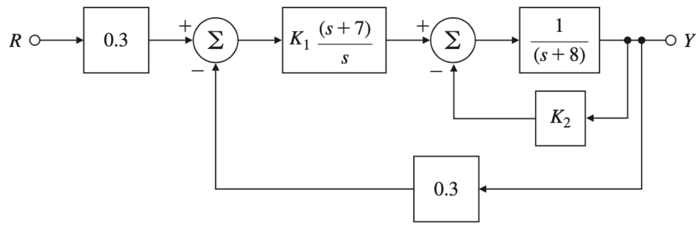
4.7 A block diagram of a control system is shown in Fig. 4.33.

(a) If r is a step function and the system is closed-loop stable, what is the steady-state tracking error?

(b) What is the system type?

(c) What is the steady-state error to a ramp velocity 2.5 if $K_2 = 2$ and K_1 is adjusted so that the system step response approximately has a rise time of 0.65 s and a settling time of 0.23 s?



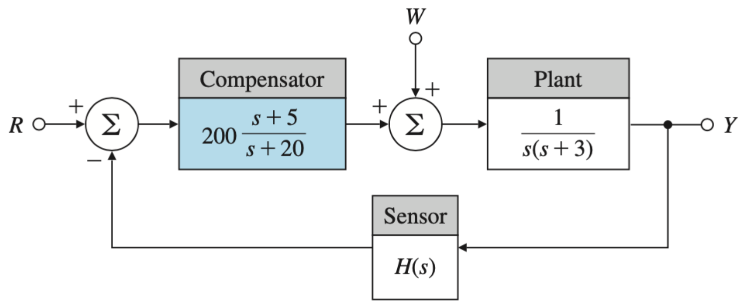
4.16 A compensated motor position control system is shown in Fig. 4.37. Assume the sensor dynamics are $H(s) = 1$.

(a) Can the system track a step reference input r with zero steady-state error? If yes, give the value of the velocity constant.

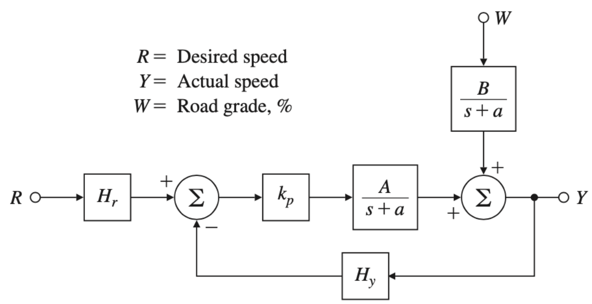
(b) Can the system reject a step disturbance w with zero steady-state error? If yes, give the value of the velocity constant.

(c) Compute the sensitivity of the closed-loop transfer function to changes in the plant pole at -3.

(d) In some instances there are dynamics in the sensor. Repeat parts (a) to (c) for $H(s) = \frac{25}{s+25}$ and compare the corresponding velocity constants.



4.27 Consider the automobile speed control system depicted in Fig. 4.46.



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

(b) Assume the desired speed is a constant reference r, so $R(s) = \frac{r_o}{s}$. Assume the road is level, so $w(t) = 0$. Compute values of the gains k_P, H_r, and H_y to guarantee that

$$\lim_{t\to\infty} y(t) = r_o.$$

Include both the open-loop (assuming $H_y = 0$) and feedback cases ($H_y \neq 0$) in your discussion.

(c) Repeat part (b) assuming 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 feedforward 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.

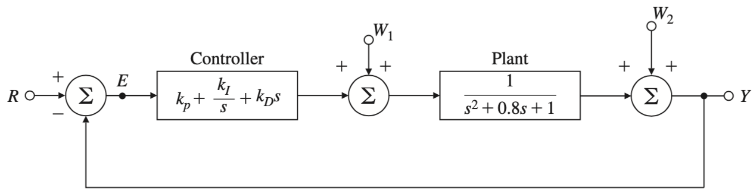
(d) Assume $w(t) = 0$ and the gain A undergoes the perturbation $A + \delta A$. Determine the error in speed due to the gain change for both the feedforward and feedback cases. How should the gains be chosen in this case to reduce the effects of δA?

4.32 A servomechanism system is shown in Fig. 4.50.

(a) Determine the conditions on the PID gain parameters to guarantee closed-loop stability.

(b) What is the system type with respect to the reference input?

(c) What is the system type with respect to the disturbance inputs w_1 and w_2?



