Reading Assignments:

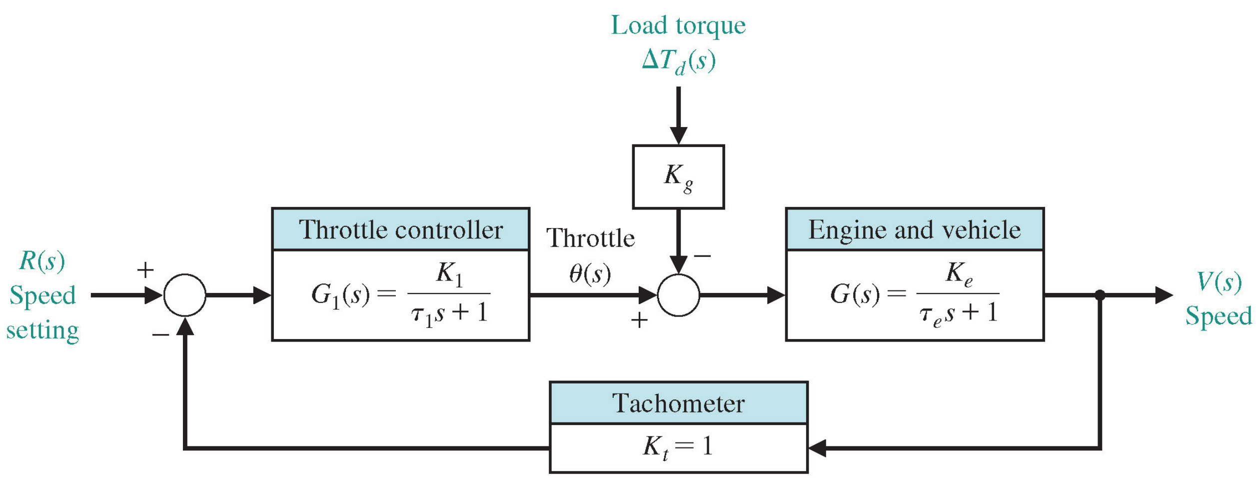
Shinners: Chapters 4 and 5.

Doyle, Francis, and Tannenbaum: Chapter 3.

Please enter your answers using the D2L Quiz for Homework #4.

1. (From Dorf and Bishop, "Modern Control Systems," Thirteenth Edition) Problem P4.6.

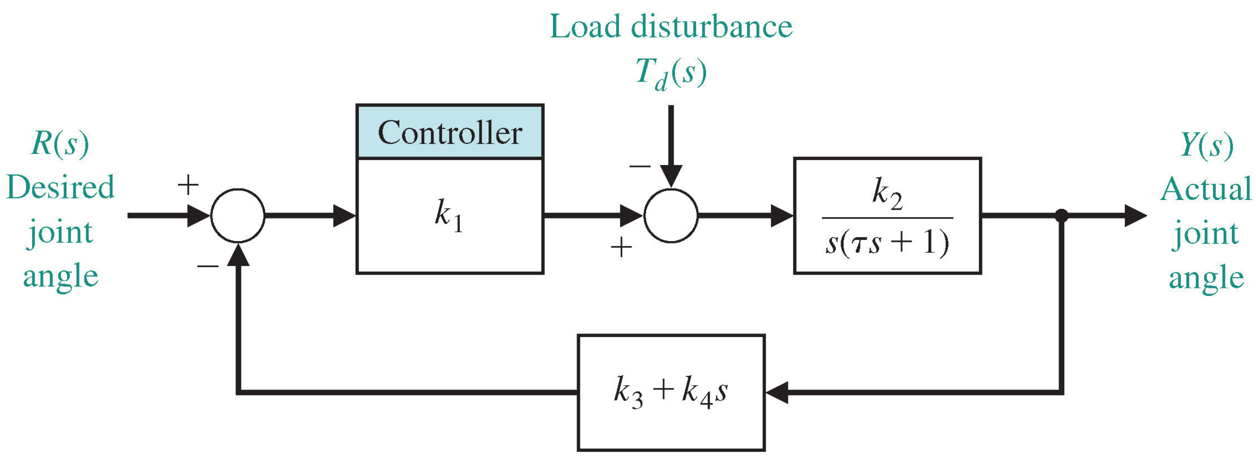
An automatic speed control system will be necessary for passenger cars traveling on the automatic highways of the future. A model of a feedback speed control system for a standard vehicle is shown in Figure P4.6. The load disturbance due to a percent grade $\Delta T_d[s]$ is also shown. The engine gain K_e varies within the range of 10 to 1000 for various models of automobiles. The engine time constant τ_e is 20 seconds. (a) Determine the sensitivity of the system to changes in the engine gain K_e. (b) Determine the effect of the load torque on the speed. (c) Determine the constant percent grade $\Delta T_d[s] = \frac{\Delta d}{s}$ for which the vehicle stalls (velocity $V[s] = 0$) in terms of the gain factors. Note that since the grade is constant, the steady-state solution is sufficient. Assume that $R[s] = \frac{30}{s}$ km/hr and that $K_e K_1 \gg 1$. When $K_g / K_1 = 2$, what percent grade Δd would cause the automobile to stall?



