Reg. No.										

MANIPAL INSTITUTE OF TECHNOLOGY

MANIPAL

A Constituent Institution of Manipal University

V SEMESTER B.TECH. (MECHATRONICS ENGINEERING)

END SEMESTER EXAMINATIONS, NOV/DEC 2016

SUBJECT: MECHANICS OF ROBOTIC SYSTEM [MTE 3102]

REVISED CREDIT SYSTEM
(26/11/2016)

Time: 3 Hours MAX. MARKS: 50

Instructions to Candidates:

- Answer **ALL** the questions.
- Missing data may be suitable assumed or referred in Appendix.

1A. **4**

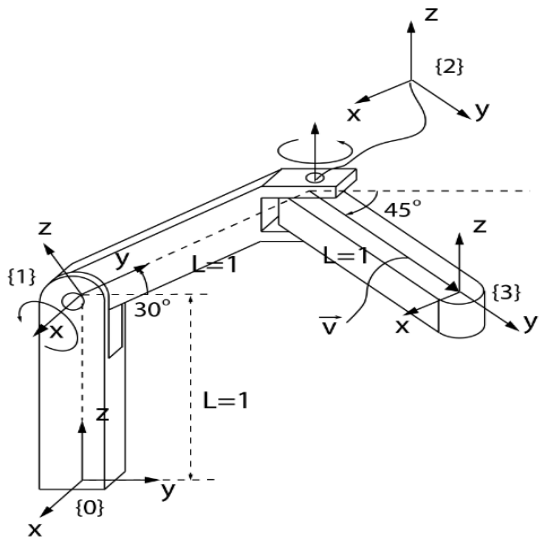

Figure Q.1A

The robot arm with 3 links is in the pose shown in Fig Q.1A.The length of each link L=1.The fixed frame and each body frame are attached as in the figure.Find T_{01},T_{12},T_{23}.

1B. Define Rot (k,dθ) about a general axis k and analyze if the order of the multiplication varies the result? Also derive the result for differential operator. **3**

1C. What is meant by Reachable Workspace (RW) and Dexterous workspace (DW). **3**

Sketch RW and DW and assess the results found for a 2-link mechanism for the following configurations:

1. Both the link lengths are same
2. Both the link lengths are different

(Range of the joint variables being θ_1[-50,50] and θ_2[-120,0]:

2A. Write a short note on different types of joints. **2**

2B. Define the various terms of D-H table. For the given RRRP manipulator is shown in the figure Q.2B.Choose appropriate link reference frame and derive the correspoding D-H paramaters.(Use the Given Fixed frame) **5**

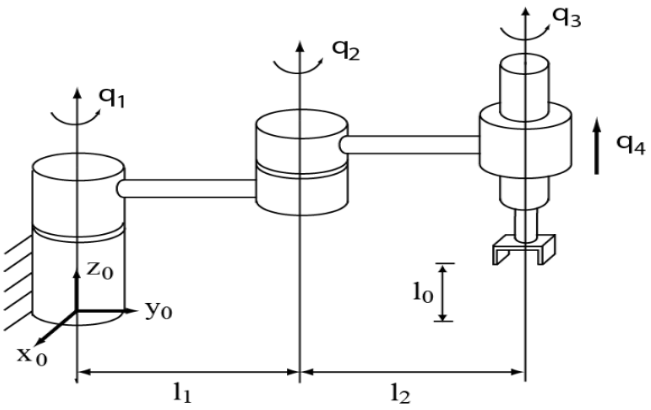

Figure Q.2B

2C. A fifth order polynomial is to be used to control the motions of the joints of a robot in joint. Find the coefficients of the fifth order polynomial that allow a joint to go from 0^o to 75^o in 3 seconds, while the initial velocity of 3 degree/s and zero final velocity, the initial acceleration and deceleration are 10 degrees/sec^2 **3**

3A. For a spherical configuration the D-H table is given in Table Q.3A: **7**

Link i	α	θ	a	d
1	90	θ_1	0	0
2	-90	θ_2	0	0
3	0	0	0	d_3

Table Q.3A

We desire to move from point A (9, 6, 10) to point B (3, 5, 8) in a straight line. Find the angles of the two joints for each intermediate point and plot the results.(Divide the line into 5 sections)

3B. Given a fixed frame [0] and a moving frame [1], we perform the following sequence of rotations on [1]: **3**

