3.21 Find the transfer functions for the block diagrams in Fig. 3.51, using the ideas of block-diagram simplification. The special structure in Fig. 3.51(b) is called the "observer canonical form" and will be discussed in Chapter 7.

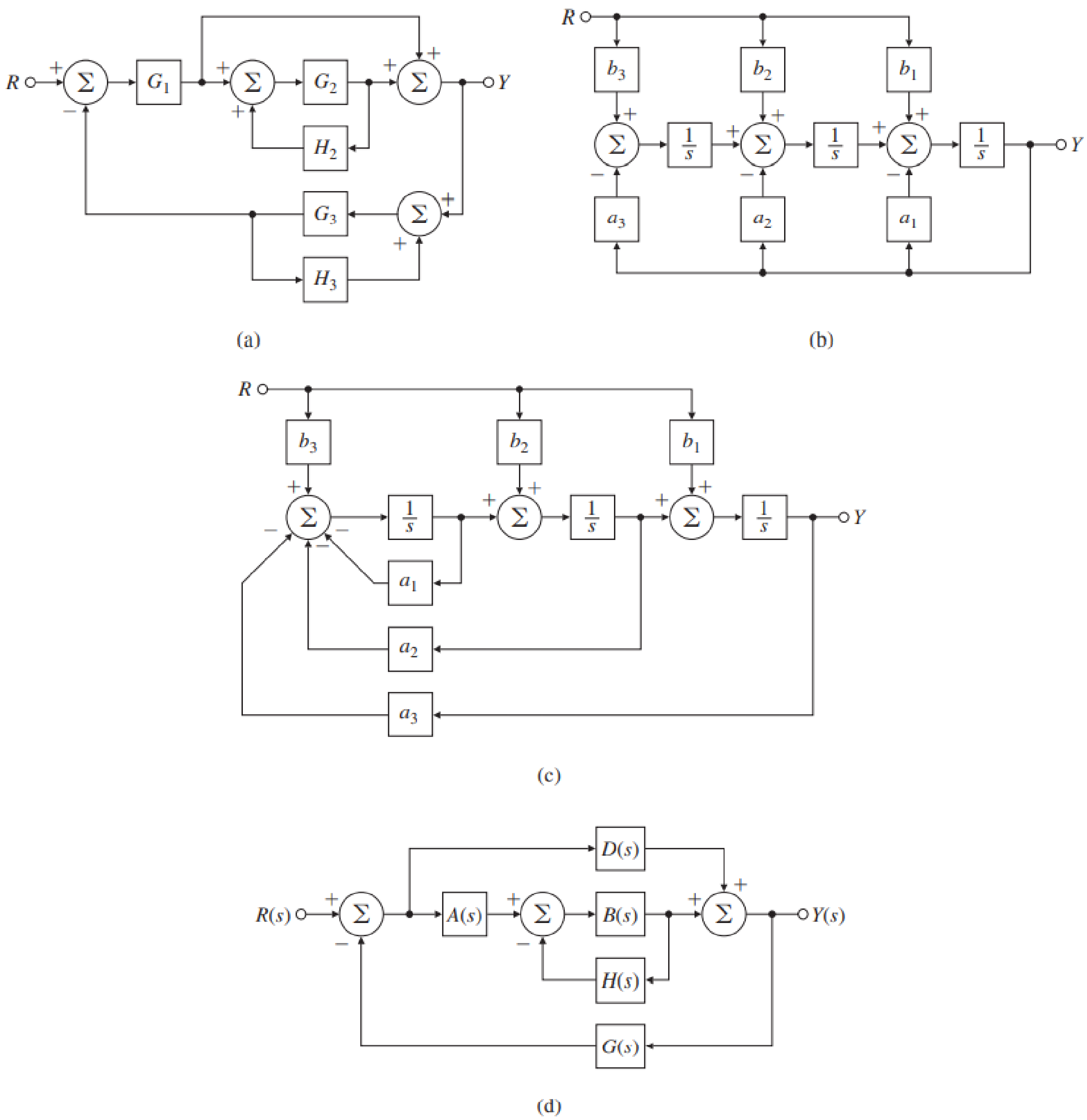

Figure 3.51

3.30 A feedback system has the following response specifications:

- Percent overshoot $M_p \leq 16\%$
- Settling time $t_s \leq 6.9$ sec
- Rise time $t_r \leq 1.8$ sec

(a) Sketch the region of acceptable closed-loop poles in the s-plane for the system, assuming the transfer function can be approximated as simple second order.

(b) What is the expected overshoot if the rise time and settling time specifications are met *exactly*?

3.32 The open-loop transfer function of a unity feedback system is

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

The desired system response to a step input is specified as peak time $t_p = 1$ sec and overshoot $M_p = 5\%$.

(a) Determine whether both specifications can be met simultaneously by selecting the right value of K.

(b) Sketch the associated region in the s-plane where both specifications are met, and indicate what root locations are possible for some likely values of K.

(c) Relax the specifications in part (a) by the same factor and pick a suitable value for K, and use Matlab to verify that the new specifications are satisfied.

3.36 You wish to control the elevation of the satellite-tracking antenna shown in Fig. 3.60 and Fig. 3.61. The antenna and drive parts have a moment of inertia J and a damping B; these arise to some extent from bearing and aerodynamic friction, but mostly from the back emf of the DC drive motor. The equations of motion are

$$J\ddot{\theta} + B\dot{\theta} = T_c,$$

where T_c is the torque from the drive motor. Assume that

$$J = 600{,}000 \text{ kg}\cdot\text{m}^2 \quad B = 20{,}000 \text{ N}\cdot\text{m}\cdot\text{sec}.$$

(a) Find the transfer function between the applied torque T_c and the antenna angle θ.

(b) Suppose the applied torque is computed so that θ tracks a reference command θ_r according to the feedback law

$$T_c = K(\theta_r - \theta),$$

where K is the feedback gain. Find the transfer function between θ_r and θ.

(c) What is the maximum value of K that can be used if you wish to have an overshoot $M_p < 10\%$?

(d) What values of K will provide a rise time of less than 80 sec? (Ignore the M_p constraint.)

(e) Use Matlab to plot the step response of the antenna system for $K = 200$, 400, 1000, and 2000. Find the overshoot and rise time of the four step responses by examining your plots. Do the plots to confirm your calculations in parts (c) and (d)?

Figure 3.60

Satellite-tracking antenna

Source: Courtesy Space Systems/Loral

Figure 3.61

Schematic of antenna for Problem 3.36