Open books and Notes

1. Consider a steady-state, subcritical \( k_o < 0 \) reactor operating at a constant power level \( P_o \) which is maintained by the presence of a source \( S_o \). At \( t = 0 \), the source strength is varied so as to produce a step decrease in the power to \( P_1 < P_o \), i.e.,

\[
P(t) = \begin{cases} 
P_o & t < 0 \\
P_1 & t \geq 0 
\end{cases}
\]

Assume that the reactor can be described by a one delayed-neutron group model. Calculate the source variation \((i/\beta)S(t)\) for \( t > 0 \) needed to produce this step change in the power. Sketch the source transient.

2. Consider a closed-loop system with negative feedback for which the open-loop transfer function is

\[
G(s)H(s) = \frac{K(s + 1)}{s(s + 2)(s + 3)(s + 4)}
\]  

(0.1)

(a) Write the characteristic for the closed-loop system as a polynomial in \( s \).
(b) Construct the Routh array for this system.
(c) For what values of \( K \) is the system stable?

3. Consider a closed-loop system with positive feedback for which the open-loop transfer function is

\[
G(s)H(s) = \frac{K(s + 6)(s + 8)}{s(s + 2)^2(s + 3)(s + 5)}
\]  

(0.2)

Sketch the root-locus diagram for the roots of the characteristic equation for both positive and negative \( K \).

4. Consider a closed-loop system with negative feedback for which the open-loop transfer function is

\[
G(s)H(s) = \frac{K(s + 10)}{s^2(s + 100)}, \quad K > 0.
\]  

(0.3)

(a) Sketch the Bode plots for this open-loop transfer function.
(b) Sketch the Nyquist diagram for the closed-loop system. Is the system stable?
(c) Is the closed-loop system stable for \( K < 0 \)?