CMPE-432. Feedback Control Systems.
Homework #3.*

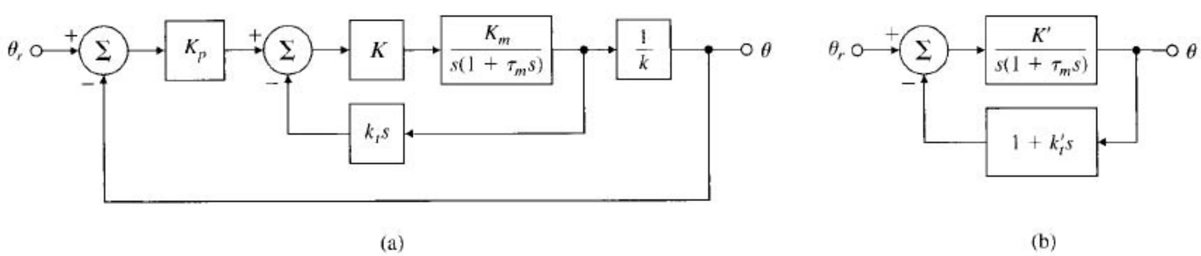
Spring 2010.

Due date March 15^{th}, 2010.

Control of Steady-State Error:

Problem 1

Consider the DC motor control system with rate feedback shown in figure:



1. Find values for K' and k_t' so that the system of figure (b) has the same transfer function as the system of figure (a).
2. Determine the system type wrt tracking θ_r and compute the system K_v in terms of parameters K' and k_t'.
3. Does addition of rate feedback with positive k_t increase or decrease K_v?

Problem 2

Consider the system shown in figure which represents control of the angle of a pendulum that has no damping.

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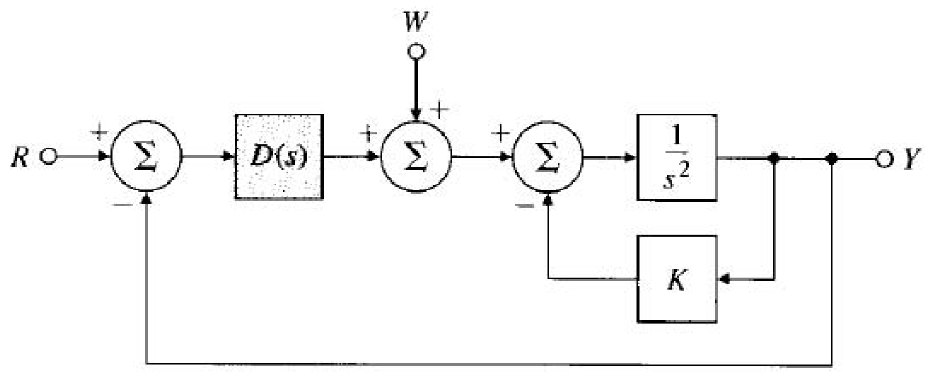


1. What condition must $D(s)$ satisfy so that the system can track a ramp reference input with constant steady-state error?

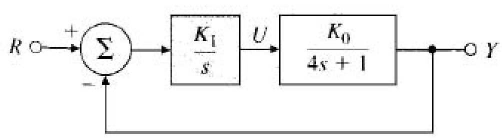
2. For a transfer function $D(s)$ that stabilizes the system and satisfies the condition in previous part, find the class of disturbances $w(t)$ that the system can reject with steady-state error.

3. Show that, although a PI controller satisfies the condition derived in first part, it will not yield a stable closed-loop system. Will a PID controller work - that is, satisfy first part and stabilize the system? If so, what constraints must k_p, k_I, and k_D satisfy?

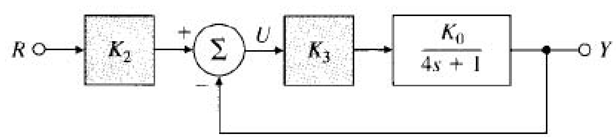
4. Discuss qualitatively and briefly the effects of small variations on the controller parameters k_p, k_I, and k_D on the system's step response, rise time and overshoot.

Problem 3

Two feedback systems are shown in figure (a) and figure (b):



(a)



(b)

