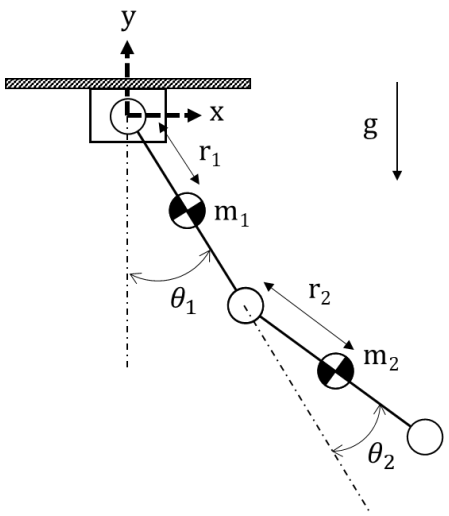
ROB 545 Spring 2022 Problem Set #4
Assigned May 11, 2022 Due: by 11:59 pm, May 24

- Upload a scanned PDF to Gradescope
- Show all work and/or computer code used in your calculations

1. Simulation of a two-dof robot and robot controller (20 points).

(a) Dynamics (5 points). Derive the dynamic model of the 2R robot under gravity (see the sketch to the right). This is an actuated double pendulum. The mass of link i is m_i, the center of mass is a distance r_i from the joint, the scalar inertia of link i about the frame attached to the center of mass at each link is I_i, and the length of link i is L_i. There is no friction at the joints.



(b) Trajectory (5 points). Write a function that generates a fifth-order polynomial trajectory moving from rest at $(\theta_1, \theta_2) = (-\pi/4, 0)$ to rest at $(\theta_1, \theta_2) = (\pi/4, \pi/2)$ in $T = 2$ s. The trajectory generator should take the following as input:

- the desired initial position, velocity, and acceleration of each joint;
- the desired final position, velocity, and acceleration; and
- the total time of motion T

A call of the form

$$[\text{qd}, \text{qdotd}, \text{qdotdotd}] = \text{trajectory}(\text{time})$$

returns the desired position, velocity, and acceleration of each joint at time time.

(c) Simulation and control (10 points). For the 2R robot and 5th order polynomial trajectory, simulate a computed torque controller that stabilizes the trajectory (the figure below shows the starting and ending configurations). You may write your own program or use the Matlab toolbox that accompanies the course textbook. You may use a first-order Euler integration to update position and velocity (see Exercise 11.7 for a description). Use $g = 9.81$ m/s^2, $L_i = 1$ m, $r_i = 0.5$ m, $m_1 = 3$ kg, $m_2 = 2$ kg, $I_1 = 2$ kg m^2, and $I_2 = 1$ kg m^2. The modeled link masses should be 20% greater than their actual values to create error in the feedforward model. Give the PID gains and plot the following:

- the reference joint angles, actual joint angles, corresponding end-effector motion in task space, and joint torques for the computed torque controller