Name:

Enrolment No:

UNIVERSITY OF PETROLEUM AND ENERGY STUDIES

End Semester Examination, December 2018

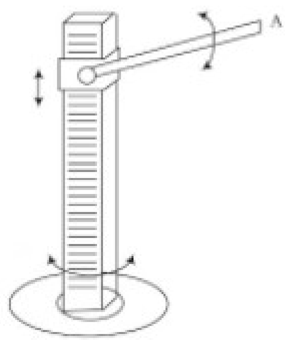
Course: Introduction to Robotics (ECEG7002) **Semester: I**

Programme: M.Tech Automation & ROBOTICS ENGG

Time: 03 hrs. **Max. Marks: 100**

Instructions:

SECTION A

S. No.		**Marks**	**CO**
Q 1	Define dexterity for a robot configuration. Sketch the approximate workspace for the following robot. Assume that the dimensions of the base and other parts are of the robot structure are as shown. 	**4**	**CO1**
Q 2	To obtain a desired trajectory, joint 2 of the a 3-dof robot moves from an initial angle of 30^0 to final angle of 70^0. The initial angular velocity for the motion is found to be 10deg/sec. Evaluate the necessary blending time required for the motion. Also, illustrate position, velocity and acceleration required for the trajectory of joint 2 with the help of a graph.	**4**	**CO4**
Q 3	Derive a matrix that represents pure rotation about z axis of the robot reference frame	**4**	**CO2**
Q 4	For a 3-dof articulated arm shown in fig, the Jacobian matrix J' is given as, $$J' = \begin{bmatrix} -S_1(L_3C_{23}+L_2C_2) & -C_1(L_3S_{23}+L_2S_2) & -L_3C_1S_{23} \\ C_1(L_3C_{23}+L_2C_2) & -S_1(L_3S_{23}+L_2S_2) & -L_3S_1S_{23} \\ 0 & L_3C_{23}+L_2C_2 & L_3C_{23} \end{bmatrix}$$ Discuss the conditions of singularity for the given robotic arm.	**4**	**CO3**
Q 5	A frame B is rotated at 90^0 about the z axis , then translated 3 and 5 units relative to n and o axes respectively, then rotated another 90^0 about n axis and finally 90^0 about	**4**	**CO2**

the y axis. Calculate the new location and orientation of the frame.

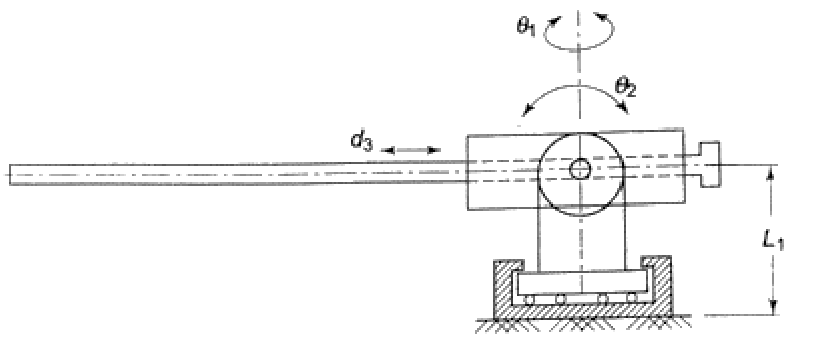
SECTION B

Q 6 — **10** — **CO4**

Derive dynamic equations of a three-link purely prismatic planar 3P manipulator whose axes of joints are mutually perpendicular using Lagrangian method. Discuss the nature of the Christoffel symbols, Hijk for the robot manipulator.

Q 7 — **10** — **CO2, CO4**

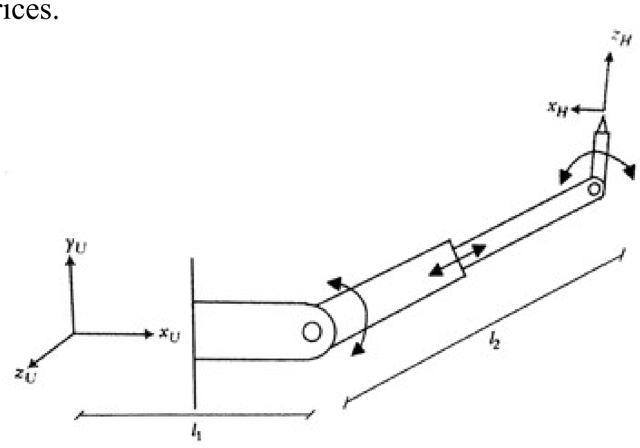
A 3-DOF spherical arm is designed to follow a particular trajectory starting from (9, 6, 10) to endpoint (3, 5, 8) .The robot geometry and DH parameter table representation is shown in below. Calculate the joint variables $\mathbf{\Theta_1}$ of the first and last joint $\mathbf{d_3}$ for 3 intermediate points.



