THE UNIVERSITY OF AUCKLAND
Department of Electrical, Computer & Software Engineering

ELECTENG 303– ASSIGNMENT #3
Systems & Control

Instructor: Akshya Swain

2020/10/29

Student Name: ______________________________

Student ID: ______________________________

This assignment contains 4 questions. Total of points is 60.

Distribution of Marks

Question	Points	Score
1	15	
2	15	
3	10	
4	20	
Total:	60	

1. The attitude control system of a space shuttle rocket is shown in Figure-1.

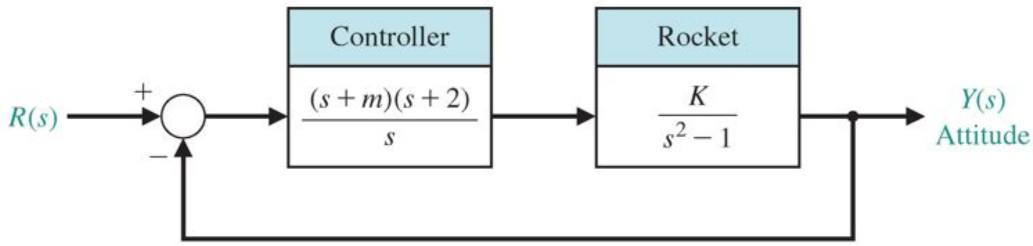

Figure 1: Shuttle Attitude Control

(a) (8 points) Determine the range of gain K and parameter m so that the system is stable, and plot the region of stability.

(b) (4 points) Select the gain and parameter values so that the steady state error to a ramp input is less than or equal to 10%.

(c) (3 points) Determine the percent overshoot for a step input for the design parameters selected in the above part.

Hints:

- Get the closed loop characteristic equation.
- Formulate the Routh's Table and find the conditions in terms of K and m which will ensure closed loop stability. This condition will be an inequality.
- Assuming this condition to be equality, plot the relation between K and m. One side of the plot is the region of stability.
- Find the condition in terms of K and m which will give the desired steady state error.
- Select the values of K and m. A good practice is to select lower value of m compared to higher value; as this will give faster response.
- With your choice of K and m, get the response of closed loop system. Use the commands **feedback**, **lsim** etc as you have done in Assignment-2 and find the overshoot.

2. The unmanned exploration of planets such as Mars requires a high level of autonomy because of the communication delays between robots in space and their Earth-based stations. This affects all the components of the system: planning, sensing, and mechanism. In particular, such a level of autonomy can be achieved only if each robot has a perception system that can reliably build and maintain models of the environment. The perception system is a major part of the development of a complete system that includes planning and mechanism design. The target vehicle is the Spider-bot, a four-legged walking robot shown in Figure-2 (a), being developed at NASA Jet Propulsion Laboratory. The control system of one leg is shown in Figure-2(b).

(a) (4 points) Sketch the Bode diagram for $G_c(s)G(s)$ Gc(s)G(s) when $K = 20$. Determine

i. Determine the gain and phase cross over frequencies.

