E9.1 The Bode plot for the transfer function $G(s)$ is shown in Figure E9.1, where

$$G(s) = \frac{4(1+s/3)}{s(1+2s)(1+s/7+s^2/49)} .$$

The gain and phase margins are

$$G.M. = 16.47 \text{ dB and } \quad P.M. = 32.5^o .$$

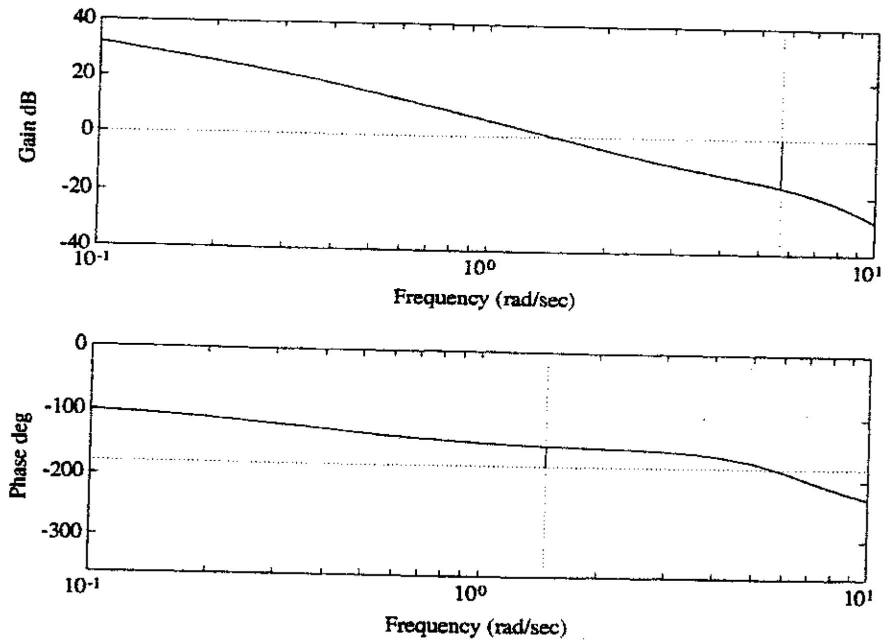

FIGURE E9.1
Bode Diagram for $G(s) = \frac{4(1+s/3)}{s(2s+1)(s^2/49+s/7+1)}$.

E9.7 The Nyquist plot is shown in Figure E9.7 for $K = 2$; the plot is a circle with radius $= K/2$. For $K > 1$, we have $P = 1$ and $N = -1$ (ccw as shown). So

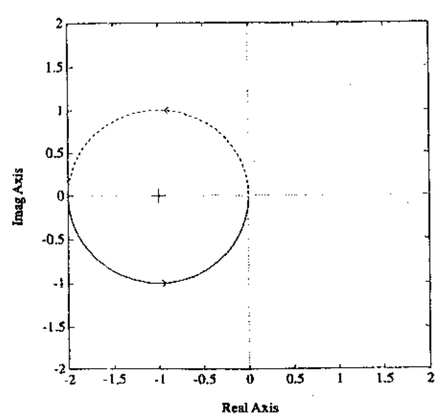

FIGURE E9.7
Nyquist Diagram for $G(s) = \frac{K}{s-1}$, where $K = 2$.

$Z = N + P = -1 + 1 = 0$ and the system is stable for $K > 1$.

E9.15 The open-loop transfer function is

$$G(s) = \frac{K}{s + 100} ,$$

and the closed-loop transfer function is

$$T(s) = \frac{K}{s + 100 + K} .$$

The magnitude plots for both the open- and closed-loop system are shown in Figure E9.15. With bandwidth defined as frequency at which the magnitude is re-

