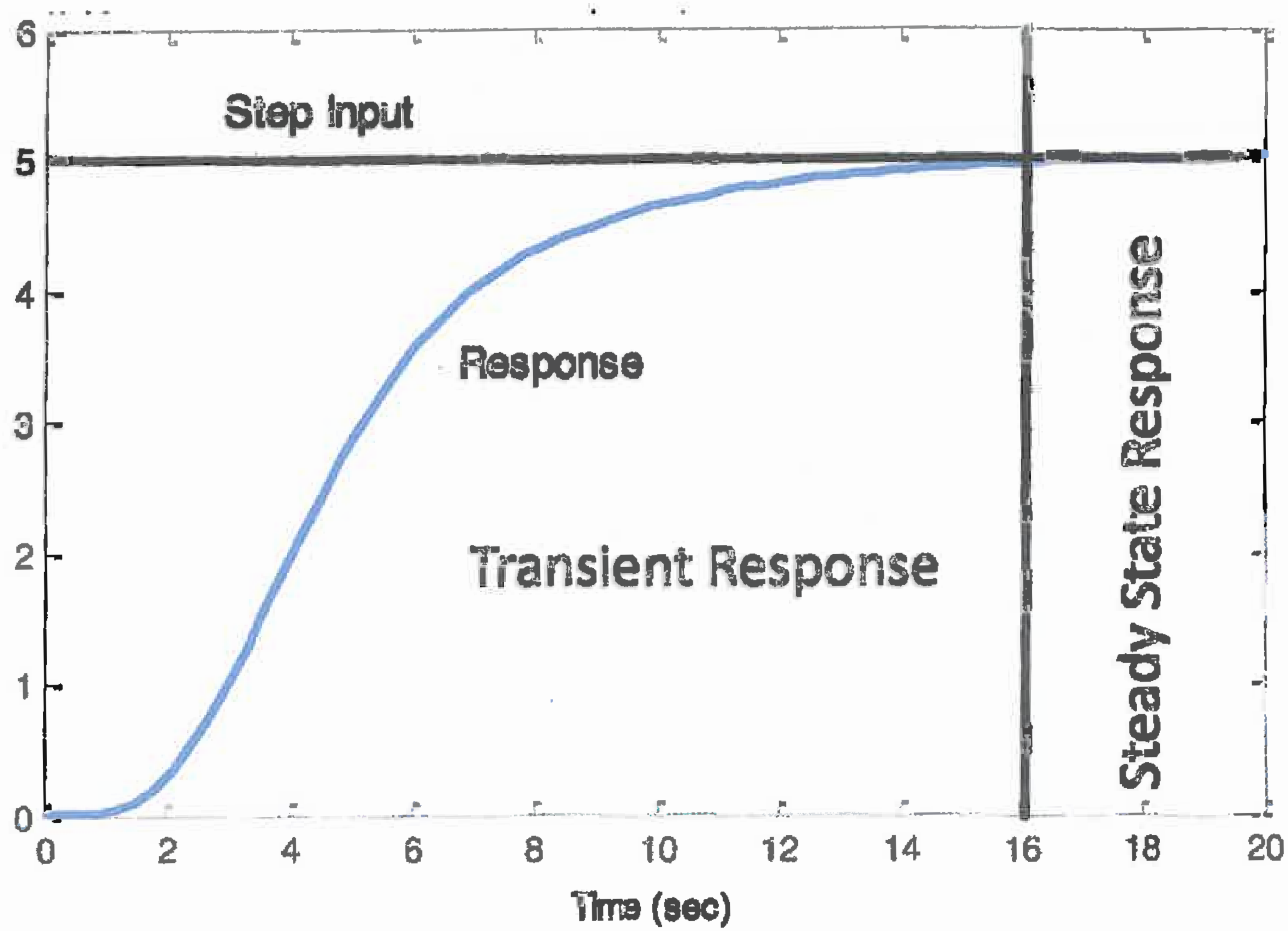
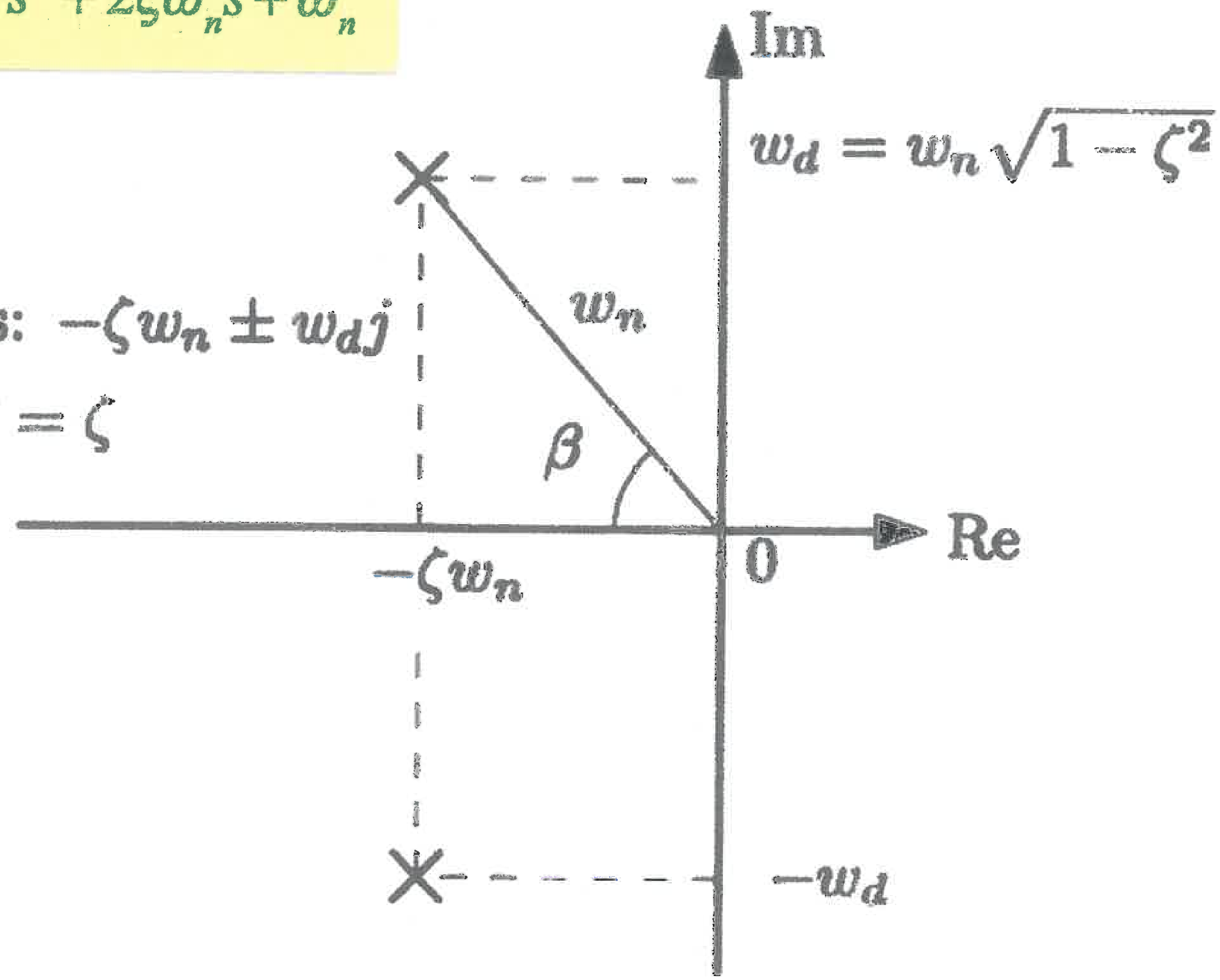


Step Input
Response
Transient Response
Steady State Response
Time (sec)
0
1
2
3
4
5
6
0
2
4
6
8
10
12
14
16
18
20

