ME 417 - Homework #2

Control of Mechanical Systems - Fall 2020

Homework Due: Thu, 07 Jan 2021 23:59

Complete the following problems and submit a hard copy of your solutions. You are encouraged to work together to discuss the problems but submitted work **MUST** be your own. This is an **individually** submitted assignment.

Problem 1

Stability Analysis (20pts)

For each of the following systems, find the poles of the system and determine the system's stability classification. Justify your answer.

a. $G(s) = \dfrac{s - 19}{s^2 + 2s + 6}$

b. $G(s) = \dfrac{s^2 - 25}{(s^2 + 2s + 20)\,(s^2 + 3s + 100)}$

c. $G(s) = \dfrac{s^2 + 20}{(s + 10)\,(s^2 + 100)}$

d. $G(s) = \dfrac{s\,(s - 19)}{s^2 - 5s + 20}$

Problem 2

Second Order Approximation (20pts)

For each of the following systems, determine if a 2nd-order approximation is valid. Justify your answer.

a. $G(s) = \dfrac{200s + 200}{(s + 2)\,(s^2 + 2s + 10)}$

b. $G(s) = \dfrac{20s + 220}{(s + 10)\,(s^2 + 4)}$

c. $G(s) = \dfrac{45}{(s + 11)\,(s^2 + 2s + 40)}$

d. $G(s) = \dfrac{s + 10}{(s + 1)\,(s^2 + 10s + 200)}$

Hint: 5 times rule of thumb for higher order poles, or if zeros are present, compare the magnitude of the higher order term.

Problem 3

Stability and Feedback Form (25pts)

On February 18th, 2021, NASA's Mars 2020 Preserverance Rover is planned for landing on Mars. A landing animation video can be seen here `http://bit.ly/Preserverance`

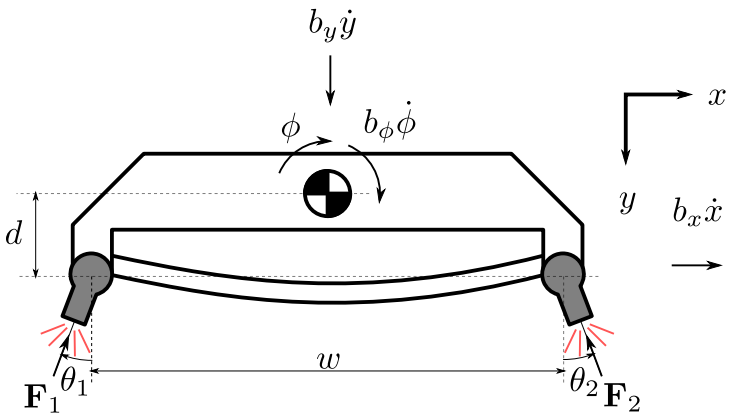
The Sky Crane, which is responsible for gracefuly landing the rover on the designated site, can be modeled as a rigid body with thruster forces being controlled by a gimbal to produce thrust at angles θ as shown.

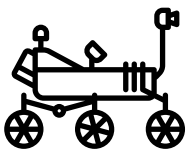
a. Derive the equations of motion for the system (3 directions)

b. List the transfers functions (just the input output signal expression) required to express all the dynamics of the system.

c. With the thrust values are constant with $F_1 - F_2 = \Delta F > 0$, and the thrust angles are equal but varying $\theta_1 = \theta_2 = \theta$. Derive the transfer function relating θ to $\dot{\phi}$, the angular velocity of the skycrane.

d. Assess the stability of this system $\frac{\dot{\Phi}}{\Theta}$





Given $m = 500kg, I = 1125.0kg \cdot m^2, d = 1m, w = 3m, g = 3.711m/s^2, b_y = 25N \cdot s/m, b_x = 10N \cdot s/m, b_\phi = 12N \cdot s$

Problem 4

Block Diagram Manipulation (15pts)

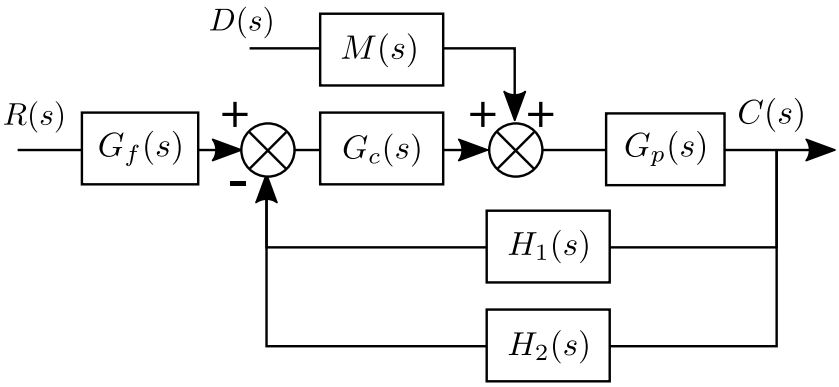
Given the following block diagram, with

$G_f = 12,\ G_c = 0.5s + 5.0,\ G_p = \dfrac{6.0}{1.0s^2 + 10.0},\ H_1 = \dfrac{1.0}{s},\ H_2 = 5,\ M = 5.0s$

a. Derive the transfer function that relates the reference $R(s)$ to the output $C(s)$

b. Derive the transfer function that relates the reference $R(s)$ to the input to the plant $U(s)$

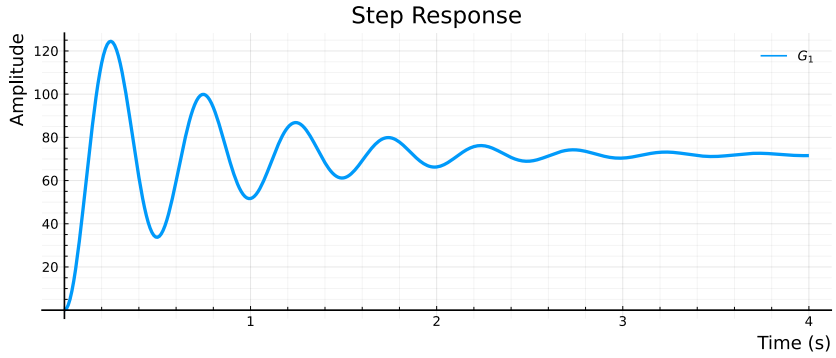
c. Derive the transfer function that relates the disturbance (noise) $D(s)$ to the output $C(s)$



Problem 5

Derive System from Response (20pts)

The following is the response of a second-order system to a step input $u = 18$



Derive, approximately, the transfer function of the system