출발각도 **at** $p = -2 + 2j$ **of** $L(s) = \frac{s+1}{s(s+5)(s^2+4s+8)}$

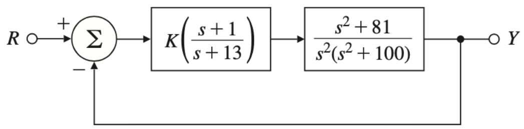
5.13 For the system in Fig. 5.53,

(a) Find the locus of closed-loop roots with respect to K.

(b) Is there a value of K that will cause all roots to have a damping ratio greater than 0.5?

(c) Find the values of K that yield closed-loop poles with the damping ratio $\zeta = 0.707$.

(d) Use Matlab to plot the response of the resulting design to a reference step.



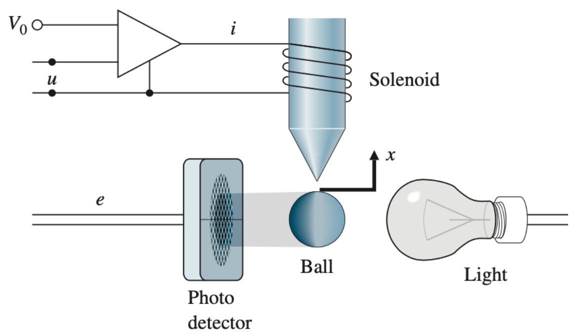
5.24 Assume that the unity feedback system of Fig. 5.59 has the open-loop plant

$$G(s) = \frac{s+7}{s(s+9)(s+5)}.$$

Design a lag compensation $D_c(s) = K\frac{(s-z)}{s-p}$ to meet the following specifications:

- The step response rise time is to be less than 0.45 sec.
- The step response overshoot is to be less than 5%.
- The steady-state error to a unit ramp input must not exceed 10%.

5.28 An elementary magnetic suspension scheme is depicted in Fig. 5.60. For small motions near the reference position, the voltage e on the photo detector is related to the ball displacement x (in meters) by $e = 100x$. The upward force (in newtons) on the ball caused by the current i (in amperes) may be approximated by $f = 0.5i + 20x$. The mass of the ball is 20 g and the gravitational force is 9.8 N/kg. The power amplifier is a voltage-to-current device with an output (in amperes) of $i = u + V_0$.



(a) Write the equations of motion for this set up.

(b) Give the value of the bias V_0 that results in the ball being in equilibrium at $x = 0$.

(c) What is the transfer function from u to e?

(d) Suppose that the control input u is given by $u = -Ke$. Sketch the root locus of the closed-loop system as a function of K.

(e) Assume a lead compensation is available in the form $\frac{U}{E} = D_c(s) = K\frac{s+z}{s+p}$. Give values of K, z, and p that yield improved performance over the one proposed in part (d).

5.35 Consider the positioning servomechanism system shown in Fig. 5.64, where

$$e_i = K_o\theta_i, \quad e_o = K_{pot}\theta_o, \quad K_o = 10 \text{ V/rad},$$

$$T = \text{motor torque} = K_t i_a,$$

$$k_m = K_t = \text{torque constant} = 0.1 \text{ N·m/A},$$

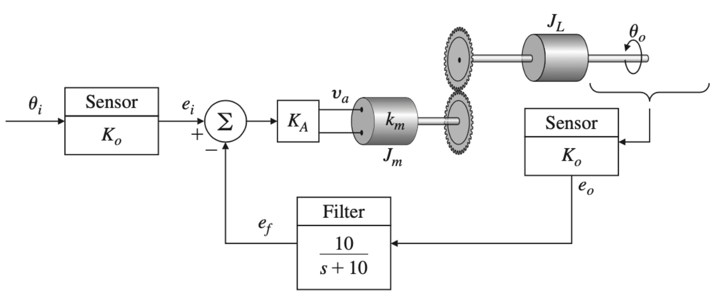
$$K_e = \text{back emf constant} = 0.1 \text{ V·sec},$$

$$R_a = \text{armature resistance} = 10\ \Omega,$$

$$\text{Gear ratio} = 1{:}1,$$

$$J_L + J_m = \text{total inertia} = 10^{-3} \text{ kg·m}^2,$$

$$v_a = K_A(e_i - e_f).$$



(a) What is the range of the amplifier gain K_A for which the system is stable? Estimate the upper limit graphically using a root-locus plot.

(b) Choose a gain K_A that gives roots at $\zeta = 0.7$. Where are all three closed-loop root locations for this value of K_A?