characteristic eqn: $s^2 + 2\zeta\omega_n s + \omega_n^2$

Poles: $-\zeta w_n \pm w_d j$

$\cos\beta = \zeta$



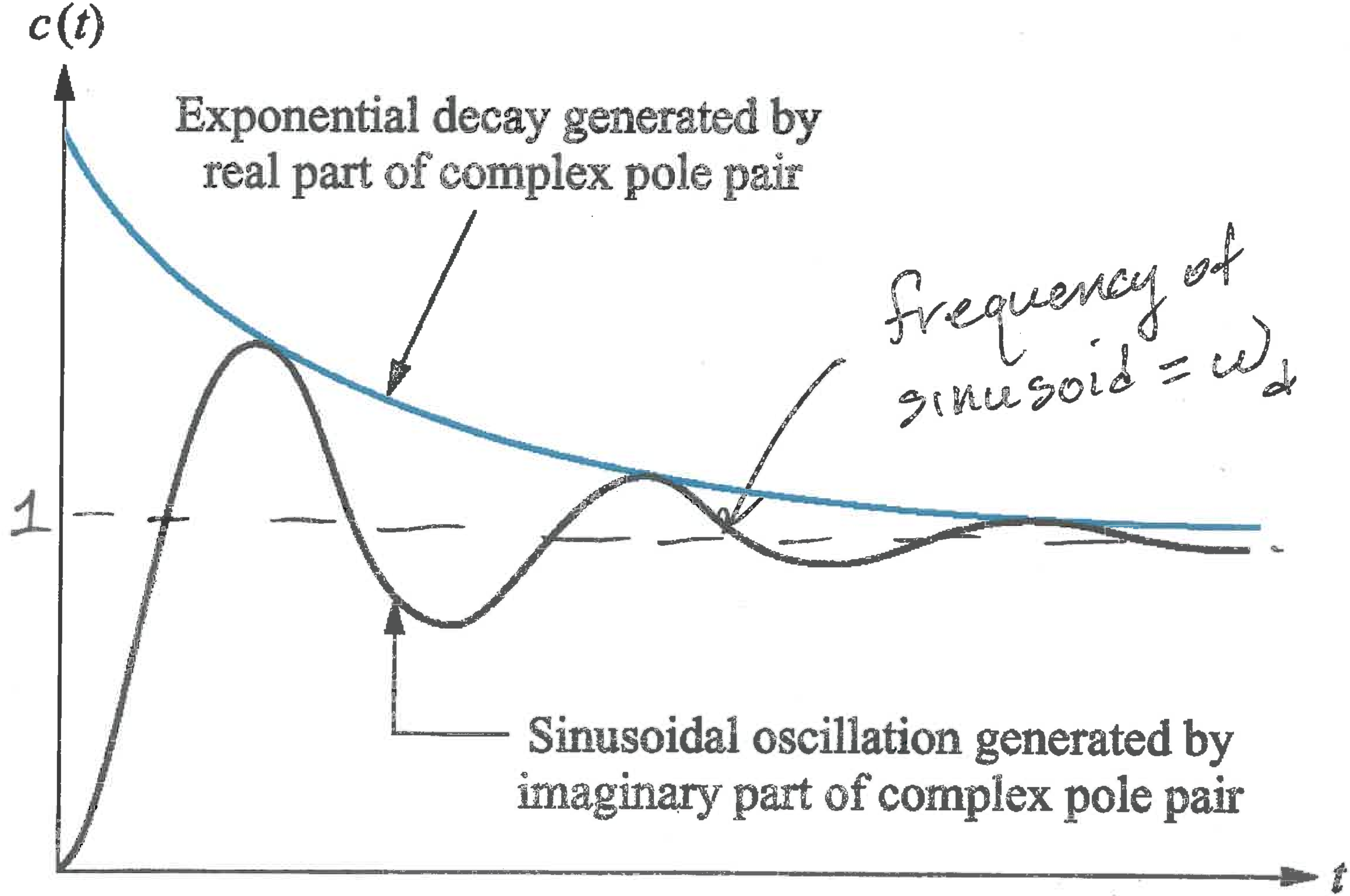
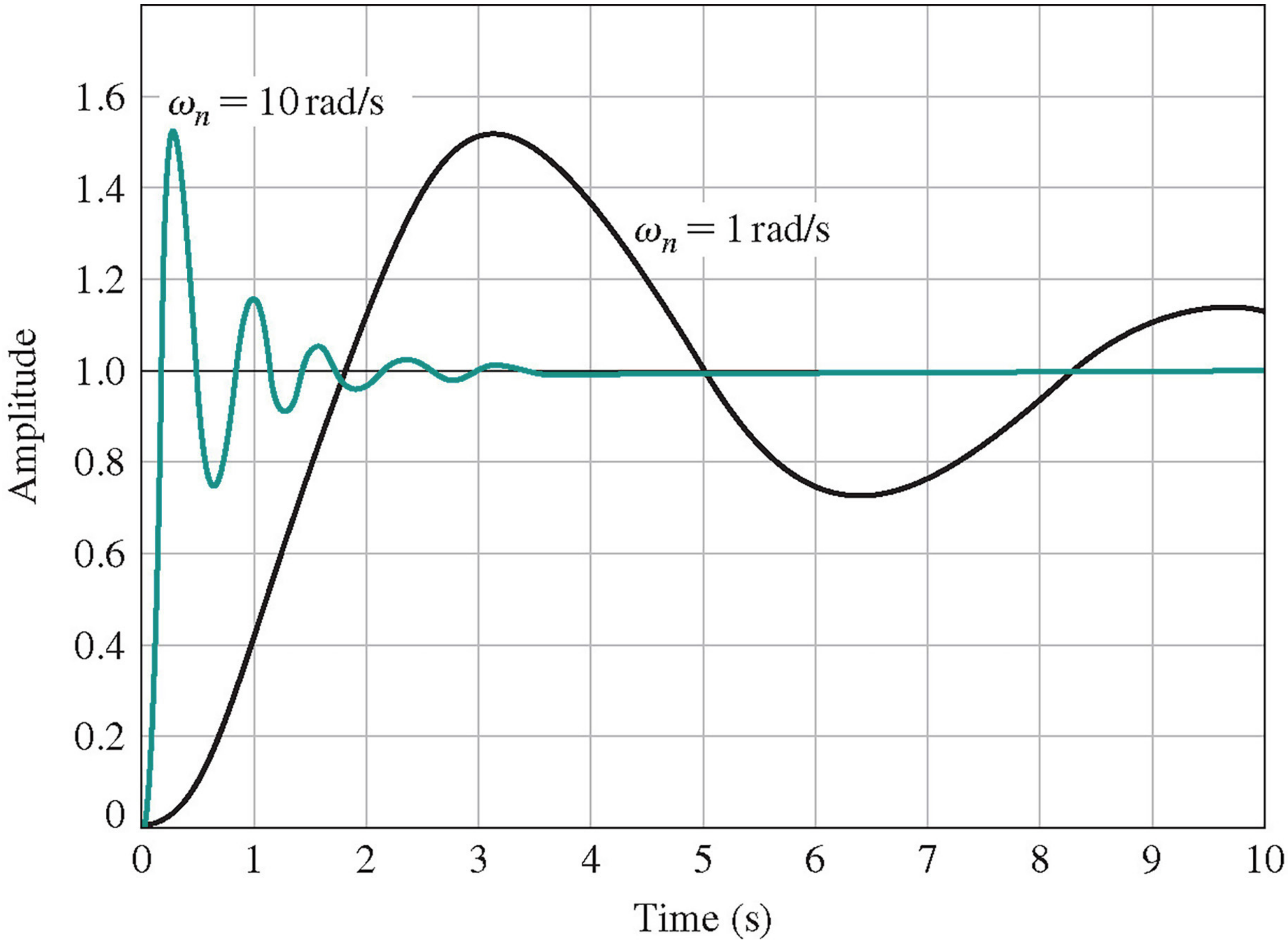

c(t)
Exponential decay generated by real part of complex pole pair
frequency of sinusoid = ωd
1
Sinusoidal oscillation generated by imaginary part of complex pole pair
t

FIGURE 5.9 The step response for ζ = 0.2 for ω_n = 1 and ω_n = 10.



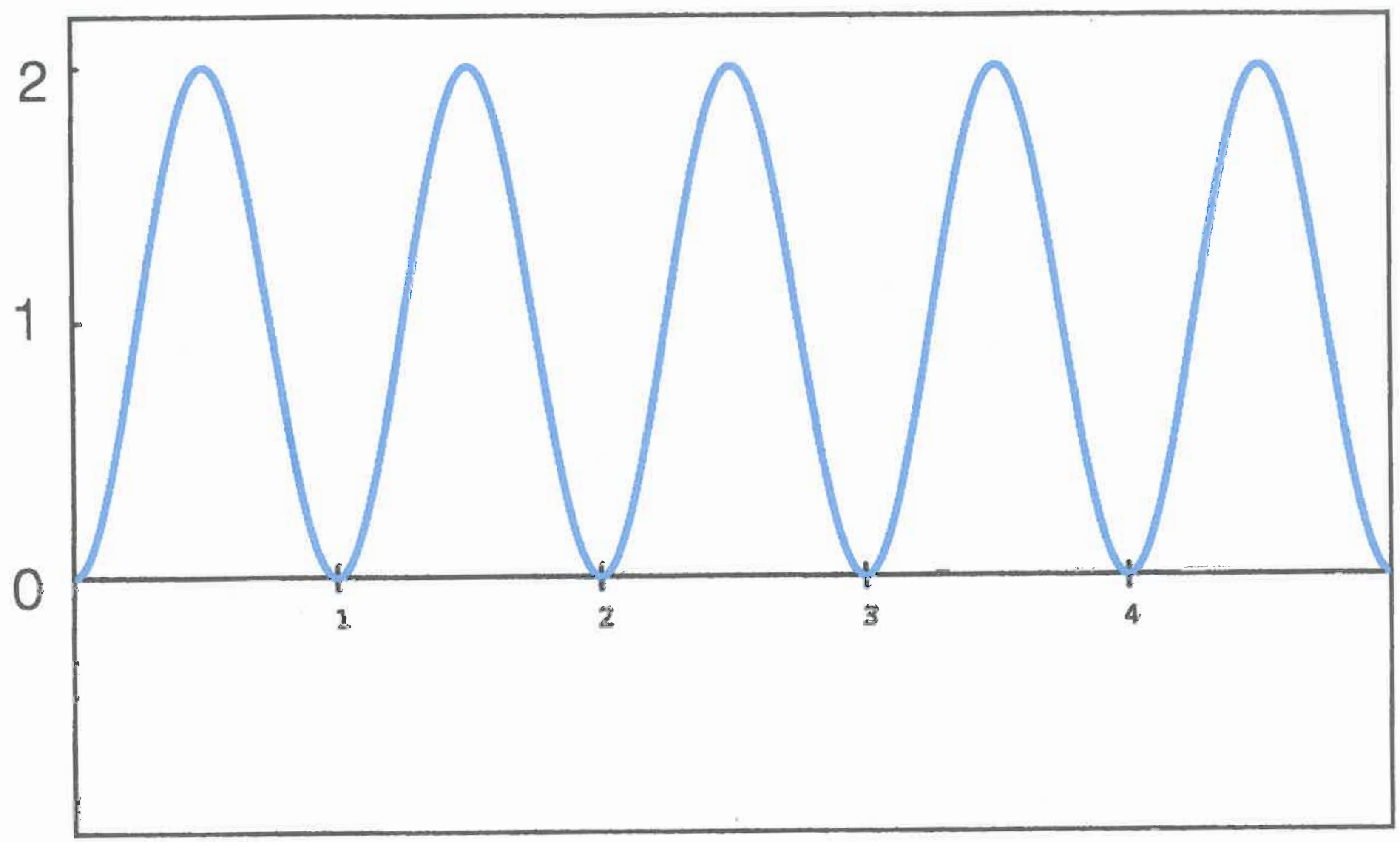

2
1
0
1
2
3
4

FIGURE 5.10 The step response for $\omega_n = 5$ with $\zeta = 0.7$ and $\zeta = 1$.

