Spring 2022

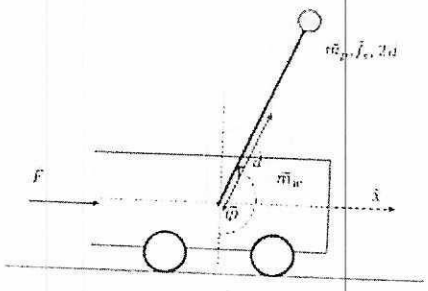
HW 1

EE 493 and EE 5234

Each problem has 50 points

Problem 1 Single-link manipulator robot – The Inverted Pendulum (IV)

Given: Consider an inverted pendulum shown here.



Dynamic model of a simplified version of the pendulum is given below:

$$\dot{x}_1 = x_2$$

$$\dot{x}_2 = \frac{g\ sin(x_1) - amlx_2^2\ sin(2x_1)/2 - a\ cos(x_1)u}{4l/3 - aml\ cos^2(x_1)}$$

Where $x_1 = \theta$, (angular position), $x_2 = d\ \theta/dt$ (angular velocity) are state variables and control variable, u is force f acting on the base of the pendulum's platform.

IV system variables are: Mass of pendulum, m = 2 kg, Cart mass, M = 8 Kg, a = 1/(m + M), Gravitational acceleration, g = 9.8 m/sec^2, and IV length l = 0.5 m.

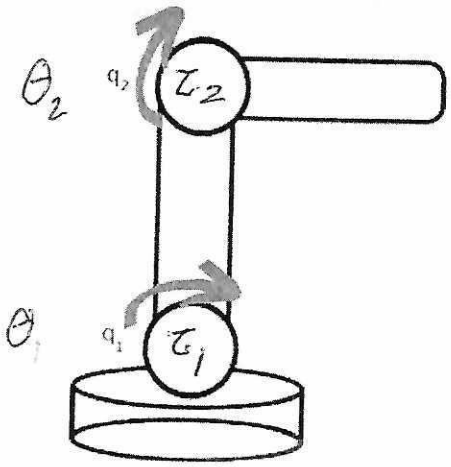
Required:

a) Using Matlab, simulate the IV system with open look control for a force, u = 1Newton. Plot responses of the two state variables vs time for up to 10 seconds.

b) Use Matlab to design a PD controller $u = K_p\theta + K_d(d\theta/dt)$, where gains K_p and K_d are unknown gains. Use trial and error approach to find the controller that will give a settling time of 5 seconds.

Problem 2 Two-link manipulator (TLM)

Given: A two-link planar robot is shown below



Dynamic model of this manipulator in given below:

$$\tau_1 = [a_1 + a_2\cos\theta_2]\,\ddot{\theta}_1 + [a_3 + \frac{a_2}{2}\cos\theta_2]\,\ddot{\theta}_2 + a_4\cos\theta_1 - (a_2\sin\theta_2)(\dot{\theta}_1\dot{\theta}_2 + \frac{\dot{\theta}_2^{\,2}}{2}) + a_5\cos(\theta_1+\theta_2)$$

$$\tau_2 = [a_3 + \frac{a_2}{2}\cos\theta_2]\,\ddot{\theta}_1 + a_3\,\ddot{\theta}_2 + (a_2\sin\theta_2)\frac{\dot{\theta}_1^{\,2}}{2} + a_5\cos(\theta_1+\theta_2)$$

Where a1 = 3.82, a2=2.12, a3=0.71, a4=81.82.

Required: Use Matlab to simulate this system given torques inputs,

a) Write the state equation for this robot as:

$$dx/dt = f(x,u)$$

Where state vector $x = [x1, x2, x3, x4] = [\theta1, \theta1dot, \theta2, \theta2dot]$ and $u = [\tau1\ \tau2]$.

b) Use two joint torque values of 2 newton each and simulate this nonlinear model of the 2-link manipulator robot. Use the following initial conditions: $[\theta1, \theta2] = [0\ 0]$, $[\theta1, \theta2] = [30^o\ 90^o]$,and $[\theta1, \theta2] = [90^o\ 30^o]$. Use a 10 seconds simulation time, but you can change that. Plot $[\theta1, \theta2]$ vs time and plot $\theta1$ vs. $\theta2$ (horizontal vs vertical axis).

c) Discuss your results and try to write a visualization of what is physically going on?

Hint: See pages Reference 2 , book by Behar, et al., pp. 324-325.