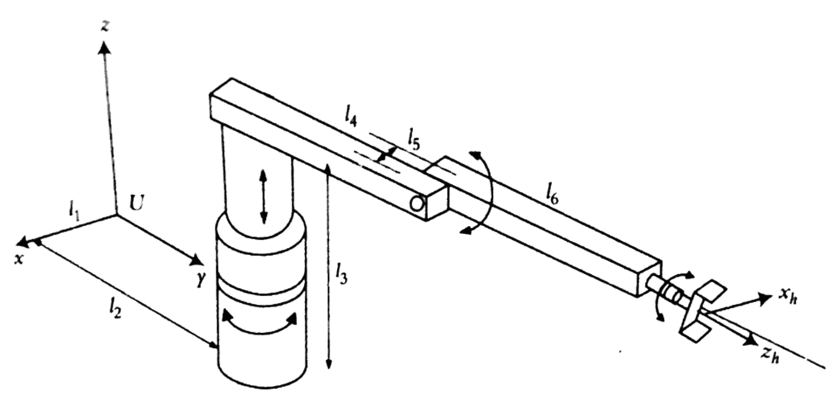
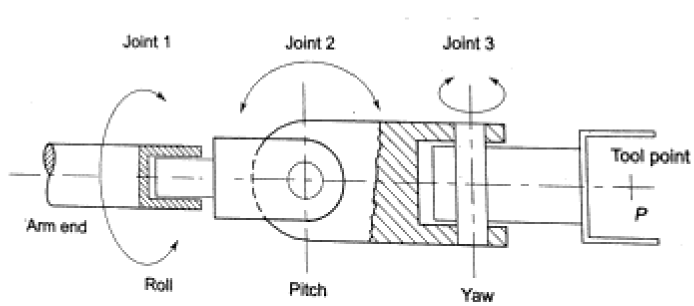
Link,i	[illegible]	[illegible]	[illegible]	[illegible]
1	[illegible]	[illegible]	[illegible]	[illegible]
2	0	0	-90	Θ_2
3	0	d_3	0	0

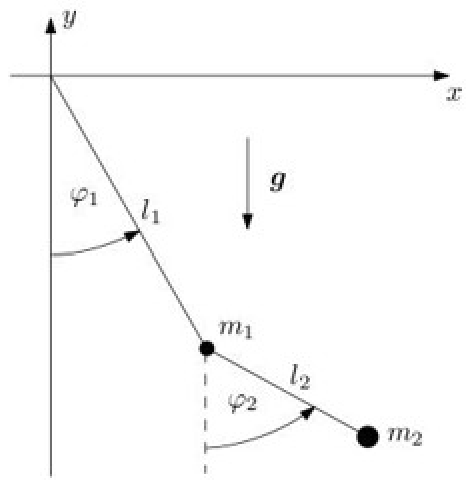
Q 8 — **10** — **CO2**

For a 3-dof robot shown in figure, identify the DH parameters and calculate the transformation matrices.



<table>
<tr><td></td><td>OR

For the given 4-dof robot configuration, identify the DH parameters and calculate the
Individual transformation matrices.
</td><td>10</td><td>CO2</td></tr>
<tr><td>Q 9</td><td>Determine the equations of motion for the 2DOF RR planar manipulator arm using the Lagrange Euler formation. Assume both links have equal length (L1=L2=L) and have equal mass (m1=m2=m). Assume further that the links are slender members with a uniform mass distribution i.e. the center of mass of each link is located at the midpoint of the link</td><td>10</td><td>CO4</td></tr>
<tr><td colspan="4">SECTION-C</td></tr>
<tr><td>Q 10</td><td>Asssumptions: Consider that the arm end point of 3R roll-pitch-yaw wrist shown in figure is stationary and can be considered as the stationary base frame for the wrist joint. The axis of joint 1 and joint 2 are perpendicular to each other and intersect at joint 2. The axis of joint 3 and joint 2 are mutually perpendicular but are in parallel lines. The three joint displacements Θ_1, Θ_2, Θ_3 are along mutually perpendicular directions: roll, pitch and yaw.