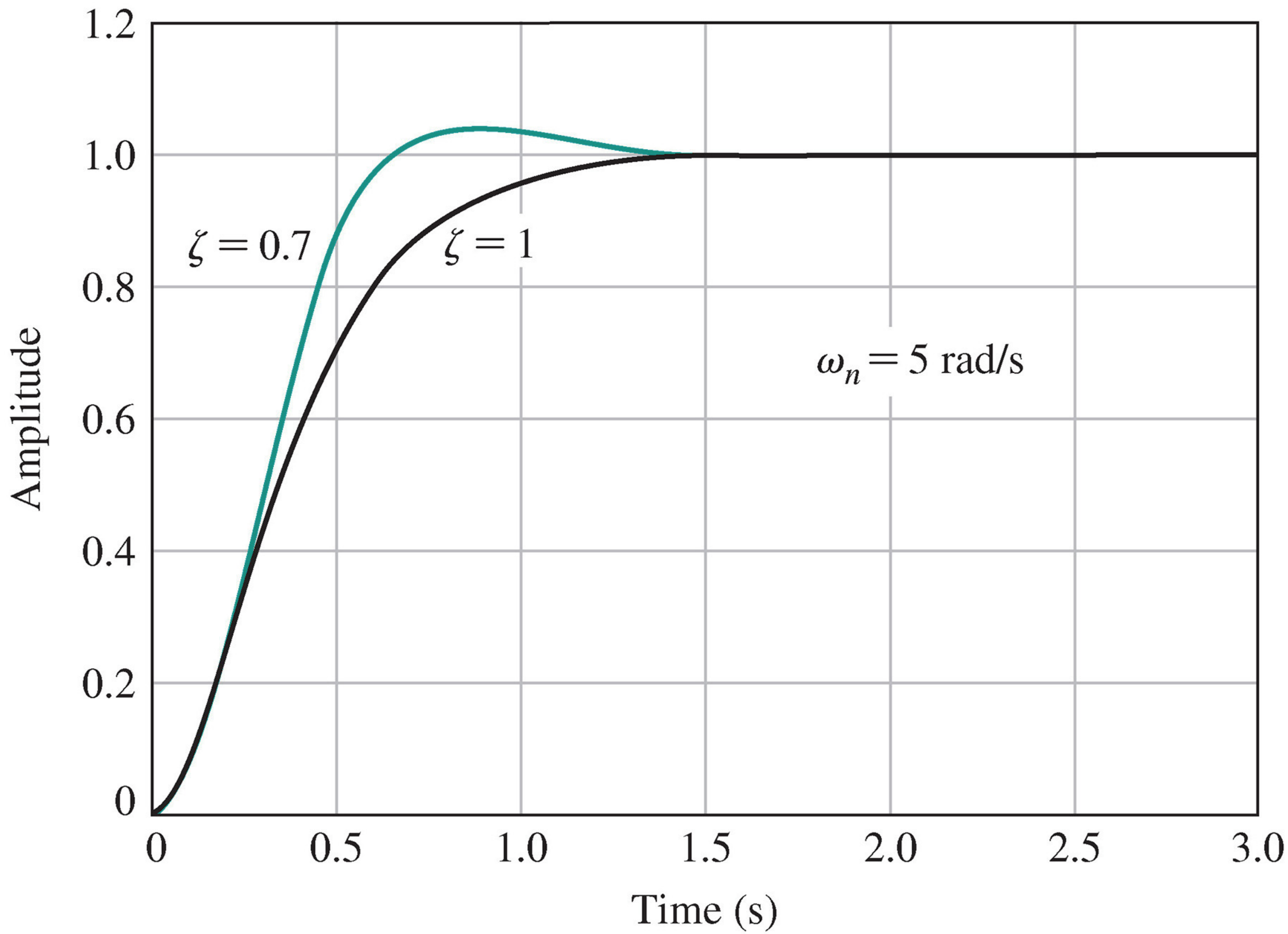
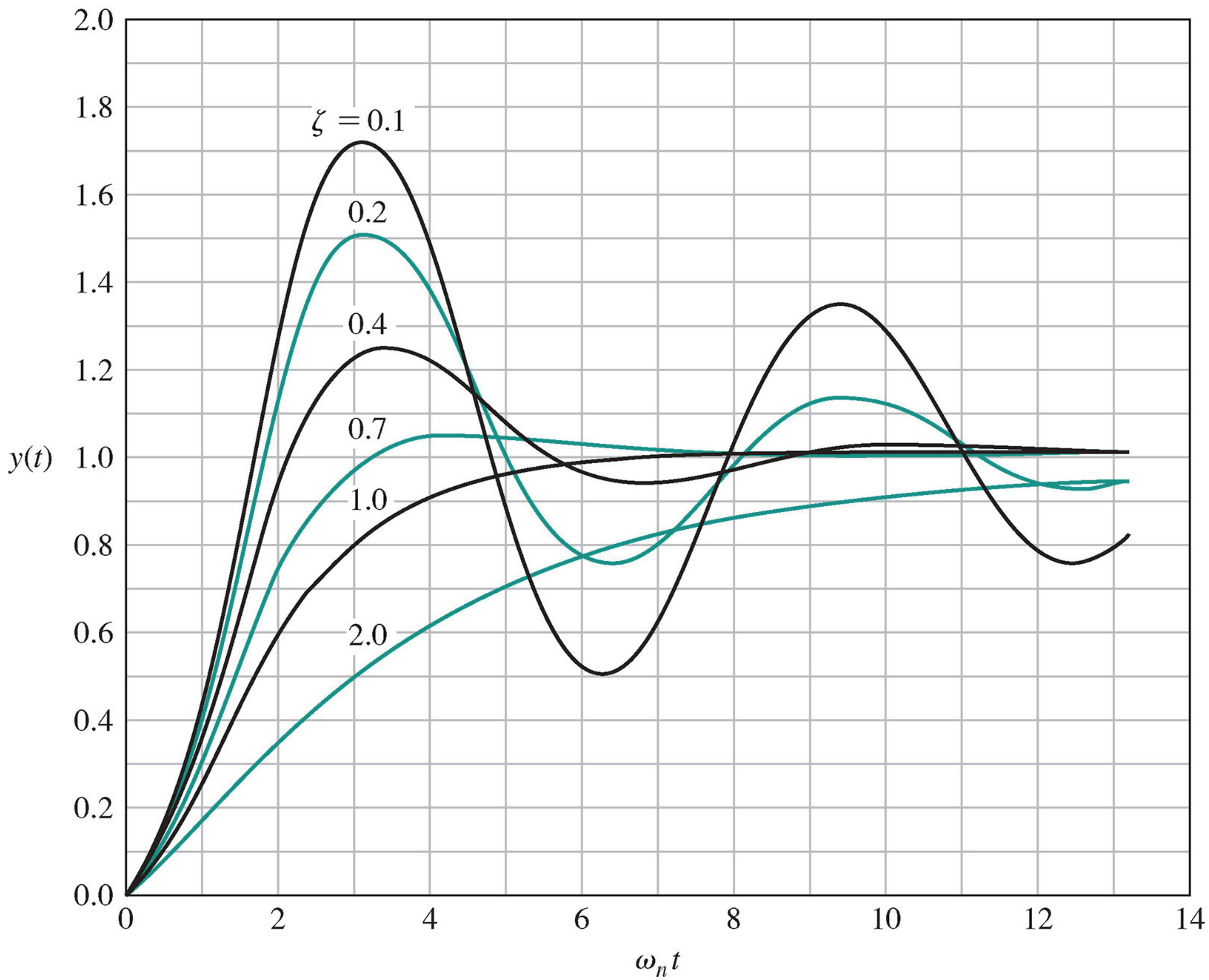
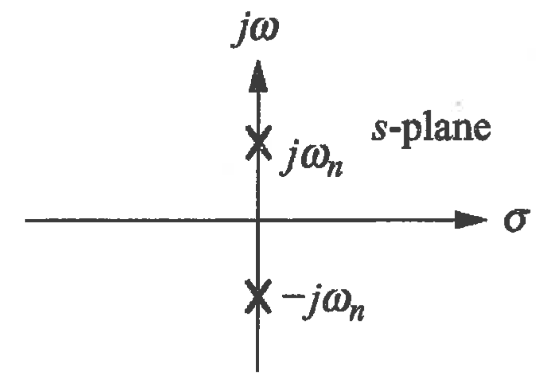


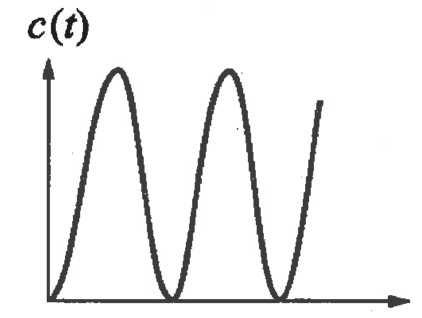
FIGURE 5.4 Transient response of a second-order system for a step input.