Above: Figure P4.6: Automobile speed control.

2. (From Dorf and Bishop, “Modern Control Systems,” Thirteenth Edition) Problem P4.7.

A robot uses feedback to control the orientation of each joint axis. The load effect varies due to varying load objects and the extended position of the arm. The system will be deflected by the load carried in the gripper. Thus, the system may be represented by Figure P4.7, where the load torque is $T_d[s] = \frac{D}{s}$. Assume $R[s] = 0$ at the index position. (a) What is the effect of $T_d[s]$ on $Y[s]$? (b) Determine the sensitivity of the closed loop to k_2 . (c) What is the steady-state error when $R[s] = \frac{1}{s}$ and $T_d[s] = 0$?



Above: Figure P4.7: Robot control system.

3. Problem 5.6 in Shinners. (See page 311 of textbook or text below.) The system’s transfer function should be $H[s] = \frac{C[s]}{R[s]}$.

   5.6. The time constant of a two-phase ac servomotor is not a precise parameter, and is subject to change caused by aging and environmental conditions such as temperature changes. The control system in Figure P5.6 containing a two-phase ac servomotor, is to be analyzed for its sensitivity to the two-phase ac servomotor’s time constant, T.

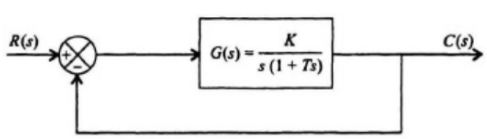


Figure P5.6

Determine the sensitivity of the control system’s transfer function, $H(s) = C(s)R(s)$, with respect to the time constant T.

4. A second-order control system has a closed-loop transfer function $G[s] = \frac{Y[s]}{R[s]}$. The system specifications for a step input follow:
   a. Percent Overshoot $P.O. \leq 5\%$.
   b. Settling Time $T_s < 4$ seconds .
   c. Peak Time $T_p < 1$ second .

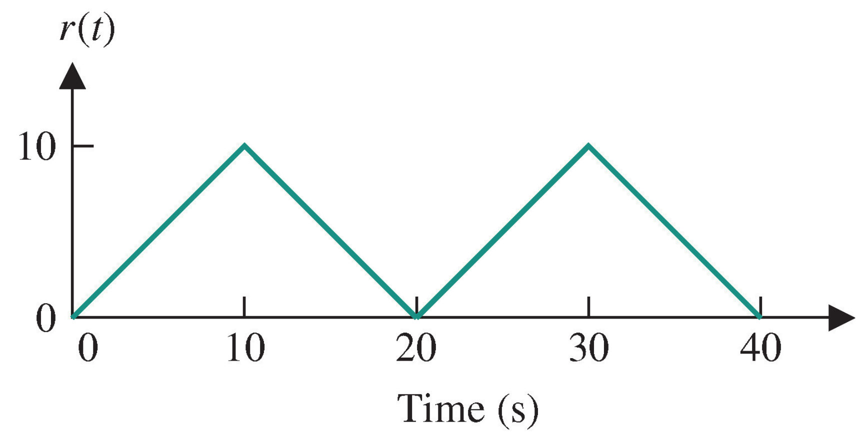
   Show the desired region in the complex s-plane in order to achieve the desired response corresponding to the performance specifications above. Use a 2% settling time for the settling time specification, i.e., let $T_s = 4\tau$ (four time constants).