In view of above assumptions, analyze and derive the conditions of singularities of the 3R roll-pitch-yaw wrist.</td><td>20</td><td>CO2
CO3</td></tr>
</table>

	OR In view of above assumptions, for the 3R roll-pitch-yaw wrist configuration shown in figure, the position and orientation of point P in Cartesian space is given by $$T = \begin{bmatrix} 0.354 & 0.866 & 0.354 & 0.106 \\ -0.612 & 0.500 & -0.612 & -0.184 \\ 0.707 & 0 & 0.707 & 0.212 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$ Interpret the feasible solutions of joint variables if the joint limits for the three joints are given as, **Joint1:** $-100<\Theta_1<100$ **Joint 2:** $-30<\Theta_2<70$ **Joint 3:** $-15<\Theta_3<45$	**20**	**CO2**
Q 11	Derive the equations of motion for the 2DOF system using the Lagrange Euler formation. Assume both links have equal length (L1=L2=L) and have equal mass (m1=m2=m). Assume further that the links have a uniform mass distribution i.e. the center of mass of each link is located at the endpoint of the link.  	**20**	**CO4**

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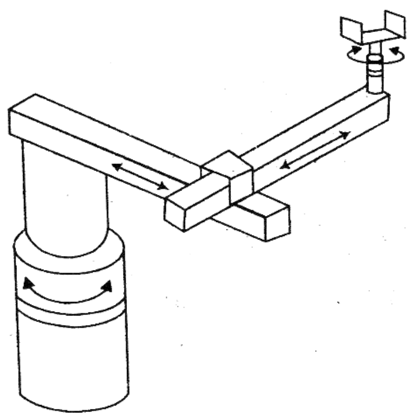
Q 1	Define dexterity for a robot configuration. Sketch the approximate workspace for the following robot. Assume that the dimensions of the base and other parts are of the robot structure are as shown. 	4	CO1
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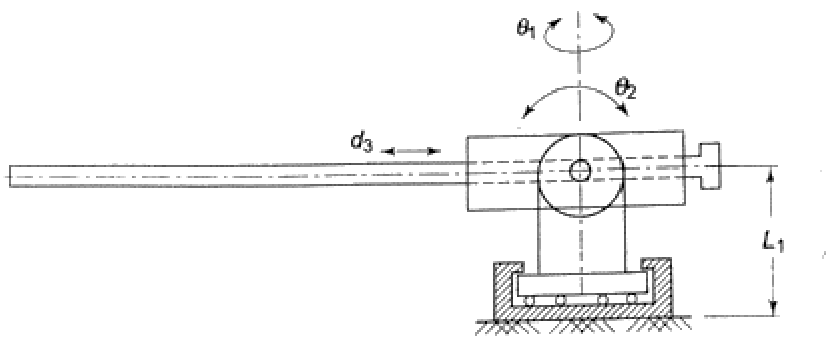
Q 5	A frame B is rotated at 90^0 about the a axis , rotated at 90^0 about the y axis then translated 2 and 4 units relative to x and y axes respectively, then rotated another 90^0 about n axis. Calculate the new location and orientation of the frame.	**4**	**CO2**

SECTION B

Q 6	Derive dynamic equations of a three-link purely prismatic planar 3P manipulator whose axes of joints are mutually perpendicular using Lagrangian method. Discuss the nature of the Christoffel symbols, Hijk for the robot manipulator.	**10**	**CO4**

Q 7 A 3-DOF spherical arm is designed to follow a particular trajectory starting from (9, 6, 10) to endpoint (3, 5, 8) .The robot geometry and DH parameter table representation for the robot configuration is shown in below. Calculate Θ_1 and d_3 , the joint variables of the first and last joint for 3 intermediate points. **10** **CO2, CO4**



