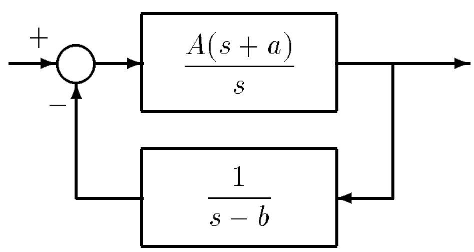
# NE-696: NUCLEAR SYSTEMS DESIGN
## Final Examination

May 7, 1994

*Open books and Notes*

1. Consider a system whose transfer function is $G(s) = 1/[(s+1)(s+2)]$. (a) Calculate and sketch the unit impulse response $z(t)$ for this system. (b) What is this system's asymptotic response $P_{as}(t)$ to an input of $A\sin(\omega t)$. *[10 points]*

2. In the following feedback system the constant $b$ is a positive fixed number, while $a$ can be any positive value and $A$ can have any positive or negative value.



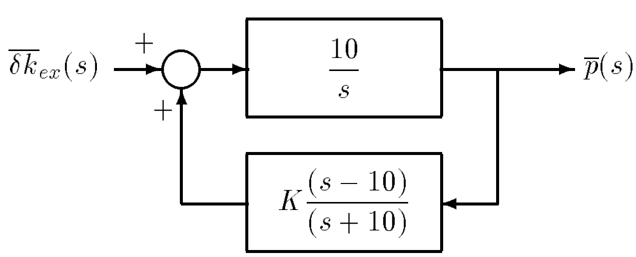

   Construct the characteristic polynomial for this system and determine for what values of $A$ and $a$ the system will be asymptotically stable. Show on a plot of $A$ versus $a$ the region of stability. *[10 points]*

3. The open-loop transfer function for a negative feedback system can be written as

$$G(s)H(s) = \frac{K+\alpha}{(s-1)(s+2)(s+\alpha)}.$$

   Use the Routh-Hurwitz method to determine conditions on $\alpha$ and $K$ for the closed-loop system to be stable. *[15 points]*

4. Consider the following reactor feedback model.




   (a) Sketch root locus diagrams for $K > 0$ and for $K < 0$. *[10 points]*
   (b) Construct the characteristic equation for this system and determine the value of $K$ at which the reactor becomes unstable. *[10 points]*
   (c) What is the frequency of the power oscillations at the threshold of instability? *[5 points]*
   (d) Sketch Nyquist diagrams for this system for $K > 0$ and for $K < 0$. *[10 points]*

5. As derived in class, the open-loop transfer function of a reactor with both temperature and xenon feedback can be written as

$$G(s)H(s) = \frac{K_X}{K_T} \frac{(s + z_1)}{(s + p_1)(s + p_2)}, \quad K_T > 0$$

where

$$K_X \equiv \frac{\sigma_x}{\kappa \beta \Sigma_{ao}} \left[ \frac{\gamma_x \lambda_x - \gamma_i \sigma_x \phi_o}{\lambda_x + \sigma_x \phi_o} \right]$$

$$z_1 \equiv \frac{\lambda_i \lambda_x (\gamma_i + \gamma_x)}{\gamma_x \lambda_x - \gamma_i \sigma_x \phi_o}$$

$$p_1 \equiv \lambda_i$$

$$p_2 \equiv \lambda_x + \sigma_x \phi_o$$

Recall that both $K_X$ and $z_1$ become negative when $\phi_o > (\phi_o)_{crit} \equiv (\gamma_x \lambda_z)/(\gamma_i \sigma_x)$.

(a) Sketch how $K_X$, $z_1$, $p_1$, and $p_2$ vary with $\phi_o$. *[5 points]*

(b) Sketch the Bode gain and phase plots for this open-loop transfer function for the case $\phi_o < (\phi_o)_{crit}$ and for the case $\phi_o > (\phi_o)_{crit}$. *[10 points]*

(c) Assuming negative feedback, draw the Nyquist diagram for this reactor feedback system for the case $\phi_o < (\phi_o)_{crit}$ and for the case $\phi_o > (\phi_o)_{crit}$. What can you say about the stability of each case? *[15 points]*