5. (From Dorf and Bishop, “Modern Control Systems,” Thirteenth Edition) Problem P5.6.

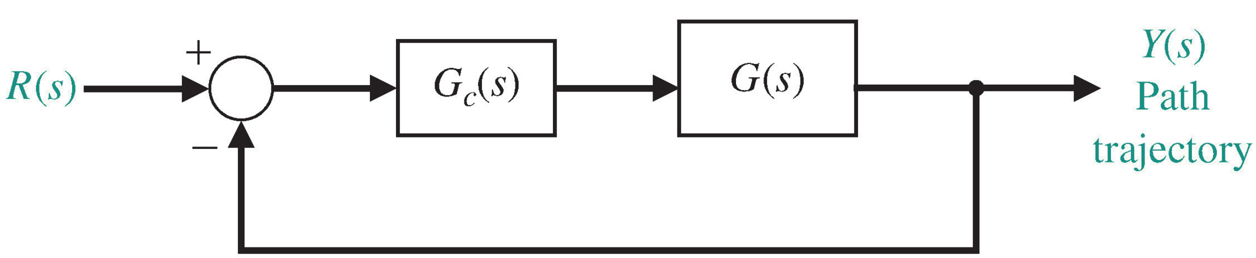
A robot is programmed to have a tool or welding torch follow a prescribed path. Consider a robot tool that is to follow a sawtooth path, as shown in Figure P5.6(a). The loop transfer function of the plant is

$$L[s] = G_c[s]G[s] = \frac{75(s+1)}{s(s+5)(s+25)}$$

for the closed-loop system shown in Figure 5.6(b). Calculate the steady-state error.



(a)



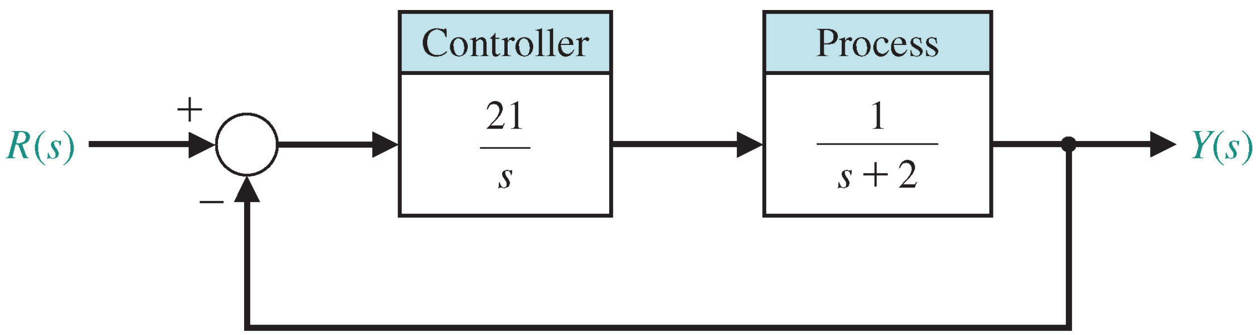
(b)

Above: Figure P5.6: Robot path control. (a) Sawtooth path for the robot to follow. (b) The closed-loop system configuration with loop transfer function $L[s] = G_c[s]G[s]$.

6. (From Dorf and Bishop, “Modern Control Systems,” Thirteenth Edition) Problem CP5.4.

Consider the control system shown in Figure CP5.4.

a. Show analytically that the expected percent overshoot of the closed-loop system response to a unit step input is $P.O. \leq 50\%$.
b. Develop an m-file, i.e., a MATLAB script file, to plot the unit step response of the closed-loop system and estimate the percent overshoot from the plot. Compare the result in part (b) with the result in part (a).



Above: Figure CP5.4: A negative feedback control system.