Link,i				
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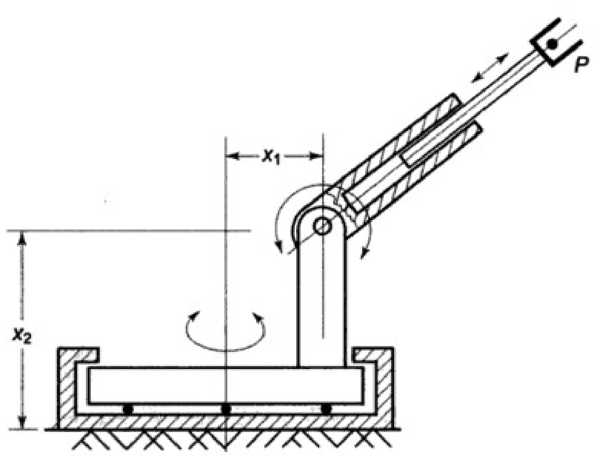
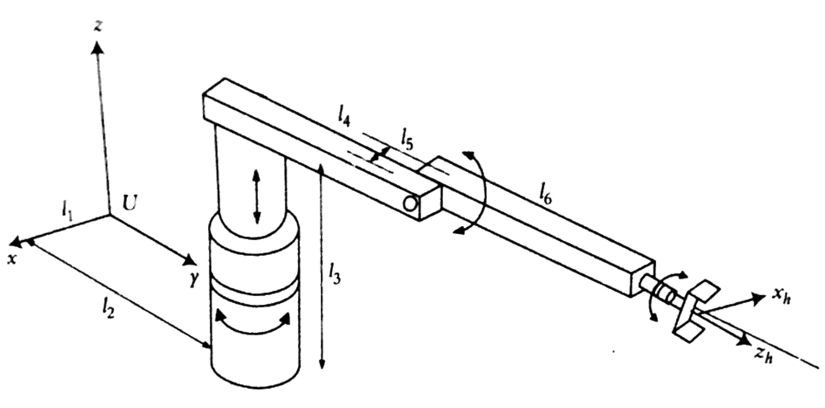


	OR For the given 4-dof robot configuration, identify the DH parameters and calculate the transformation matrices. 	**10**	**CO2**
Q 9	Determine the equations of motion for the 2DOF RP planar manipulator arm using the Lagrange Euler formation. Assume both links have equal length (L1=L2=L) and have equal mass (m1=m2=m). Assume further that the links are slender members with a uniform mass distribution i.e. the center of mass of each link is located at the midpoint of the link	**10**	**CO4**
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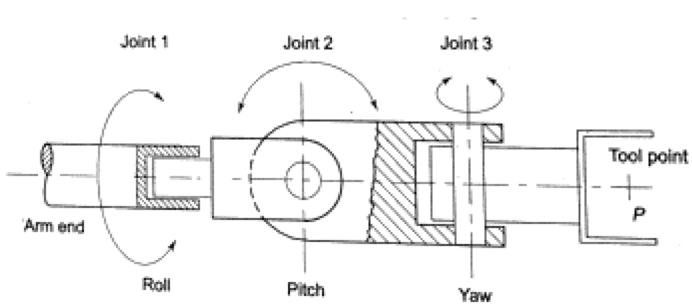
Q 10	**Asssumptions:** Consider that the arm end point of 3R roll-pitch-yaw wrist shown in figure is stationary and can be considered as the stationary base frame for the wrist joint. The axis of joint 1 and joint 2 are perpendicular to each other and intersect at joint 2. The axis of joint 3 and joint 2 are mutually perpendicular but are in parallel lines. The three joint displacements Θ_1, Θ_2, Θ_3 are along mutually perpendicular directions: roll, pitch and yaw.  In view of above assumptions, analyze and derive the conditions of singularities of the 3R roll-pitch-yaw wrist.	**20**	**CO2** **CO3**

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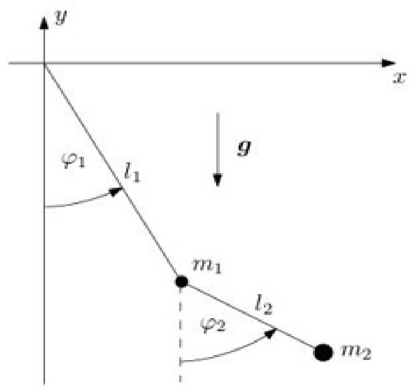
Q 11	Derive the equations of motion for the 2DOF system using the Lagrange Euler formation. Assume both links have equal length (L1=L2=L) and have equal mass (m1=m2=m). Assume further that the links have a uniform mass distribution i.e. the center of mass of each link is located at the endpoint of the link. 	**20**	**CO4**