Name: Enrolment No:	UPES

UNIVERSITY OF PETROLEUM AND ENERGY STUDIES
End Semester Examination, December 2018

Course: Robotics and Control **Semester: V**
Programme: B.Tech. Mechatronics (ECEG 3001)
Time: 03 hrs. **Max. Marks: 100**
Instructions: Assume any missing data (Total pages = 3)

S. No.		Marks	CO
	SECTION A		
Q 1	Describe in brief the various control schemes/strategies used for position and force control of manipulators.	**4**	**CO4**
Q 2	The arm lengths of a planar two-link manipulator having two revolute joints are 1 m each. If the joint velocities are constant at $\dot{\theta}_1=1$, $\dot{\theta}_2=2$, find the instantaneous velocity of the tool when $\theta_1=\theta_2=\frac{\pi}{4}$.	**4**	**CO1/ CO2**
Q 3	Derive the rotation matrix about Z-axis.	**4**	**CO2**
Q 4	Discuss the step response of a second-order system.	**4**	**CO4**
Q 5	Compare among the four fundamental robot arms giving at least one advantage and one disadvantage of each.	**4**	**CO1**
	SECTION B		
Q 6	a) Derive the pseudo-inertia matrix for a two-link planar manipulator having two revolute joints. Make use of DH parameters in your derivation. OR b) Derive the Jacobian matrix for a three-link planar manipulator having three revolute joints.	**10**	**CO2**
Q 7	It is required to insert a peg into a hole with the help of a robot. Divide your assembly task into simple sub-tasks and hence determine the natural and artificial constraints for each sub-task.	**10**	**CO4**
Q 8	A joint drive system consists of a DC servomotor with total inertia of 0.02 kg m^2 and bearing friction of 0.5 N/s and a gearbox with gear ratio of 32. The link inertia is 5 kg m^2 and the link bearing friction is 2 N/s. Determine (i) the effective inertia and effective damping for the joint. (ii) the closed loop transfer function for a proportional controller with proportional gain K = 10. (iii) the unit step response . (iv) the steady state error.	**10**	**CO4**
Q 9	It is desired to have the first joint of a six-axis robot to move from the initial	**10**	**CO3**

<table>
<tr><td></td><td>position, $\theta_0 = 15^o$, to a final position, $\theta_f = 75^o$, in 3 seconds using a cubic polynomial. Determine the trajectory.</td><td></td><td></td></tr>
<tr><td colspan="4">SECTION-C</td></tr>
<tr><td>Q 10</td><td>
a) Consider the top view of a robotic workstation, with parts A and B, shown in Fig. 1. Suppose the centroid of part A has coordinates $[6, 12, 2]^T$ and the centroid of part B has coordinates $[10, 5, 1]^T$.

(i) Find the arm matrix value T_{base}^{pick} needed to pick up part A from above grasping it along the long sides

(ii) Find the arm matrix value T_{base}^{place} needed to place part A on top of part B aligning the centroids and the major axes.

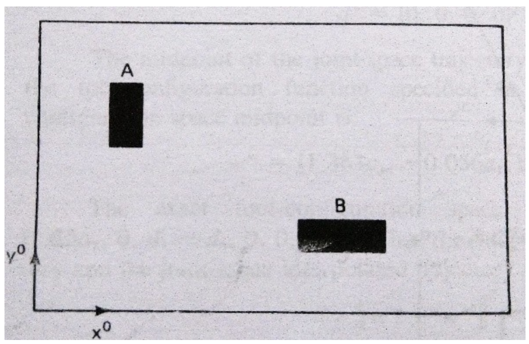

Fig. 1: Robotic workstation (Q. 10 a)

b) For a robotic controller it is proposed to implement partitioned proportional integral (PPI) control strategy. Develop the block diagram and mathematical model for PPI controller.
</td><td>20</td><td>CO2/
CO3/
CO4</td></tr>
<tr><td>Q 11</td><td>
a) For the two-link planar manipulator having two revolute joints, design the hybrid position force controller to follow a surface defined as

$$x = \cos(t);\ y = \sin(t)$$

while maintaining a constant contact force f_d with the friction surface. Draw the block diagram of the controller. (Note: *t* represents time)

OR

b) Design a control system based upon partitioned PD control law for the three axes SCARA manipulator shown in Fig. 2. (Hint: First derive the expressions for the three joint variables.)
</td><td>20</td><td>CO2/
CO4</td></tr>
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	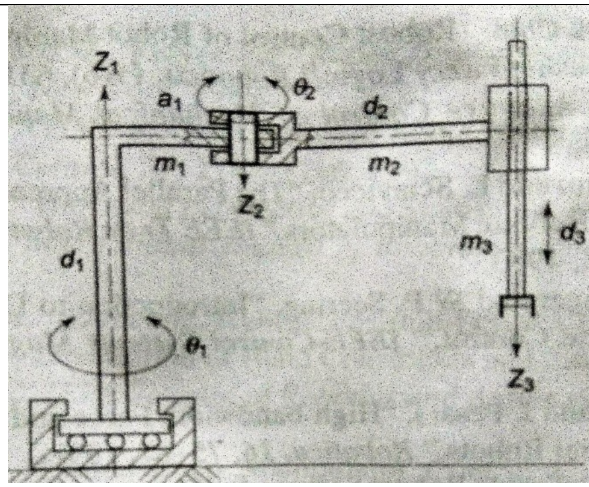 Fig. 2: A 3-DoF SCARA manipulator (Q 11 b)		