1)Rotate [1] about the [0] frame x-axis by a and call it [2]
2)Rotate [2] about the [0] frame y-axis by b and call it [3]
3)Rotate [3] about the [0] frame z-axis by c and call it [4]
Find the final orientation R_{04}

4A **10**

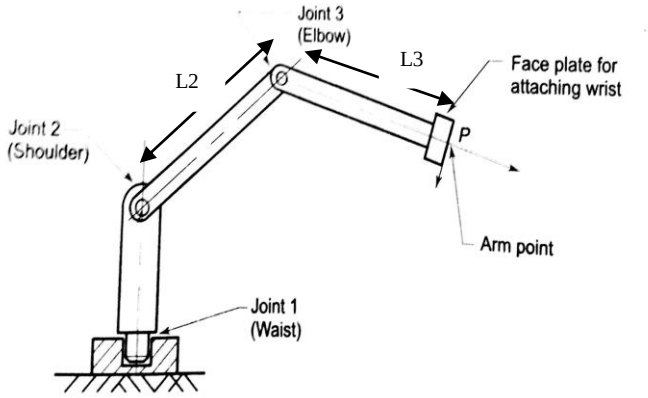

Figure Q.4A

For a 3-DOF articulated arm as shown in figure Q.4A, determine the joint variable for known position and orientation of the end of the arm point given as.

$$[T_E] = \begin{bmatrix} n_x & s_x & a_x & p_x \\ n_y & s_y & a_y & p_y \\ n_z & s_z & a_z & p_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Also Calculate the angular velocity of the first joint for the given values such that the hand frame will have linear and angular velocities as:
dx/dt=1cm/sec; dy/dt=-2 cm/sec; δx/dt=0.1 rad/sec.
Given joint variable are in the range [90,0,90] and L2=15cm and L3=15cm .

5A. Derive the equations of motion for the two link mechanism with distributed mass as shown in figure Q.5A. **6**

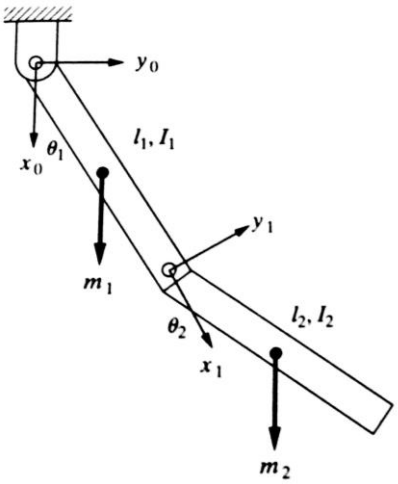

Figure Q.5A

Also define the various terms involved.

5B. A cylindrical robot has a prismatic joint with a range of travel of 800 mm. The control memory for this joint has 10bit capacity. It has been recorded that the associated mechanical inaccuracies with the said arm show a random distribution of random variable of the robot position about the mean position of the taught point gives a standard deviation of 0.1mm. The standard deviation is **2**

equal in all direction.
Determine the following:

a) The control resolution for the axis.

b) The spatial resolution for the prismatic joint.

c) The accuracy defined.

d) The repeatability of the robot link.

5C. In a robot specification, how are accuracy control resolution and spatial resolution terms related to each other? **2**

Appendix

	Equations	Solutions
1	$a\sin\theta + b\cos\theta = c$	$\theta = A\tan 2(a,b) \mp A\tan 2\left(\sqrt{a^2+b^2-c^2}, c\right)$
2	$a\sin\theta + b\cos\theta = 0$	$\theta = A\tan 2(-b, a)$ or $\theta = A\tan 2(b, -a)$
3	$\cos\theta = a$ and $\sin\theta = b$	$\theta = A\tan 2(b, a)$
4	$\cos\theta = a$	$\theta = A\tan 2\left(\mp\sqrt{1-a^2}, a\right)$
5	$\sin\theta = a$	$\theta = A\tan 2\left(a, \mp\sqrt{1-a^2}\right)$

$$A_{n+1} = \begin{bmatrix} C\theta_{n+1} & -S\theta_{n+1}C\alpha_{n+1} & S\theta_{n+1}S\alpha_{n+1} & a_{n+1}C\theta_{n+1} \\ S\theta_{n+1} & C\theta_{n+1}C\alpha_{n+1} & -C\theta_{n+1}S\alpha_{n+1} & a_{n+1}S\theta_{n+1} \\ 0 & S\alpha_{n+1} & C\alpha_{n+1} & d_{n+1} \\ 0 & 0 & 0 & 1 \end{bmatrix}$$