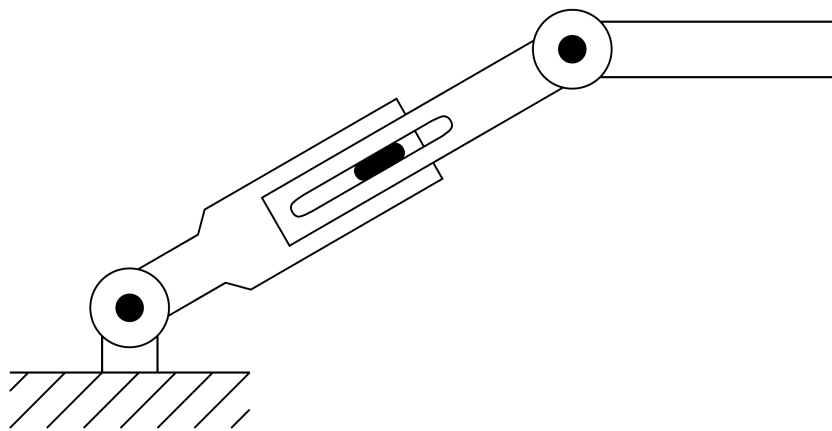


# ME604: Introduction to Robotics

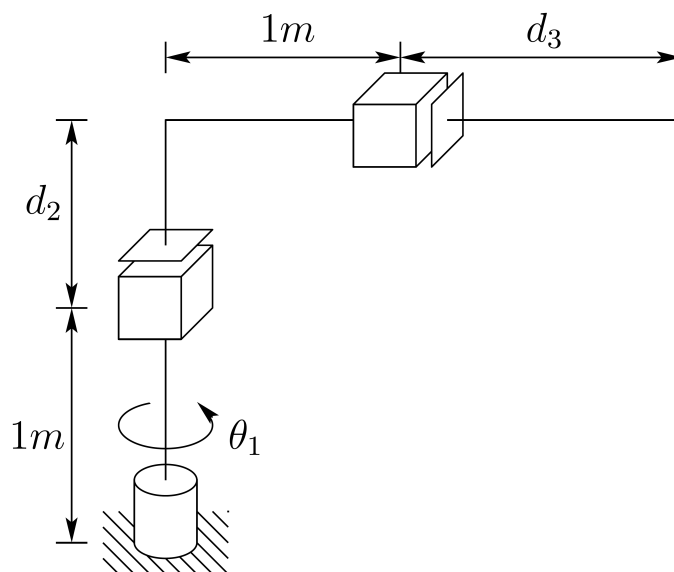
Spring 2022

## Tutorial 4

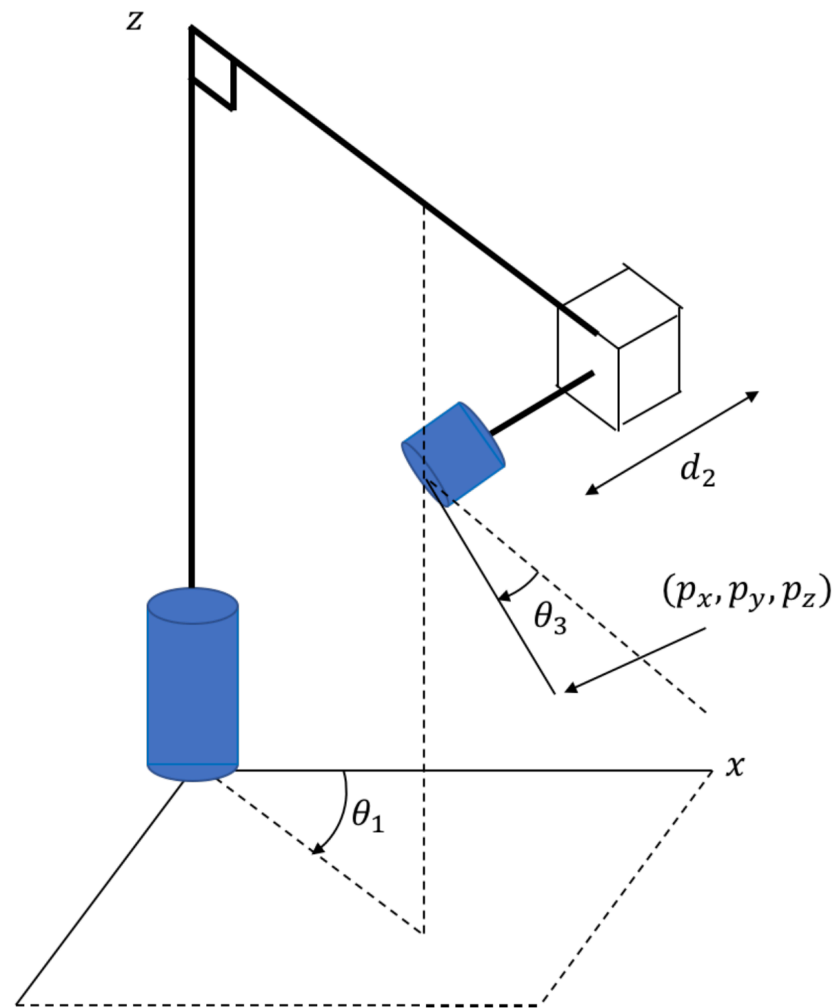
1. Given the desired position of the end-effector, find the solutions to the inverse kinematics of the three link planar arm shown below. Consider the following task space variables –  
a) only the position of the end-effector and b) position and orientation of the end-effector



2. Solve the inverse position kinematics for the cylindrical manipulator shown here.



3. Consider the manipulator shown below:



- Geometrically, solve the inverse kinematics problem for the position of the end-effector, i.e, given a desired end effector position  $(p_x, p_y, p_z)$  determine the set(s) of values of joint variables  $\theta_1$ ,  $d_2$  and  $\theta_3$  to achieve it. You should provide all possible solutions.
- Suppose a spherical wrist is attached to end of this 3-link manipulator. The desired orientation of the end-effector is given by  $(45^\circ, 30^\circ, 45^\circ)$  in ZYZ Euler angles. Find the joint angles for the spherical wrist to achieve this orientation, if the orientation of the last link of the 3-link manipulator with respect to the base frame is given by

$${}^0_3R = \begin{bmatrix} -0.8 & 0.4242 & 0.4242 \\ 0.6 & 0.5656 & 0.5656 \\ 0 & 0.707 & -0.707 \end{bmatrix}$$

- Analytically, obtain all the solutions to the inverse kinematics problem for the robot arm, whose forward kinematic solution you computed in the first programming assignment.