Reg. No.										

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

VII SEMESTER B.TECH. (MECHATRONICS ENGINEERING)

END SEMESTER EXAMINATIONS, NOV 2019

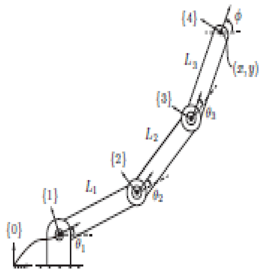
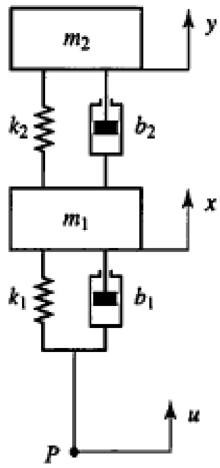
SUBJECT: ROBOT DYNAMICS AND CONTROL [MTE 4007]

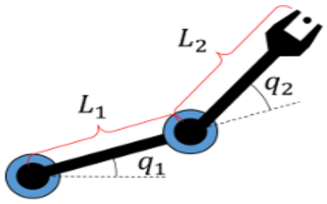
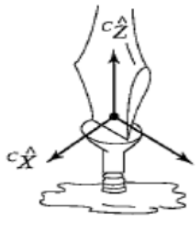
(26/11/2019)

Time: 3 Hours MAX. MARKS: 50

Instructions to Candidates:

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

1A.	Derive the torque equation at each joint of the manipulator shown in Fig:1A with the help of Newton Euler method.  Fig:1A	06	CO1
1B.	Develop an appropriate control method for the manipulator shown in Fig.1A for pick and place operation of eggs.	03	CO3
1C.	Discuss on the Computational issues of the control algorithm developed in question 1B and state its merits over other control algorithms.	01	CO3
2A	A simplified version of motor front suspension system is shown in Fig.2A. Point *P* is the contact point with the ground. The vertical displacement *u* of point *P* is the input to the system. The displacements *x* and *y* are measured from their respective equilibrium positions before the input *u* is given to the system. Consider that m_1,b_1 and k_1 represent the front tire and shock absorber assembly and m_2, b_2 and k_2 represent half of the body of the vehicle. Given that the system is at rest for $t < 0$. At $t = 0$, *P* is given a triangular bump input. Point *P* moves only in the vertical direction. Assume that $m_1 = 10$ kg, $m_2 = 100$ kg, $b_1 = 50$ *N-s/m*, $b_2 = 100$ *N-s/m*, $k_1 = 50$ *N/m*, and $k_2 = 200$ *N/m*. Obtain a state-space representation of the system.  Fig.2A	4	CO2

2B	Select a suitable control method for the system shown in Fig.2A and explain it with a neat block diagram.	4	CO2
2C	Define system stability with the help of an example shown in Fig. 2A	2	CO2
3A	Develop the Partitioned model based control law for a 2R manipulator equation shown in equation 1 $$\tau_1 = m_2 l_2^2(\ddot{\theta}_1 + \ddot{\theta}_2) + m_2 l_1 l_2 c_2(2\ddot{\theta}_1 + \ddot{\theta}_2) + (m_1 + m_2) l_1^2 \ddot{\theta}_1 - m_2 l_1 l_2 s_2 \dot{\theta}_2^2 - 2 m_2 l_1 l_2 s_2 \dot{\theta}_1 \dot{\theta}_2 + m_2 l_2 g c_{12} + (m_1 + m_2) l_1 g c_1, \quad (1)$$ $$\tau_2 = m_2 l_1 l_2 c_2 \ddot{\theta}_1 + m_2 l_1 l_2 s_2 \dot{\theta}_1^2 + m_2 l_2 g c_{12} + m_2 l_2^2(\ddot{\theta}_1 + \ddot{\theta}_2).$$	4	CO3
3B	State and prove the asymptotic stability criterion for the equation1 stated in question 3A.	4	CO3
3C	Describe on Actuator saturation and Integrator windup.	2	CO3
4A	Develop a symbolic torque equation of the RR manipulator shown in Fig.3A using Lagrangian method. Here, m_1 is mass of first link, m_2 is mass of second link, l_1 is first link length, l_2 is second link length, q_1 is angle associated with first link and q_2 is the angle associated with second link.  Fig.3A	4	CO1
4B	Implement a hybrid control method with the help of an appropriate block diagram for the torque equation developed in question 4A, and explain each term associated with the control equation.	4	CO3
4C	A and B were working on a Model-based partitioned PID control of a spray painting robot. To achieve the stability of Spray painting robot they were forced to find out the gain associated with the PID controller. Help them by providing necessary equation with proper explanation. (hint: Ziegler Nicholas Method)	2	CO2
5A	Find out the state space representation of a 2R manipulator equation given in equation 2. $$\tau_1 = m_2 l_2^2(\ddot{\theta}_1 + \ddot{\theta}_2) + m_2 l_1 l_2 c_2(2\ddot{\theta}_1 + \ddot{\theta}_2) + (m_1 + m_2) l_1^2 \ddot{\theta}_1 - m_2 l_1 l_2 s_2 \dot{\theta}_2^2 - 2 m_2 l_1 l_2 s_2 \dot{\theta}_1 \dot{\theta}_2 + m_2 l_2 g c_{12} + (m_1 + m_2) l_1 g c_1, \quad (2)$$ $$\tau_2 = m_2 l_1 l_2 c_2 \ddot{\theta}_1 + m_2 l_1 l_2 s_2 \dot{\theta}_1^2 + m_2 l_2 g c_{12} + m_2 l_2^2(\ddot{\theta}_1 + \ddot{\theta}_2).$$	4	CO1
5B	Develop cooperative distributed control law for equation no 2 with a neat block diagram.	4	CO3
5C	ABC Robotics decided to develop a manipulator to fix the screws in an automobile manufacturing assembly line as shown in Fig. 4A. Help the developers by identifying natural and artificial constraints of the turning screw driver attached as an end-effector of manipulator.  Fig.4A	2	CO3