23.

a. $\zeta = \dfrac{-\ln\left(\frac{\%OS}{100}\right)}{\sqrt{\pi^2 + \ln^2\left(\frac{\%OS}{100}\right)}} = 0.56$, $\omega_n = \dfrac{4}{\zeta T_s} = 11.92$. Therefore, poles $= -\zeta\omega_n \pm j\omega_n\sqrt{1-\zeta^2}$

$= -6.67 \pm j9.88$.

b. $\zeta = \dfrac{-\ln\left(\frac{\%OS}{100}\right)}{\sqrt{\pi^2 + \ln^2\left(\frac{\%OS}{100}\right)}} = 0.591$, $\omega_n = \dfrac{\pi}{T_P\sqrt{1-\zeta^2}} = 0.779$.

Therefore, poles $= -\zeta\omega_n \pm j\omega_n\sqrt{1-\zeta^2} = -0.4605 \pm j0.6283$.

c. $\zeta\omega_n = \dfrac{4}{T_s} = 0.571$, $\omega_n\sqrt{1-\zeta^2} = \dfrac{\pi}{T_P} = 1.047$. Therefore, poles $= -0.571 \pm j1.047$.

25.

a. Writing the equation of motion yields, $(3s^2 + 15s + 33)X(s) = F(s)$

Solving for the transfer function,

$$\frac{X(s)}{F(s)} = \frac{1/3}{s^2 + 5s + 11}$$

b. $\omega_n^2 = 11$ r/s, $2\zeta\omega_n = 5$. Therefore $\zeta = 0.754$, $\omega_n = 3.32$. $T_s = \dfrac{4}{\zeta\omega_n} = 1.6$ s; $T_P = \dfrac{\pi}{\omega_n\sqrt{1-\zeta^2}} = 1.44$ s; $\%OS = e^{-\zeta\pi / \sqrt{1-\zeta^2}} \times 100 = 2.7\ \%$; $\omega_n T_r = (1.76\zeta^3 - 0.417\zeta^2 + 1.039\zeta + 1)$; therefore, $T_r = 0.69$ s.

28.

Since the third pole is more than five times the real part of the dominant pole, $s^2+1.204s+2.829$

determines the transient response. Since $2\zeta\omega_n = 1.204$, and $\omega_n = \sqrt{2.829} = \omega_n = 1.682$, $\zeta = 0.358$,

$\%OS = e^{-\zeta\pi/\sqrt{1-\zeta^2}} x100 = 30\%$, $T_s = \dfrac{4}{\zeta\omega_n} = 6.64$ sec, $T_p = \dfrac{\pi}{\omega_n\sqrt{1-\zeta^2}} = 2$ sec; $\omega_n T_r = 1.4$,

therefore, $T_r = 0.832$.

1.

$$e(\infty) = \lim_{s \to 0} sE(s) = \lim_{s \to 0} \frac{sR(s)}{1+G(s)}$$

where

$$G(s) = \frac{450(s+12)(s+8)(s+15)}{s(s+38)(s^2+2s+28)}.$$

For step, $e(\infty) = 0$. For 37tu(t), $R(s) = \frac{37}{s^2}$. Thus, $e(\infty) = 6.075 \times 10^{-2}$. For parabolic input,

$e(\infty) = \infty$.

4.

Reduce the system to an equivalent unity feedback system by first moving 1/s to the left past the summing junction. This move creates a forward path consisting of a parallel pair, $\left(\frac{1}{s}+1\right)$ in cascade with a feedback loop consisting of $G(s)=\frac{2}{s+3}$ and $H(s)=7$. Thus,

$$G_e(s)=\left(\frac{(s+1}{s}\right)\left(\frac{2/(s+3)}{1+14/(s+3)}\right)=\frac{2(s+1)}{s(s+17)}$$

Hence, the system is Type 1 and the steady-state errors are as follows:

Steady-state error for $15u(t)=0$.

Steady-state error for $15tu(t)=\frac{15}{K_v}=\frac{15}{2/17}=127.5$.

Steady-state error for $15t^2u(t)=\infty$

15.

Collapsing the inner loop and multiplying by 1000/*s* yields the equivalent forward-path transfer function as,

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$$G_e(s) = \frac{10^5(s+2)}{s(s^2+1005s+2000)}$$

Hence, the system is Type 1.

18.

a. $e(\infty)=\frac{1/10}{K_v}=0.01$; where $K_v=\frac{7K}{5x8x12}=10$. Thus, $K=685.71$.

b. $K_V = 10$.

c. The minimum error will occur for the maximum gain before instability. Using the Routh-Hurwitz Criterion along with $T(s)=\frac{K(s+7)}{s^4+25s^3+196s^2+(480+K)s+7K}$:

s^4	1	196	$7K$	For Stability
s^3	25	$480+K$		
s^2	$4420-K$	$175K$		$K<4420$
s^1	$-K^2-435K+2121600$			$-1690.2<K<$ 1255.2
s^0	$175K$			$K>0$

Thus, for stability and minimum error $K = 1255.2$. Thus, $K_v=\frac{7K}{5x8x12}=18.3$ and

$e(\infty)=\frac{1/10}{K_v}=\frac{1/10}{18.3}=0.0055$.