 & 0 & -1 & 12\\ 0 & 0 & 0 & 1\end{bmatrix}\quad [T3]=\begin{bmatrix}1 & 0 & 0 & 8\\ 0 & 1 & 0 & 6\\ 0 & 0 & 1 & 6\\ 0 & 0 & 0 & 1\end{bmatrix}$$

Determine

i. The position and the orientation of the object with respect to the base coordinate.

ii. The position and the orientation of the object with respect to gripper.

5A. For a SCARA robot as shown in Figure Q.5A, determine the joint displacement for known position and orientation of the end of the arm point.Given the matrix for the end effector position as: **10**

$$T_E=\begin{bmatrix}n_x & o_x & a_x & 0\\ n_y & o_y & a_y & 0\\ n_z & o_y & a_z & 0\\ 0 & 0 & 0 & 1\end{bmatrix}$$

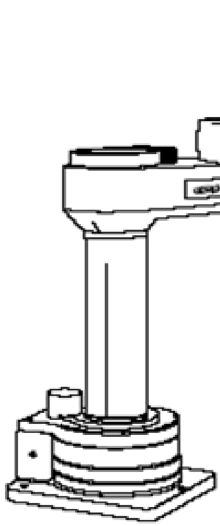

Figure Q.5A

Appendix:

$$ {}^{i-1}_{\;\;i}\boldsymbol{T} = \begin{bmatrix} c\theta_i & -s\theta_i & 0 & a_{i-1} \\ s\theta_i c\alpha_{i-1} & c\theta_i c\alpha_{i-1} & -s\alpha_{i-1} & -s\alpha_{i-1} d_i \\ s\theta_i s\alpha_{i-1} & c\theta_i s\alpha_{i-1} & c\alpha_{i-1} & c\alpha_{i-1} d_i \\ 0 & 0 & 0 & 1 \end{bmatrix} $$ (Craig's methods) and

$$ A_{n+1} = \begin{bmatrix} C\theta_{n+1} & -S\theta_{n+1}C\alpha_{n+1} & S\theta_{n+1}S\alpha_{n+1} & a_{n+1}C\theta_{n+1} \\ S\theta_{n+1} & C\theta_{n+1}C\alpha_{n+1} & -C\theta_{n+1}S\alpha_{n+1} & a_{n+1}S\theta_{n+1} \\ 0 & S\alpha_{n+1} & C\alpha_{n+1} & d_{n+1} \\ 0 & 0 & 0 & 1 \end{bmatrix} $$ (Mc Carty's method).