1. [5 points each, 20 points total] Consider the block diagram shown below.

(a) With $D(s) = K$, what is the maximum value of $K$ for which the closed loop is stable?
(b) With $D(s) = K$, for what values of gain $K$ does the system track unit step reference inputs with less than 0.1 steady state error?
(c) With $D(s) = K/s$, what is the maximum value of $K$ for which the closed loop is stable?
(d) With $D(s) = K/s$, for what values of gain $K$ does the system track unit ramp reference inputs with less than 0.5 steady state error?
2. [4 points each, 20 points total] Short answer.

(a) What are the effects of a PD-control on the rise time and settling time of a control system?

(b) Explain why a system compensated with a PD controller is relatively more stable than the same system compensated with a PI controller.

(c) What is a PID controller? Write down a general expression for the transfer function of a PID controller.

(d) What are the general effects of a lead compensator on the transient response of the controlled system?

(e) In terms of \(a, b, c\) and \(d\), give an expression for the intersection of the asymptotes for the \(K > 0\) root locus of \((s + a)(s + b)(s + c) + K(s + d)\).
3. [20 points] Consider a negative unity feedback system whose forward path transfer function is

\[ \frac{K}{s(s + 2)(s^2 + 2s + 5)} \],

For each point given below, state whether the point lies on the \( 0 < K < \infty \) root locus, and if it does, find the value of \( K \) which achieves that pole location.

(a) \( s = -3 \)
(b) \( s = -1 + j1 \)
(c) \( s = -2 + j2 \)
(d) \( s = -1 \)
4. [10 points each, 20 points total] For the following two pole/zero plots for $G(s)$, sketch the root locus for $1 + KG(s)$ as $K$ varies from 0 to $+\infty$.

(a) The two poles are at $s = -3 \pm j3$ and the zero is at $s = -3$. Include in your plot the value of all breakaway and break-in points, all arrival and departure angles, and the asymptotes and their intersection with the real axis.
(b) There are poles at $s = 0, -2, -4$ and $-6$. Include in your plot the asymptotes and their intersection with the real axis, and the $j\omega$-axis crossings.
5. [20 points] Design $D(s)$ in

\[
\begin{align*}
 R & \quad + \quad D(s) \quad \frac{1}{s+4} \quad Y \\
 & \quad - \quad \quad \\
\end{align*}
\]

so that step reference inputs are tracked with zero steady state error and all closed loop poles have real part less than $-3$. 
EXTRA WORKSHEET. Indicate problem number clearly.
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