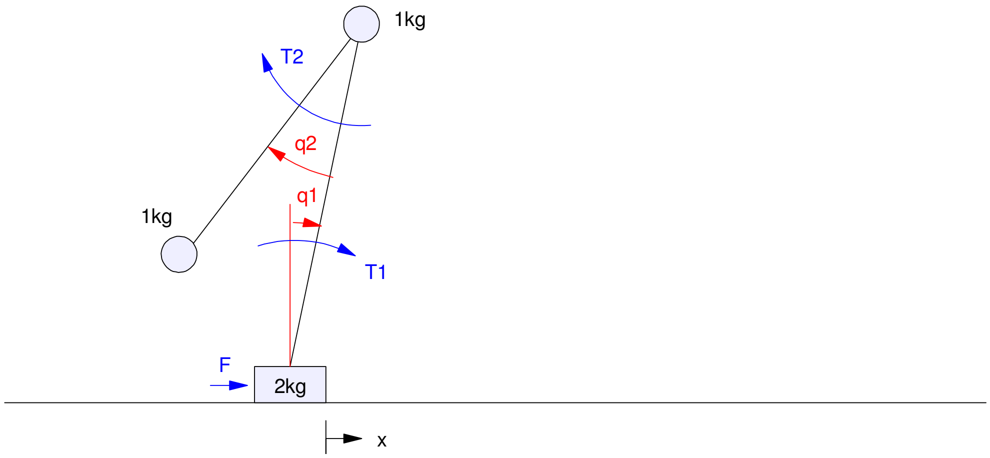
ECE 463/663 - Test #3: Name ________________

Due midnight Sunday, May 5th.   Individual Effort Only (no working in groups)



The dynamics for a cart & double pendulum are

$$\begin{bmatrix} 3 & (2c_1+c_{12}) & c_{12} \\ (2c_1+c_{12}) & (3+2c_2) & (1+c_2) \\ c_{12} & (1+c_2) & 1 \end{bmatrix}\begin{bmatrix} \ddot{x} \\ \ddot{\theta}_1 \\ \ddot{\theta}_2 \end{bmatrix} = C\left(\theta,\dot{\theta}\right) + g\begin{bmatrix} 0 \\ 2s_1+s_{12} \\ s_{12} \end{bmatrix} + \begin{bmatrix} F+d \\ T_1 \\ T_2 \end{bmatrix}$$

Linearizing about

- x = 0
- q1 = 0 (first link points up)
- q2 = pi   (second link points down)

$$\begin{bmatrix} 3 & 1 & -1 \\ 1 & 1 & 0 \\ -1 & 0 & 1 \end{bmatrix}\begin{bmatrix} \ddot{x} \\ \ddot{\theta}_1 \\ \ddot{\theta}_2 \end{bmatrix} = g\begin{bmatrix} 0 \\ 3\theta_1-\theta_2 \\ \theta_1-\theta_2 \end{bmatrix} + \begin{bmatrix} F+d \\ T_1 \\ T_2 \end{bmatrix}$$

or in state-space form with a disturbance (d):

$$s\begin{bmatrix} x \\ \theta_1 \\ \theta_2 \\ \dot{x} \\ \dot{\theta}_1 \\ \dot{\theta}_2 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & -2g & 0 & 0 & 0 & 0 \\ 0 & 5g & -g & 0 & 0 & 0 \\ 0 & -g & -g & 0 & 0 & 0 \end{bmatrix}\begin{bmatrix} x \\ \theta_1 \\ \theta_2 \\ \dot{x} \\ \dot{\theta}_1 \\ \dot{\theta}_2 \end{bmatrix} + \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 1 & -1 & 1 \\ -1 & 2 & -1 \\ 1 & -1 & 2 \end{bmatrix}\begin{bmatrix} F+d \\ T_1 \\ T_2 \end{bmatrix}$$

Design a feedback control law using LQR or LQG/LTR or VSS techniques (your pick) which

- Uses all three inputs (F, T1, and T2),
- Results in a 2% settling time between 6 to 12 seconds
- Less than 10% overshoot for a step input,
- An ability to track a constant set point, and
- An ability to reject a contant disturbance

Turn in for your exam

- A block diagram of your plant and controller
- Matlab code used to determine your control law,
- The resulting control law
- A step response with respect Ref = 1 and d = 1 for the linear model (above),
- A step response for the nonlinear simulation (Cart2 / Cart2Display / Cart2Dynamics) with your control law, and
- The main calling routine (Cart2.m) you used to generate this step response.

C Level (max 80 points)

Assume

- No noise
- All states are measured
- A constant set point, and
- A constant disturbance (d = 1)

B Level (max 90 points)

Assume

- No noise
- Only positions and angles are measured $\{x, \theta_1, \theta_2\}$
- A constant set point, and
- No disturbance (d = 0)

A Level (max 100 points)

Assume

- No noise
- Only positions and angles are measured $\{x, \theta_1, \theta_2\}$
- A constant set point, and
- An input disturbance (d = 1)