EEL 301 MINOR TEST 2

Duration: 1 hour

Total Marks: 20

Instructions

1. Show all relevant steps clearly and briefly.
2. If needed, make suitable assumptions. But, state them clearly.

Please note reference to following figures in some of the questions,

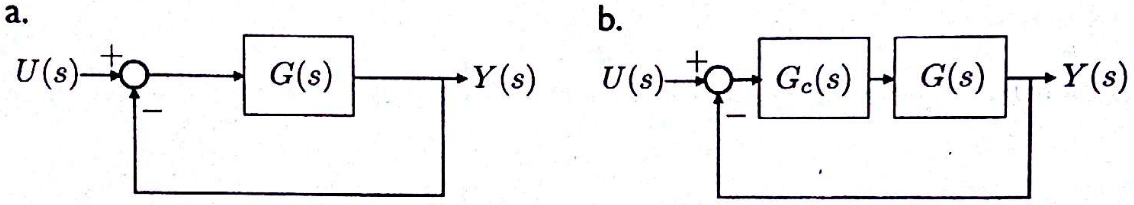

Figure 1: Please note reference to following figures in some of the questions.

Question 1. *(4 marks)* The simplified transfer function model from the steering angle $\delta(s)$ to the tilt angle $\phi(s)$ in a bicycle can be obtained as,

$$B(s) = \frac{\phi(s)}{\delta(s)} = \frac{V}{2}\left(\frac{s + 5V/3}{s^2 - (7/2)^2}\right).$$

In order to stabilize the bicycle, it is assumed that the bicycle is placed in a closed-loop configuration (Fig. 1a. with $G(s) = B(s)$) and that the only available control variable is V, the rear wheel velocity. Sketch the locus of roots of the characteristic equation of this closed-loop system as V is varied from 0 to ∞.

Question 2. *(6 marks)* A unity feedback system $G(s) = K/s^2$ (see Fig. 1a.), where gain K can be varied in the range $K \geq 0$, is to be modified to get a settling time (2% criterion) of $1.667 sec$ and a maximum overshoot of 16.3%. Design an appropriate compensator $G_c(s)$ (as in Fig. 1b.) aimed at achieving these objectives with the constraint that the compensator has a single zero that is placed at -1.4. Based on the design or otherwise, comment on whether a PD controller with transfer function $K_p(1 + T_d s)$ can be used to achieve the design objectives.

Question 3. *(5 marks = 4 marks for a) + 1 mark for b))* An X-4 quadrotor flyer is designed as a small-sized unmanned autonomous vehicle (UAV) that flies mainly indoors and can help in search and recognizance missions. To minimize mechanical problems and for simplicity, this aircraft uses fixed pitch rotors with specifically designed blades. Therefore, for thrust it is necessary to add a fifth propeller. A simplified design of the thrust control design can be modeled as in Fig. 1b., where

$$G(s) = \frac{1.91\left(\frac{s}{0.43} + 1\right)}{\left(\frac{s}{9.6} + 1\right)\left(\frac{s}{0.54} + 1\right)},$$

represents the dynamics of the thruster rotor gain, the motor and the battery dynamics. The error can be defined as $e(t) = u(t) - y(t)$. Initially, the system is designed using a proportional compensator given by $G_c(s) = 3$ and the resulting steady-state error for a unit step input ($U(s) = 1/s$) is found to be approximately 0.15.

a) It is desired to halve the steady-state error obtained using the proportional compensator, without appreciably altering the overall system's transient response. Design a lag compensator ($G_c(s) = \hat{K}_c(s + 1/T)/(s + 1/(T\beta)), \beta > 1$) aimed at achieving this objective.

b) Justify whether or not the design objectives can be met with a PI controller with transfer function $K_p(1 + 1/(T_i s))$.

Question 4. *(5 marks)* Consider the unity feedback system shown in Fig. 1a. with

$$G(s) = K\frac{s^4}{(s^2 + s + 1)^2}.$$

Plot the root-locus of the closed-loop system as K is varied from 0 to ∞. (Hint: Consider how the root locus behaviour on the real and imaginary axes, asymptotically and at any possible break points. Also, consider the angles of arrival/ departure at the zero/ pole of the system.)