ζ	Poles	Step response

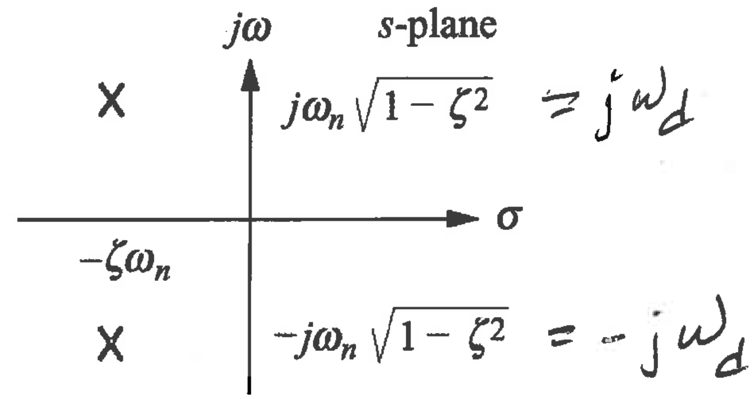
$\zeta = 0$

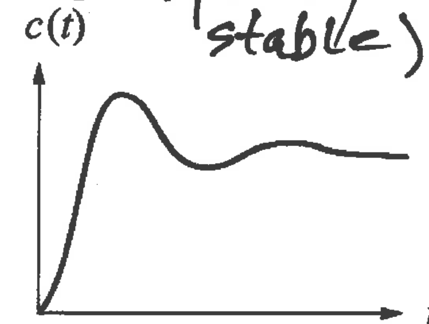




Undamped
(marginally stable)

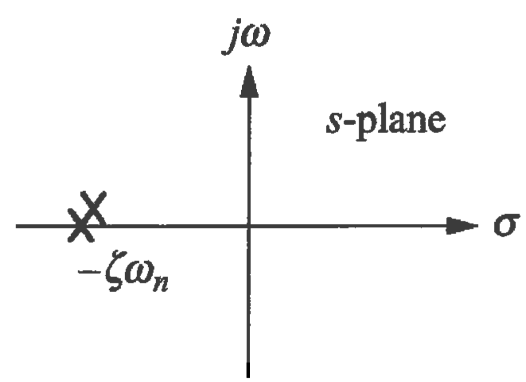
$0 < \zeta < 1$

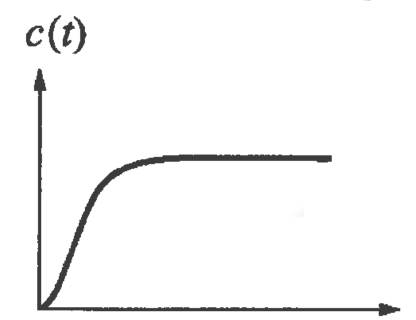




Underdamped

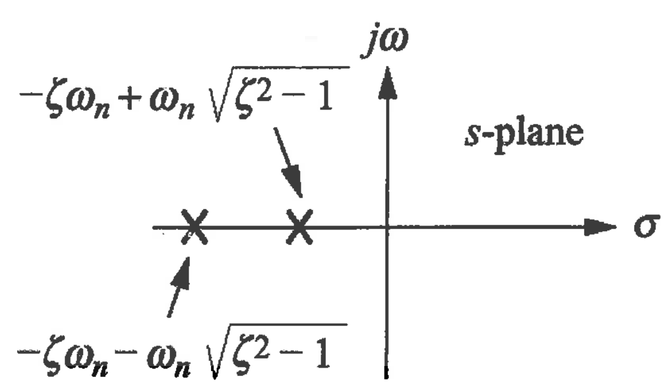
$\zeta = 1$

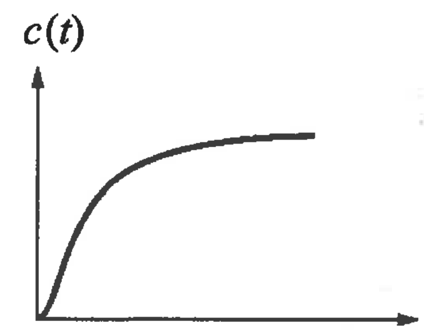




Critically damped

$\zeta > 1$





Overdamped

Table 2.3 Important Laplace Transform Pairs

$f(t)$	$F(s)$
$\frac{1}{a^2 + \omega^2} + \frac{1}{\omega\sqrt{a^2 + \omega^2}} e^{-at} \sin(\omega t - \phi),$ $\phi = \tan^{-1} \frac{\omega}{-a}$	$\frac{1}{s[(s + a)^2 + \omega^2]}$
$1 - \frac{1}{\sqrt{1 - \zeta^2}} e^{-\zeta\omega_n t} \sin\left(\omega_n \sqrt{1 - \zeta^2} t + \phi\right),$ $\phi = \cos^{-1}\zeta, \zeta < 1$	$\frac{\omega_n^2}{s(s^2 + 2\zeta\omega_n s + \omega_n^2)}$
$\frac{\alpha}{a^2 + \omega^2} + \frac{1}{\omega}\left[\frac{(\alpha - a)^2 + \omega^2}{a^2 + \omega^2}\right]^{1/2} e^{-at} \sin(\omega t + \phi).$ $\phi = \tan^{-1} \frac{\omega}{\alpha - a} - \tan^{-1} \frac{\omega}{-a}$	$\frac{s + \alpha}{s[(s + a)^2 + \omega^2]}$

FIGURE 5.4 Transient response of a second-order system for a step input.

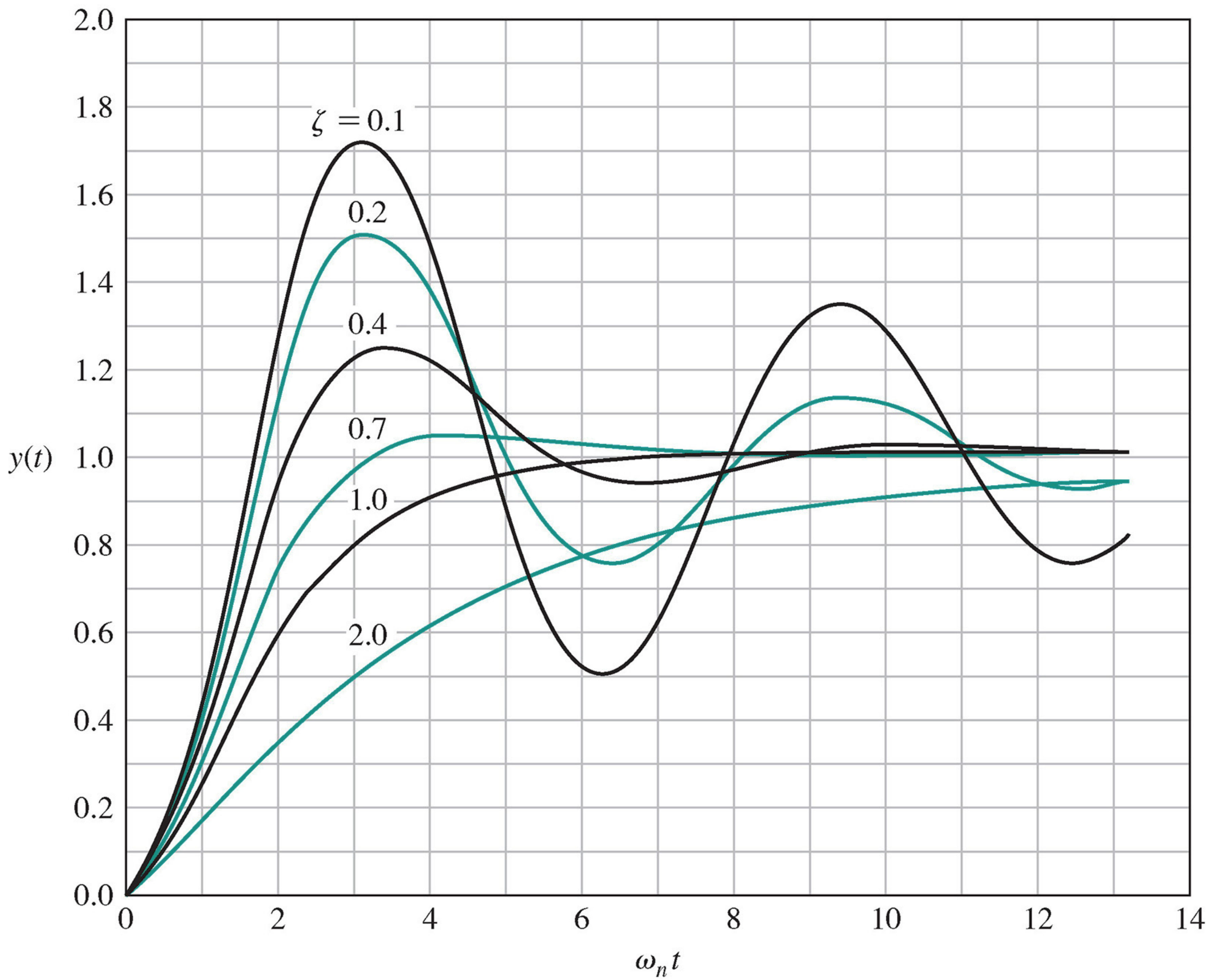


FIGURE 5.5 Response of a second-order system for an impulse input.

