Problem 7.29

a. For 20% overshoot, $\zeta = 0.456$. Also, $K_v = 1000 = \frac{K}{a}$. Since $T(s) = \frac{K}{s^2 + as + K}$, $2\zeta \omega_n = a$, and $\omega_n = \sqrt{K}$. Hence, $a = 0.912 \sqrt{K}$. Solving for $a$ and $K$, $K = 831.744$, and $a = 831.744$.

b. For 10% overshoot, $\zeta = 0.591$. Also, $\frac{1}{K_v} = 0.01$. Thus, $K_v = 100 = \frac{K}{a}$. Since $T(s) = \frac{K}{s^2 + as + K}$, $2\zeta \omega_n = a$, and $\omega_n = \sqrt{K}$. Hence, $a = 1.182 \sqrt{K}$. Solving for $a$ and $K$, $K = 13971$ and $a = 139.71$.

Problem 7.34

$$e(\infty) = \lim_{s \to 0} \frac{sR(s) - sD(s)G_2(s)}{1 + G_1(s)G_2(s)}$$

where $G_1(s) = \frac{1}{s+5}$ and $G_2 = \frac{100}{s+2}$. From the problem statement,

$$R(s) = D(s) = \frac{1}{s}.$$ 

Hence, $e(\infty) = \lim_{s \to 0} \frac{1}{1 + \frac{100}{s+5} + \frac{100}{s+2}} = \frac{49}{11}$.

Problem 7.44

First find the forward transfer function of an equivalent unity feedback system.

$$G_c(s) = \frac{K}{s(s+1)(s+4)} = \frac{K}{s^3 + 5s^2 + (K+4)s + K(a-1)}$$

Thus, $e(\infty) = e(\infty) = \frac{1}{1 + KP} = \frac{1}{1 + \frac{K}{K(a-1)}} = \frac{a - 1}{a}$

Finding the sensitivity of $e(\infty)$, $Se:a = \frac{a}{a} = \frac{a}{a^2} \left( a - (a-1) a \right) = \frac{a - 1}{a^2}$. 

![Graph showing sensitivity analysis](https://via.placeholder.com/150)