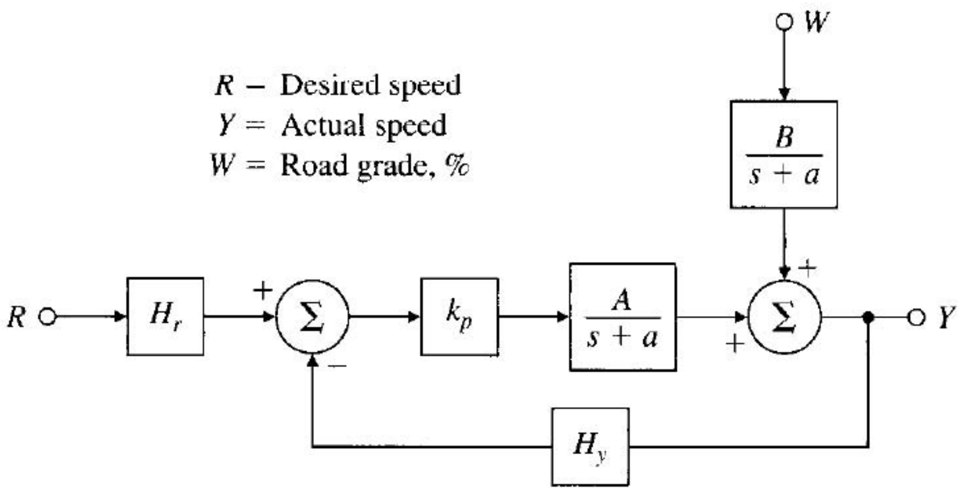
1. Determine values for K_1, K_2 and K_3 so that both systems exhibit zero steady-state error to step inputs (that is both are type 1) and whose static velocity error constant $K_v = 1$ when $K_0 = 1$.

2. Suppose K_0 undergoes a small perturbation: $K_0 \longrightarrow K_0 + \delta K_0$. What effect does this have on system type in each case? Which system has a type which is robust? Which system do you think would be preferred?

3. Estimate the transient response of both systems to a step reference input, and give estimates for t_s, t_r and M_p. In your opinion, which system has a better transient response at the nominal parameter values?

Problem 4

Consider the automobile speed-control system depicted in figure:



1. Find the transfer functions from $W(s)$ and from $R(s)$ to $Y(s)$.

2. Assume that the desired speed is a constant reference r, so that $R(s) = \frac{r_o}{s}$. Assume that the road is level, so $w(t) = 0$. Compute values of the gains K, H_r and H_f to guarantee that $lim_{t \longrightarrow \infty} y(t) = r_o$ Include both the open loop (assuming $H_y = 0$) and feedback cases ($H_y \neq 0$) in your discussion.

3. Repeat part(2) assuming that a constant grade disturbance $W(s) = \frac{w_o}{s}$ is present in addition to the reference input. In particular, find the variation in speed due to the grade change for both the feed forward and feedback cases. Use your results to explain (1) why feedback control is necessary and (2) how the gain k_p should be chosen to reduce steady-state error.

4. Assume that $w(t) = 0$ and that the gain A undergoes perturbation $A + \delta A$. Determine the error in speed due to the gain change for both the feed forward and feedback cases. How should the gains be chosen in this case to reduce the effects of δA?

Problem 5

Consider the satellite attitude-control problem shown in figure, where the normalized parameters are:

$J = 10$ spacecraft inertia.

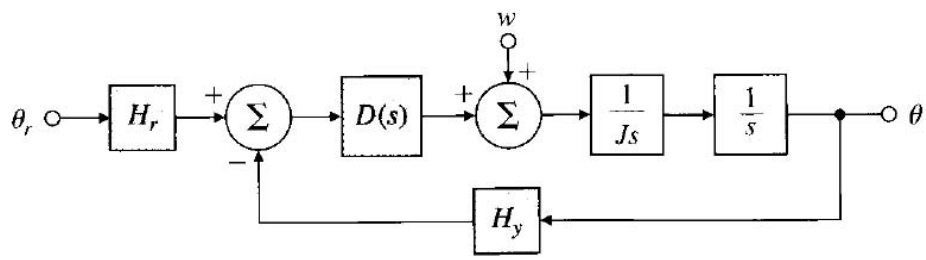
$\theta_r =$ reference satellite attitude.

$\theta =$ actual satellite attitude.

$H_y = 0.25$ sensor scale factor.

$H_r = 0.1$ reference sensor scale factor.

$w =$ disturbance torque.



1. Use proportional control, P with $D(s) = k_p$, and give the range of values for k_p for which the system will be stable.
2. Use PD control, let $D(s) = (k_p + k_D s)$, and determine the system type and error constant wrt reference inputs.
3. Use PD control, let $D(s) = (k_p + k_D s)$, and determine the system type and error constant wrt disturbance inputs.
4. Use PI control, let $D(s) = (k_p + \frac{k_I}{s})$, and determine the system type and error constant wrt reference inputs.
5. Use PI control, let $D(s) = (k_p + \frac{k_I}{s})$, and determine the system type and error constant wrt disturbance inputs.
6. Use PID control, let $D(s) = (k_p + k_D s + \frac{k_I}{s})$, and determine the system type and error constant wrt reference inputs.
7. Use PID control, let $D(s) = (k_p + k_D s + \frac{k_I}{s})$, and determine the system type and error constant wrt disturbance inputs.