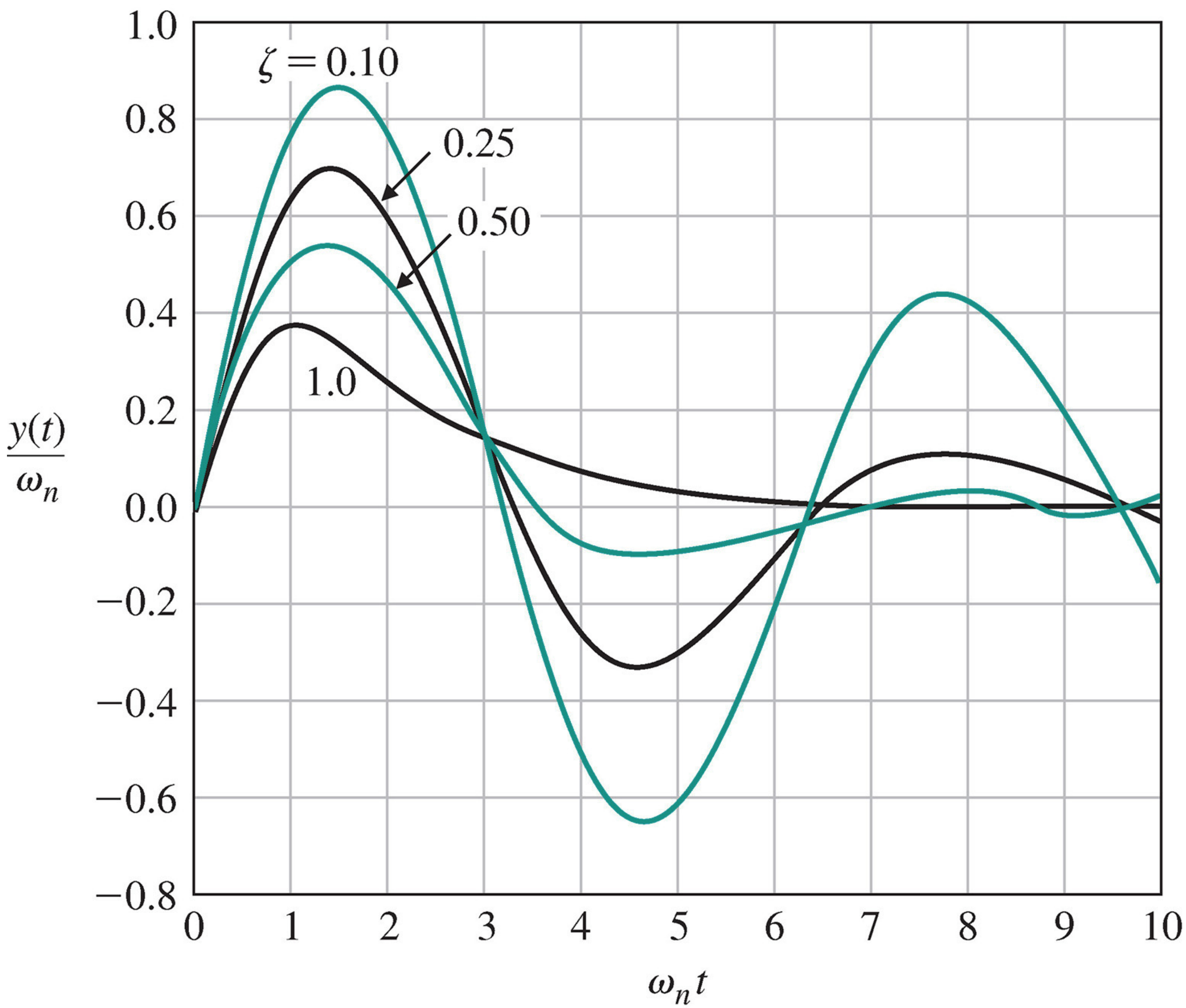


FIGURE 5.17 Impulse response for various root locations in the *s*-plane. (The conjugate root is not shown.)

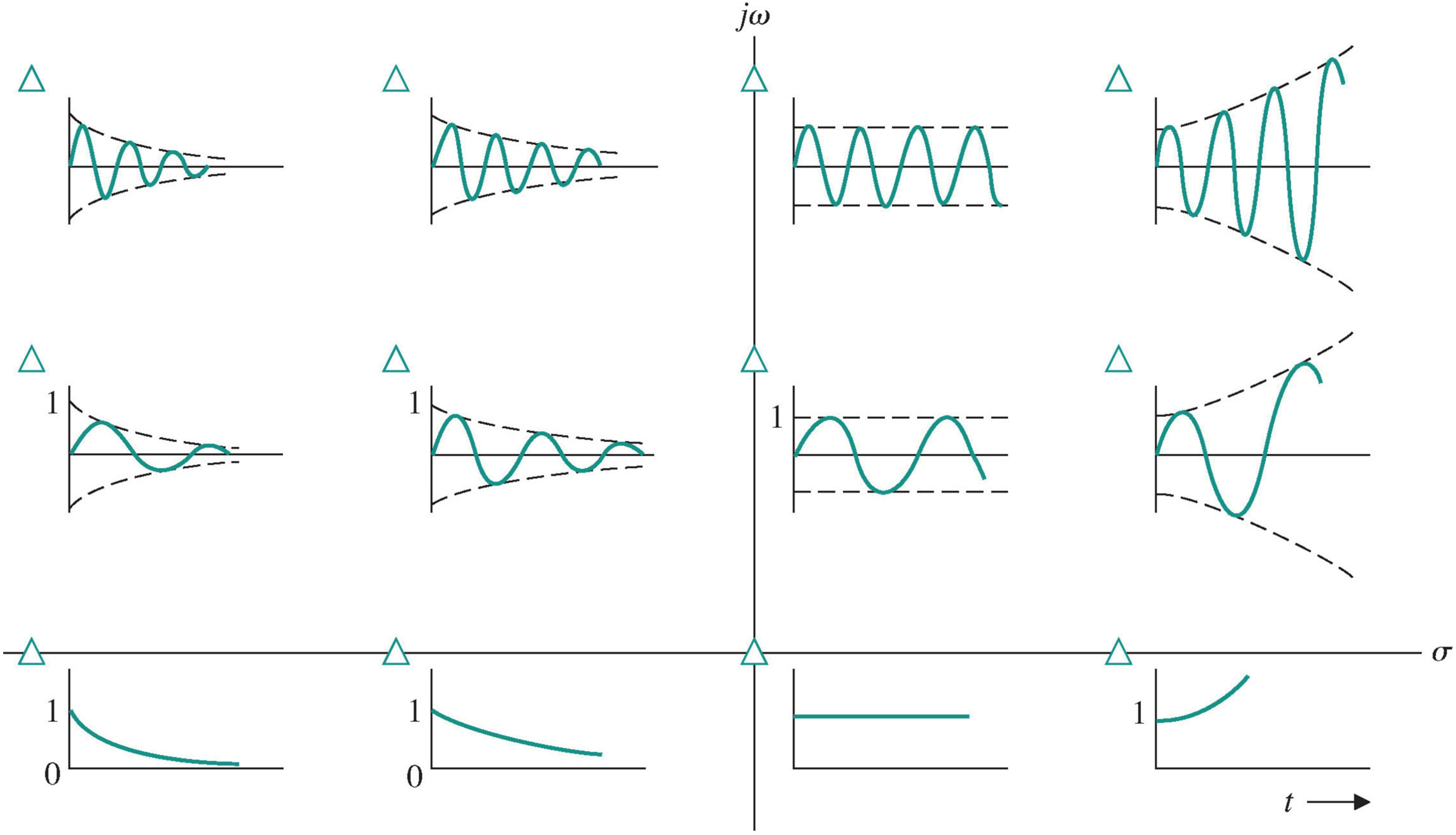


FIGURE 5.6 Step response of a second-order system.

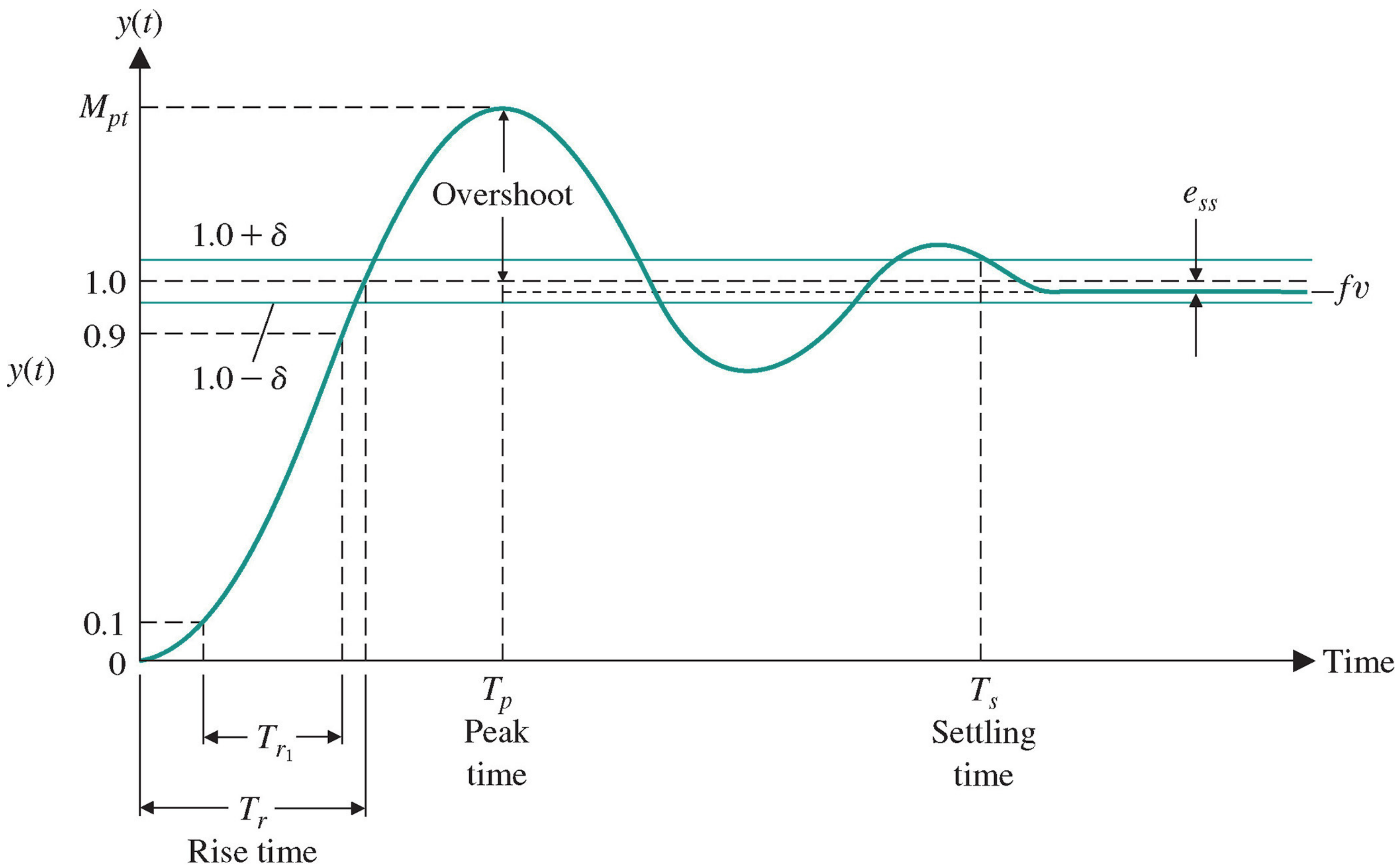


FIGURE 2.12 Response of the spring-mass-damper system.