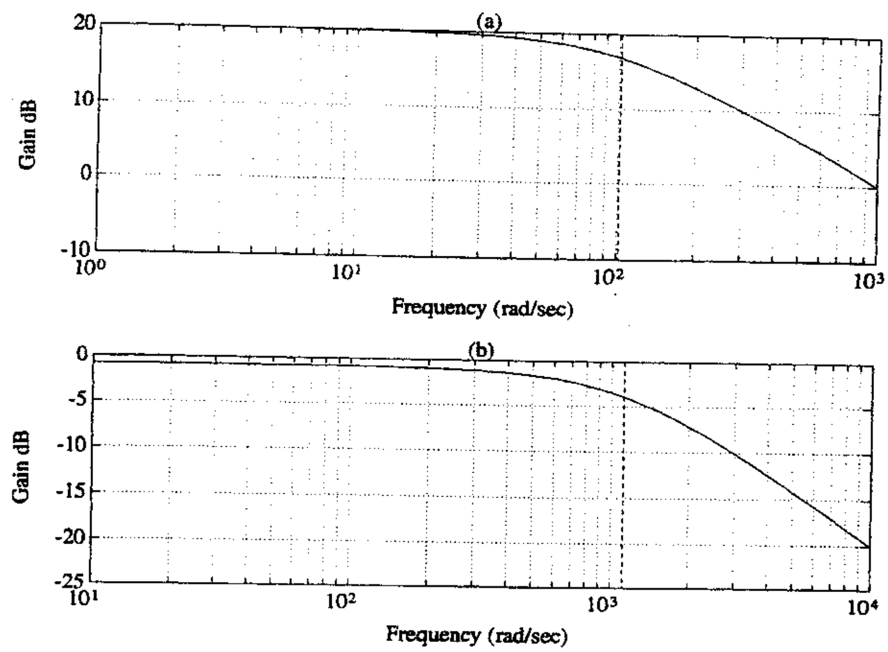

FIGURE E9.15
Magnitude plots for (a) open-loop $G(s) = \frac{1000}{s+100}$ and (b) closed-loop $T(s) = \frac{1000}{s+1100}$.

duced by 0.707 from the dc value, we determine that $\omega_B = 100$ rad/sec for the open-loop and $\omega_B = 1100$ rad/sec for the closed-loop system.

P9.2 (a) The transfer function is

$$GH(s) = \frac{K}{s(s^2+s+4)} ,$$

and

$$GH(j\omega) = \frac{K}{j\omega(-\omega^2+j\omega+4)} == \frac{K[-\omega^2 - j\omega(4-\omega^2)]}{[(4-\omega^2)^2\omega^2+\omega^4]} .$$

To determine the real axis crossing, we let

$$\mathrm{Im}\{GH(j\omega)\} = 0 = -K\omega(4-\omega^2)$$

or

$$\omega = 2 .$$

Then,

$$\mathrm{Re}\{GH(j\omega)\}_{\omega=2} = \left.\frac{-K\omega^2}{\omega^4}\right|_{\omega=2} = \frac{-K}{4} .$$

So, $-K/4 > -1$ for stability. Thus $K < 4$ for a stable system.

(b) The transfer function is

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

The polar plot never encircles the -1 point, so the system is stable for all gains K (See Figure 10 in Table 9.6 in Dorf & Bishop).

P9.23 The phase margin is

$$P.M. = 60.05 \text{ deg}$$

when $K = 4.15$. The gain margin is then

$$G.M. = 17.18 \text{ dB} .$$

The Bode plot is shown in Figure P9.23.

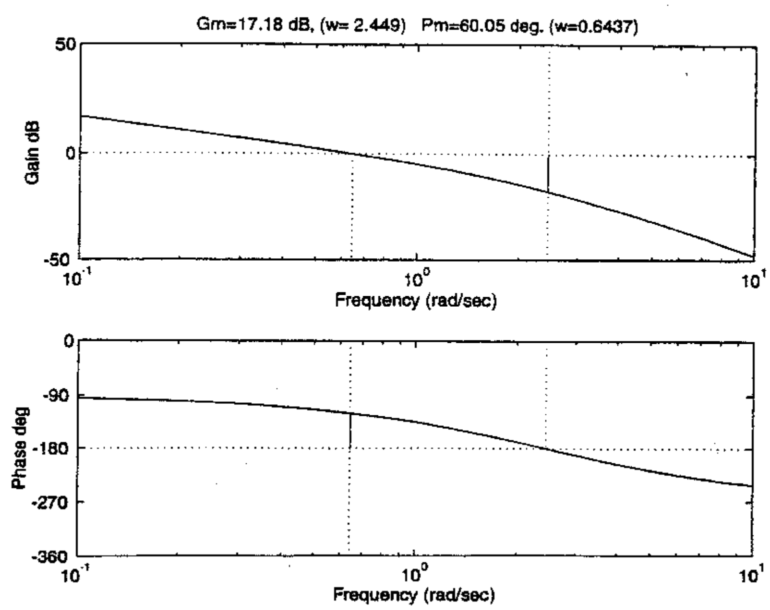

FIGURE P9.23
Bode diagram for $G(s) = \frac{K}{s(s+1)(s+10)}$, where $K = 5.75$.