Note: Sometimes small change in pole-zero configuration may cause significant changes in root-locus.

2. If \( n \geq n+3 \) (i.e., the number of open-loop poles exceeds the number of open-loop zeros by three or more), one of the asymptotes will enter the RHP. Hence, there exists a value of \( K \) beyond which the root-locus enters the RHP \( \Rightarrow \) the system will become unstable.
More on root-locus

1. Pole-zero cancellations  p 356 in text

Sometimes a feedback loop may have pole-zero cancellations:

\[ \frac{s-1}{s+1} \]

Thus the closed-loop poles are obtained by solving

\[ 1 + K \cdot \frac{1}{s-1} \cdot \frac{s-1}{s+1} = 0 \]

It would be tempting to cancel the \((s-1)\) term and get

\[ 1 + K \cdot \frac{1}{s+1} = 0 \]

\[ \Rightarrow s = -(1+k) \leq -1 \text{ for all } K \]

\[ \Rightarrow \text{ system is stable for all } K \]

This is WRONG!

Correct procedure: Suppose there are pole-zero cancellations in \(G(s)\). Then, the root-locus consists of the "reduced" root-locus, obtained
from $G(s)$ in its reduced form:

$0$ (cancelled poles).

In this example, the correct root-locus should include the pole/zero at 1. Hence, the system is always unstable.

Why? In real systems, due to uncontrollable variations in electrical/mechanical components, we will never be able to cancel a pole exactly.

We can make $\alpha$ close to 1, but never exactly 1. Let us now plot the root-locus for $\alpha$ near 1.

$$1 + K \cdot \frac{s - \alpha}{(s+1)(s-1)} = 0$$
There is always a branch near the pole \(1/\lambda\). As \(\lambda \to 1\), the branch shrinks to a point \(1\).

\[ \Rightarrow \text{system is always unstable}. \]

\[ \text{a branch that starts \& ends at } s = 0. \]

(b) Root locus with positive feedback \[ p \text{373-377} \]

\[ \text{The characteristic equation is} \]

\[ 1 - K \cdot G(s) = 0 \]
Changes:

1. Basic Relationships
   - Angle condition:
     \[ \angle G(s) = 360^{\circ} \]
   - Magnitude condition: unchanged
   - Start/end of branches: unchanged

2. Steps
   Step 1: Standard form
   \[ 1 - K \frac{(s-z_1)(s-z_2)\ldots(s-z_m)}{(s-p_1)(s-p_2)\ldots(s-p_n)} = 0 \]

   Step 2: Locate poles & zeros
   Step 3: Find real segments of the locus.
   A point on the real axis lies on the locus if there is an even number of real poles
   \& zeros to its right.

   Step 4: Find asymptotes
   Angle of asymptotes \( \phi_a = \frac{360^{\circ} \cdot L}{n-m} \)
   Intersection of asymptotes \( s_a \) unchanged.

   Step 5: Find imaginary closed-loop poles
   Use Routh array (unchanged).

   Step 6: Find break-in/break-away points
   Use \( \frac{df}{ds} = 0 \) (unchanged).

   Step 7: Find angles of arrival and departures
   Angles must add up to \( 360^{\circ} \).