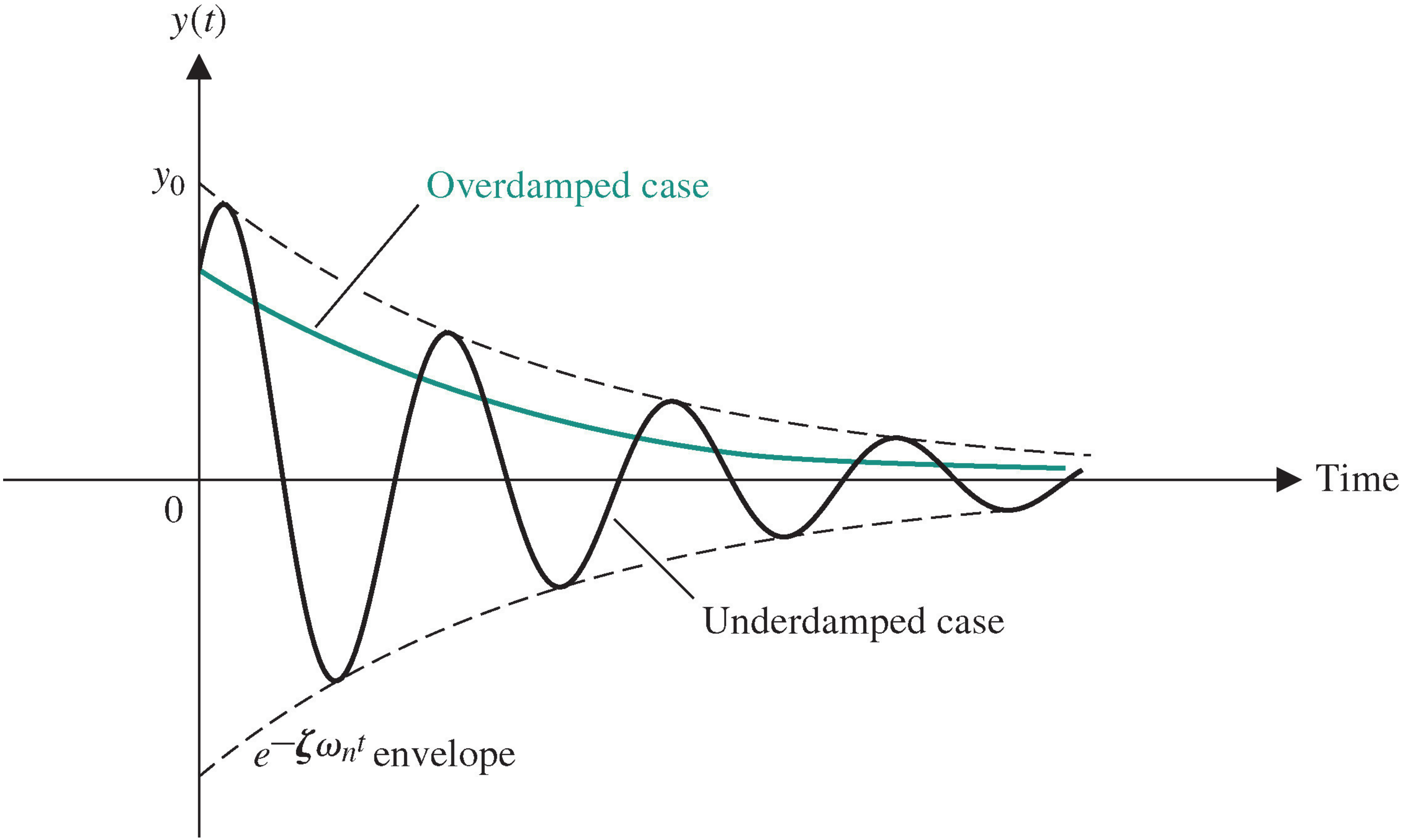


FIGURE 5.7 Percent overshoot and normalized peak time versus damping ratio ζ for a second-order system (Equation 5.8).

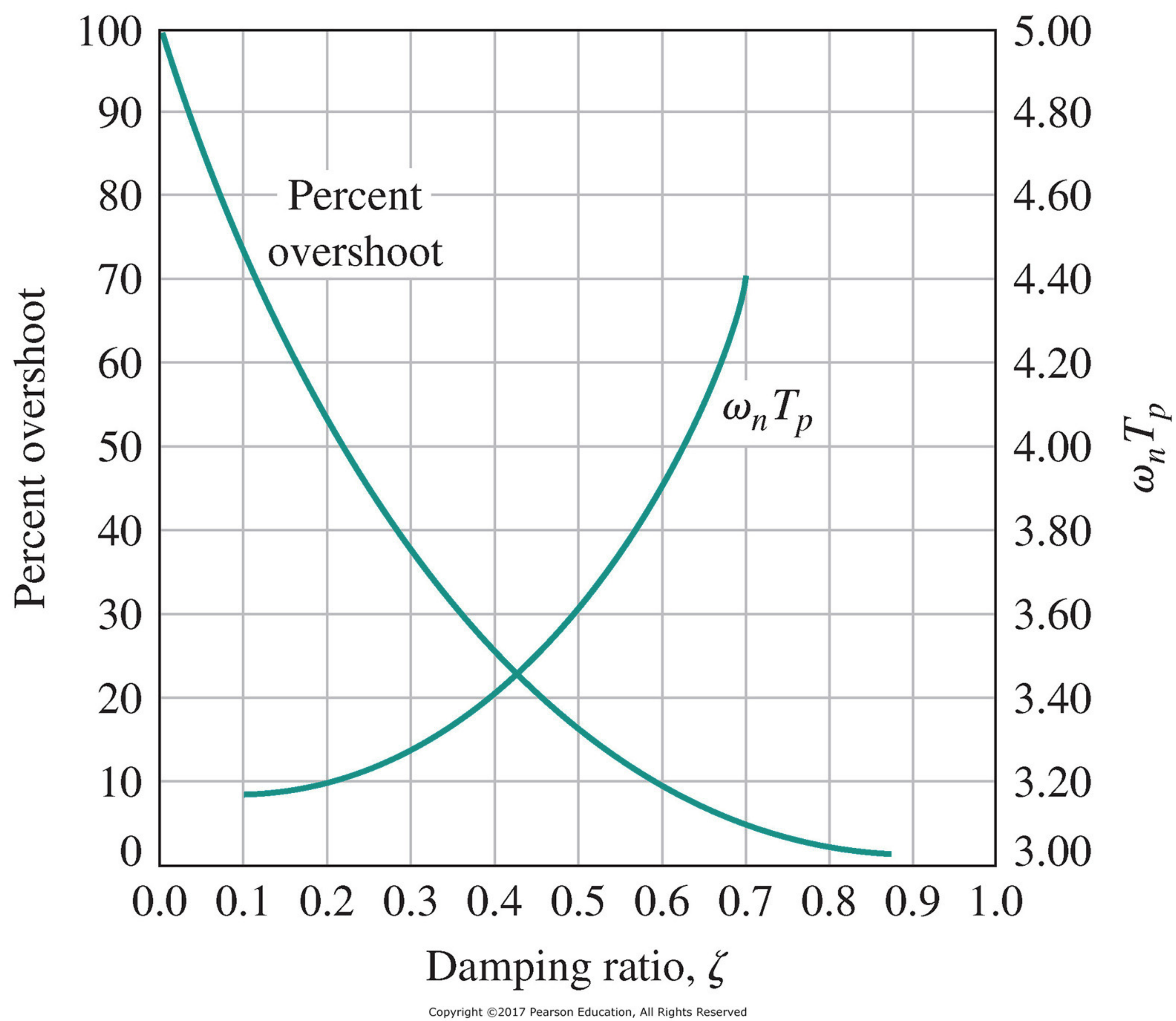


FIGURE 5.15 Specifications and root locations on the *s*-plane.