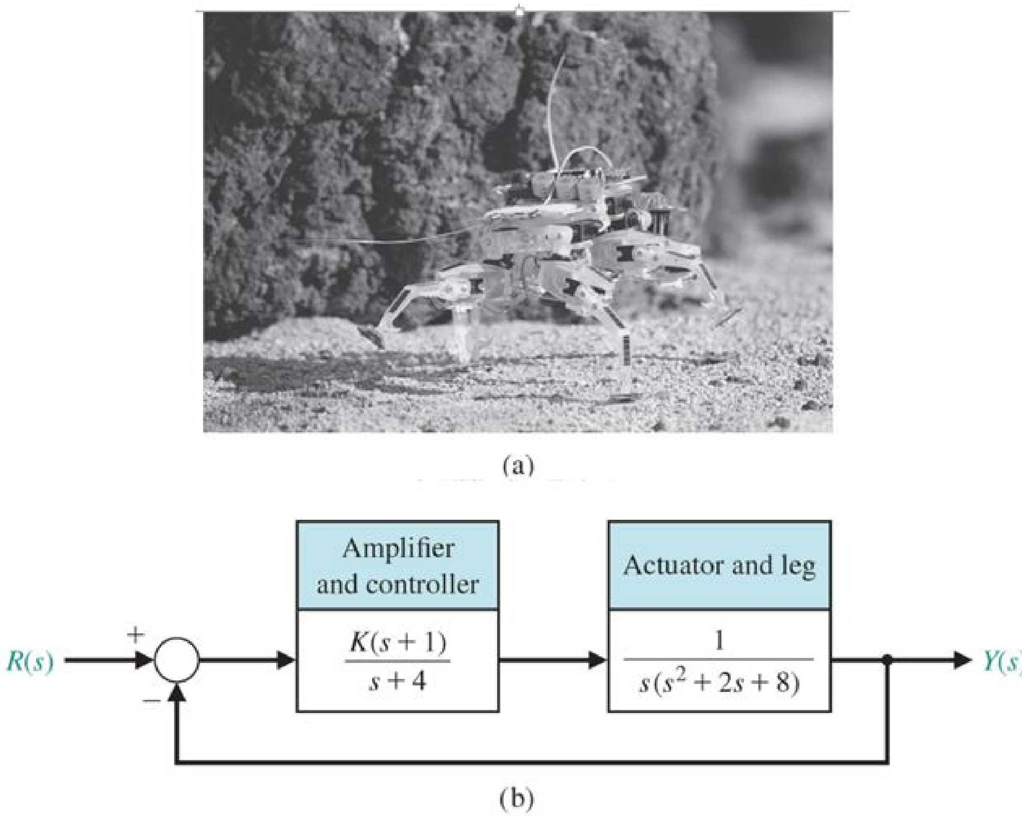

Figure 2: Block Diagram of the Control System for One Leg

(b) (2 points) Plot the Bode diagram for the closed-loop transfer function $T(s)$ when $K = 20$.

(c) (6 points) Determine M_r (resonant peak), ω_r (resonant frequency), and ω_B (bandwidth) for the closed-loop system when $K = 25$ and $K = 35$.

(d) (3 points) Compute the step response of closed loop system for both cases i.e. for $K = 25$ and for $K = 35$. Comment which gain you would prefer.

Hints

Plot the Bode plot of this system using the functions **bode** and **margin** functions of MATLAB. (see the lecture handout Module8 on Bode Plot).

- Get the closed loop transfer function. Use the command **feedback** as explained in the basics MATLAB commands I have provided.
- Plot Bode plot and find the maximum amplitude and related frequencies.

3. The linearized model of a particular network link working under TCP/IP and controlled using a random early detection (RED) algorithm can be described by a unity feedback

closed loop system with feed forward path transfer function $G(s) = M(s)P(s)$ where

$$M(s) = \frac{0.0005L}{(s + 0.005}$$
$$P(s) = \frac{140625e^{-T_d s}}{(s + 2.67)(s + 10)}$$

Considering $L = 1$

(a) (10 points) i. Plot the Nyquist diagram of the system for various values of delays T_d.

ii. Compute both the gain and phase margin of the system for following time delays T_d of $0.0, 0.01, 0.05, 0.08, 0.1, 0.3$ and 0.5 second and comment on your observation.

Hints:

Example: Let us represent the following time delay system in MATLAB.

$$G(s) = \frac{10e^{-T_d s}}{(s + 3)(s + 5)}$$

```
numG=[10];
denG=conv([1 3],[1 5]);
G=tf(numG,denG,'InputDelay',Td);
```

- You construct the open loop transfer function using **series** command.
- You should use the functions **nyquistplot** and **margin** to determine the relative stability at various values of delay. Make a table and show your results.

4. Consider the unity feedback system with forward path transfer function

$$G(s) = \frac{K}{s(s + 5)(s + 20)}$$

(a) (3 points) Determine the value of K which gives the velocity error constant $K_v = 10$. Compute the step response of the uncompensated system with the selected value of K. What is the percentage overshoot ?

(b) (15 points) Use frequency response methods to design a lead compensator to reduce the percent overshoot to 10%, while keeping the peak time and steady state error about the same or less. You can make any required assumptions.

(c) (2 points) Using MATLAB, compute and plot the step response of the compensated system.

Hints

a. Follow the various steps of designing lead compensator as described in the lecture handout.