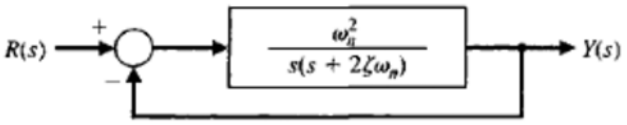
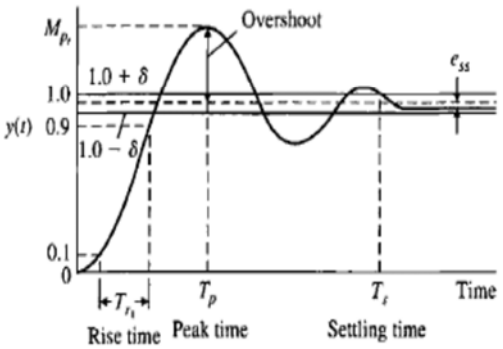
A second-order closed-loop system



UNIT STEP RESPONSE



- Settling time (to within 2% of the final value)

$$T_s = \frac{4}{\zeta\omega_n}$$

- Percent overshoot

$$M_p = 1 + e^{-\zeta\pi/\sqrt{1-\zeta^2}} \quad \text{and} \quad P.O. = 100e^{-\pi\zeta/\sqrt{1-\zeta^2}}$$

- Time-to-peak

$$T_p = \frac{\pi}{\omega_n\sqrt{1 - \zeta^2}}$$

- Resonant frequency ($\zeta \leq 0.7$)

$$\omega_r = \omega_n\sqrt{1 - 2\zeta^2}$$

- Rise time (time to rise from 10% to 90% of final value)

$$T_r = \frac{2.16\zeta + 0.60}{\omega_n} \quad (0.3 \leq \zeta \leq 0.8)$$

- Bandwidth ($0.3 \leq \zeta \leq 0.8$)

$$\omega_B = (-1.196\zeta + 1.85)\omega_n$$

Table 2.3 Important Laplace Transform Pairs

f(t)	*F(s)*
Step function, $u(t)$	$\frac{1}{s}$
e^{-at}	$\frac{1}{s + a}$
$\sin \omega t$	$\frac{\omega}{s^2 + \omega^2}$
$\cos \omega t$	$\frac{s}{s^2 + \omega^2}$
t^n	$\frac{n!}{s^{n+1}}$
$f^{(k)}(t) = \frac{d^k f(t)}{dt^k}$	$s^k F(s) - s^{k-1}f(0^-) - s^{k-2}f'(0^-) - \ldots - f^{(k-1)}(0^-)$