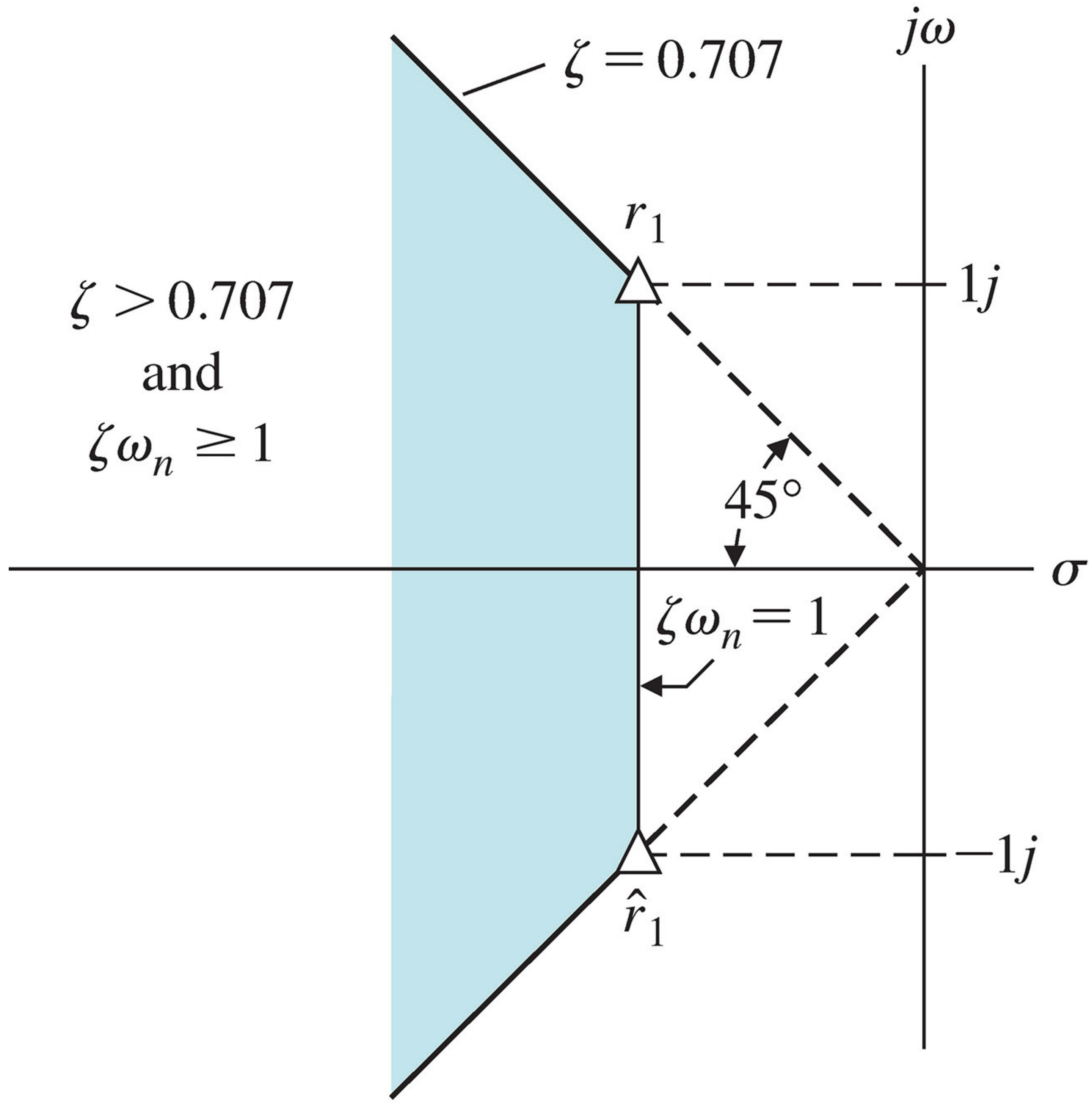


FIGURE 5.11 An *s*-plane diagram of a third-order system.

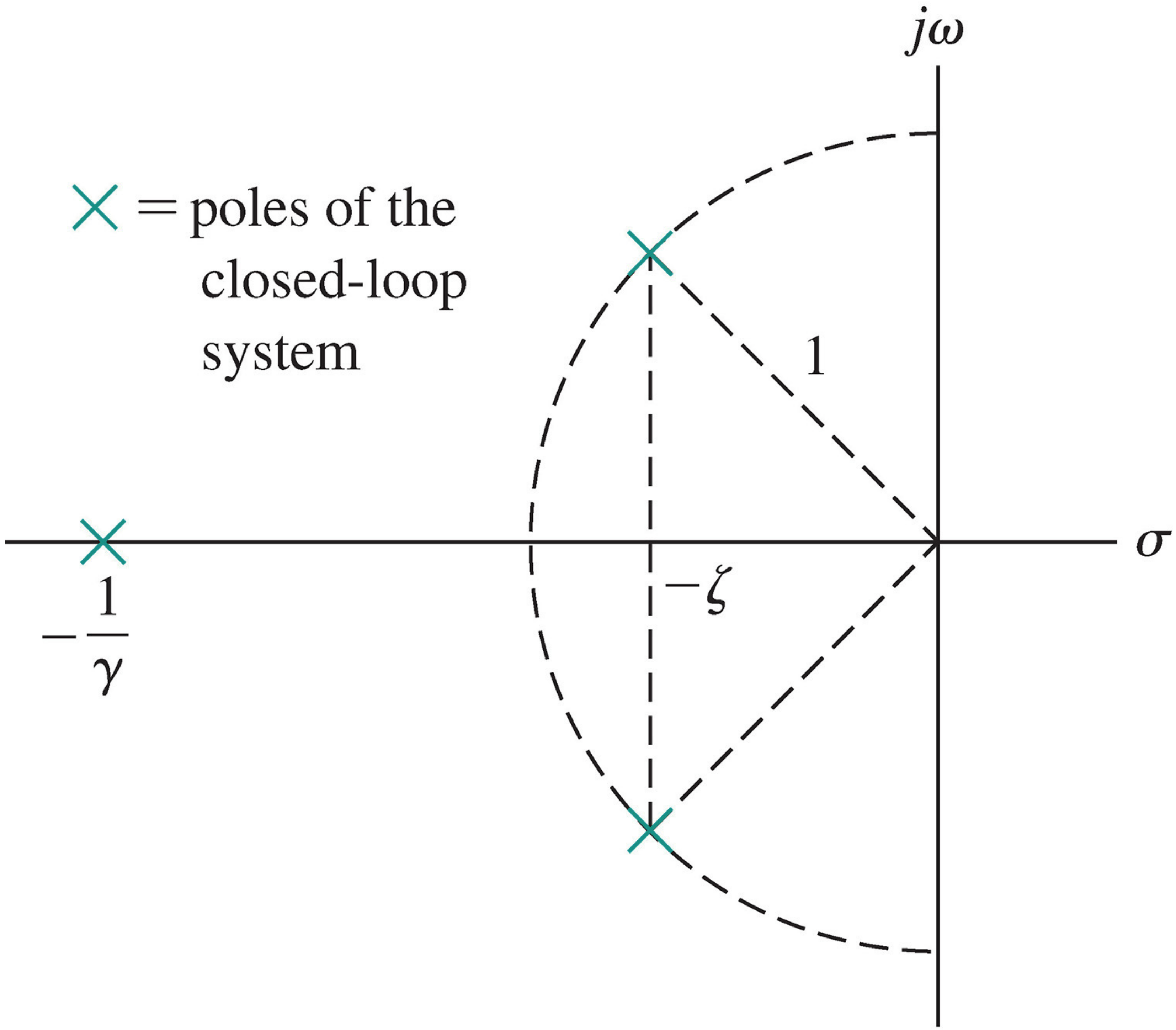
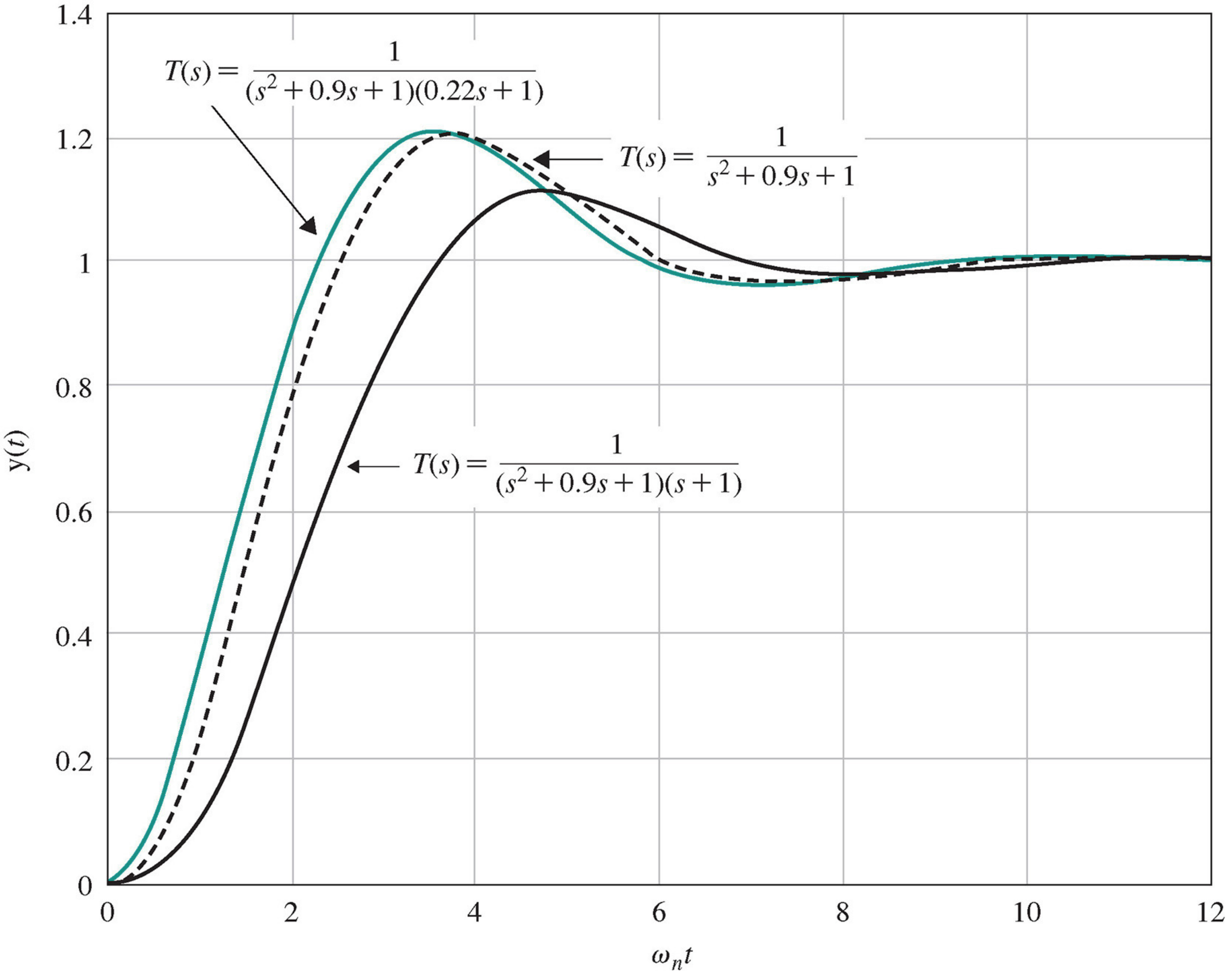
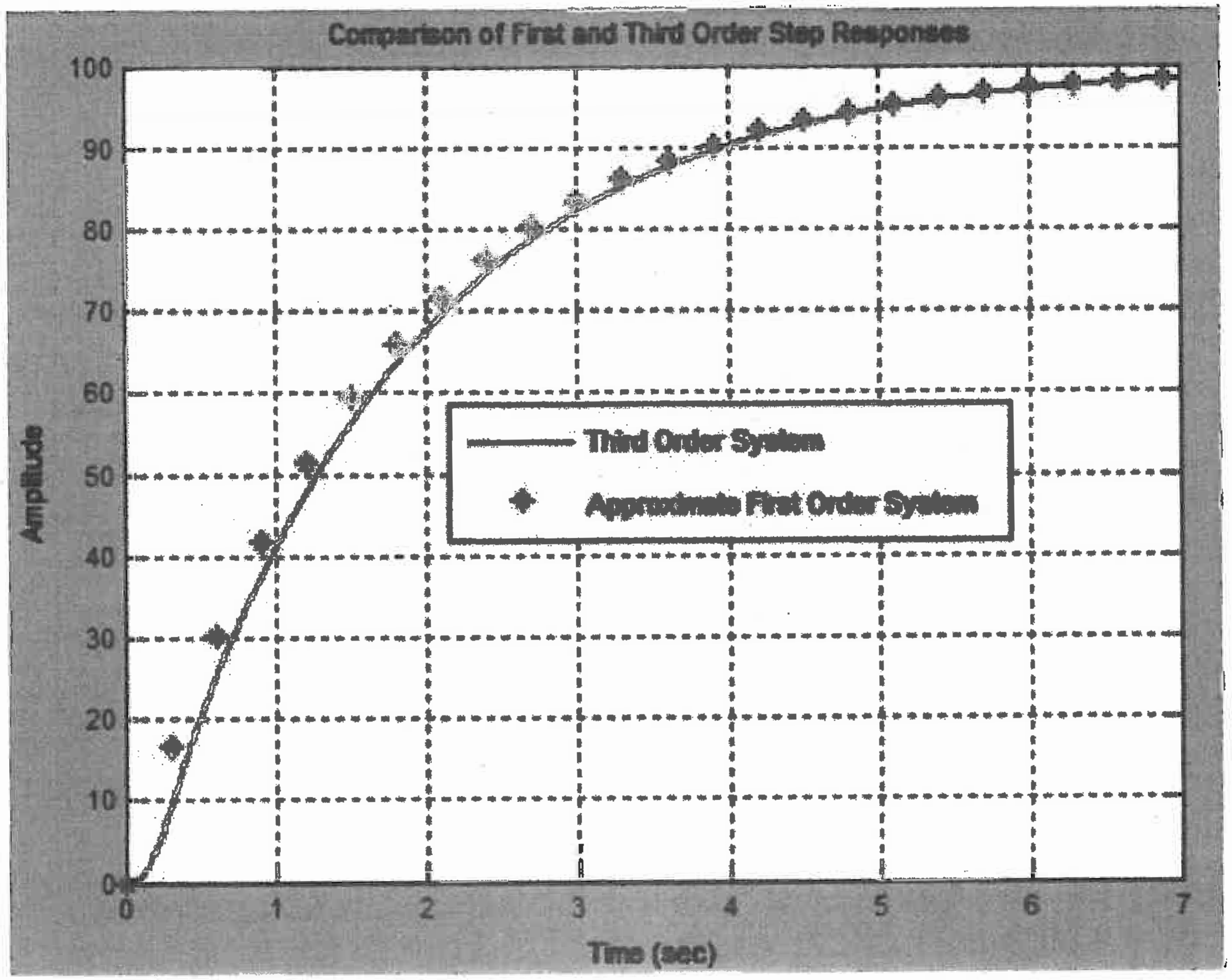


