7-12. Construct the root-locus diagram for each of the following control systems for which the poles and zeros of $G(s)H(s)$ are given. The characteristic equation is obtained by equating the numerator of $1 + G(s)H(s)$ to zero.

(a) Poles at 0, –5, –6; zero at –8

(b) Poles at 0, –1, –3, –4; no finite zeros

(c) Poles at 0, 0, –2, –2; zero at –4

(d) Poles at 0, $-1 + j$, $-1 - j$; zero at –2

(e) Poles at 0, $-1 + j$, $-1 - j$; zero at –5

(f) Poles at 0, $-1 + j$, $-1 - j$; no finite zeros

(g) Poles at 0, 0, –8, –8; zeros at –4, –4

(h) Poles at 0, 0, –8, –8; no finite zeros

(i) Poles at 0, 0, –8, –8; zeros at $-4 + j2$, $-4 - j2$

(j) Poles at –2, 2; zeros at 0, 0

(k) Poles at j, $-j$, $j2$, $-j2$; zeros at –2, 2

(l) Poles at j, $-j$, $j2$, $-j2$; zeros at –1, 1

(m) Poles at 0, 0, 0, 1; zeros at –1, –2, –3

(n) Poles at 0, 0, 0, –100, –200; zeros at –5, –40

(o) Poles at 0, –1, –2; zero at 1

7-14. The characteristic equations of linear control systems are given as follows. Construct the root loci for $K \geq 0$.

(a) $s^3 + 3s^2 + (K + 2)s + 5K = 0$

(b) $s^3 + s^2 + (K + 2)s + 3K = 0$

(c) $s^3 + 5Ks^2 + 10 = 0$

(d) $s^4 + (K + 3)s^3 + (K + 1)s^2 + (2K + 5) + 10 = 0$

(e) $s^3 + 2s^2 + 2s + K(s^2 - 1)(s + 2) = 0$

(f) $s^3 - 2s + K(s + 4)(s + 1) = 0$

(g) $s^4 + 6s^3 + 9s^2 + K(s^2 + 4s + 5) = 0$

(h) $s^3 + 2s^2 + 2s + K(s^2 - 2)(s + 4) = 0$

(i) $s(s^2 - 1) + K(s + 2)(s + 0.5) = 0$

(j) $s^4 + 2s^3 + 2s^2 + 2Ks + 5K = 0$

(k) $s^5 + 2s^4 + 3s^3 + 2s^2 + s + K = 0$

7-18. A unity-feedback control system has the forward-path transfer functions given in the following. Construct the root locus diagram for $K \geq 0$. Find the values of K at all the breakaway points.

(a) $G(s) = \dfrac{K}{s(s + 10)(s + 20)}$

(b) $G(s) = \dfrac{K}{s(s + 1)(s + 3)(s + 5)}$

(c) $G(s) = \dfrac{K(s - 0.5)}{(s - 1)^2}$

(d) $G(s) = \dfrac{K}{(s + 0.5)(s - 1.5)}$

(e) $G(s) = \dfrac{K(s + \frac{1}{3})(s + 1)}{s(s + \frac{1}{2})(s - 1)}$

(f) $G(s) = \dfrac{K}{s(s^2 + 6s + 25)}$

7-20. The forward-path transfer function of a unity-feedback control system is

$$G(s) = \frac{K}{(s+4)^n}$$

Construct the root loci of the characteristic equation of the closed-loop system for $K \geq \infty$, with **(a)** $n = 1$, **(b)** $n = 2$, **(c)** $n = 3$, **(d)** $n = 4$, and **(e)** $n = 5$.

7-21. Use MATLAB to solve Problem 7-20.

7-30. The forward-path transfer function of a control system is

$$G(s) = \frac{K(s+0.4)}{s^2(s+3.6)}$$

(a) Construct the root loci for $K \geq 0$.

(b) Use MATLAB to verify your answer to part (a).