FIGURE 5.12 Comparison of two third-order systems with a second-order system (dashed line) illustrating the concept of dominant poles when $|1/\gamma| \geq 10\zeta\omega_n$.



$K = 6000, \quad \zeta = 0.6, \quad \omega_n = 10, \quad p = 0.6$

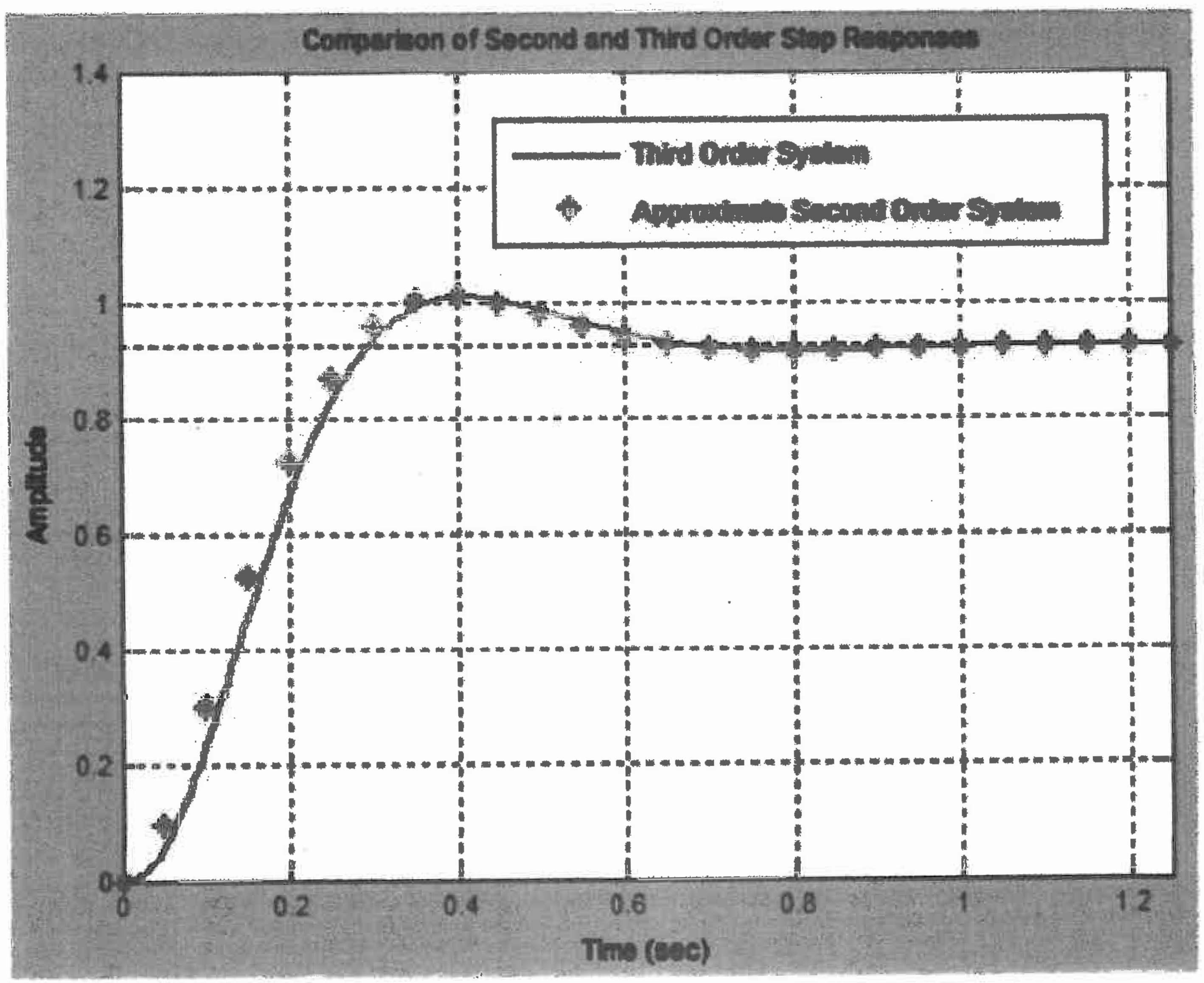


$K = 6000$

orig sys $\quad G(s) = \dfrac{6000}{(s^2 + 12s + 100)(s + 0.6)}$

approx sys $\quad \hat{G}(s) = \dfrac{K/\omega_n^2}{s + 0.6}$

$K = 6600$, $\zeta = 0.6$, $\omega_n = 10$, $p = 65$



approx sys $\hat{G}(s) = \dfrac{K/p}{s^2 + 12s + 100}$

FIGURE 5.13 The response for the second-order 0.5 transfer function with a zero for four $a>\zeta\omega_n$ = 0.5, 1,2, and 10.0 when ζ = 0.45.