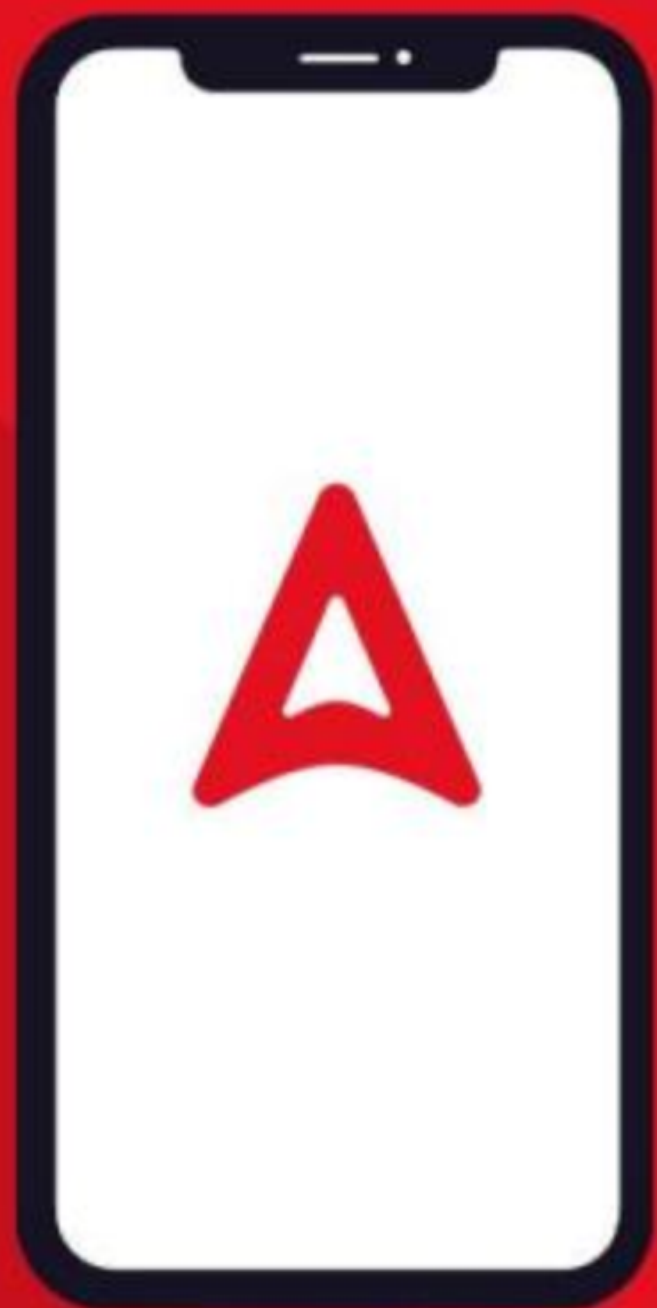


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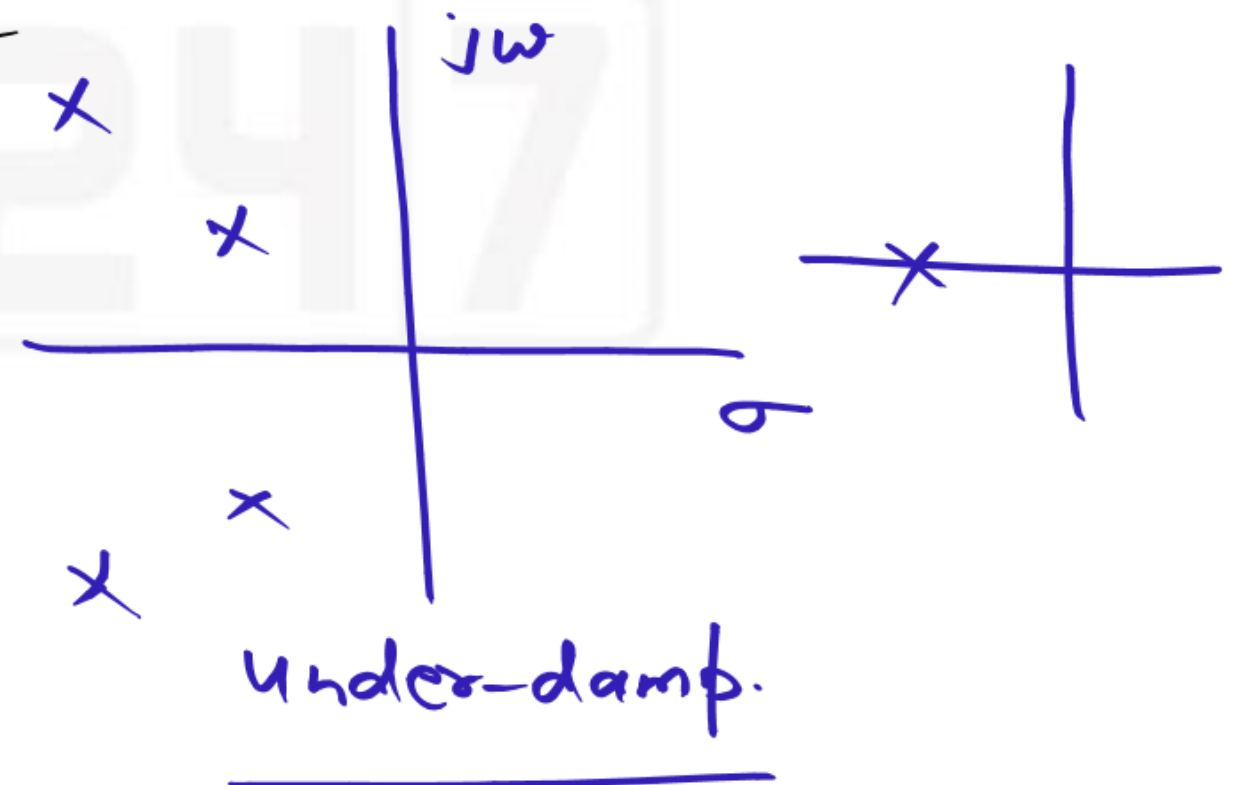


Control system

underdamped system

$$s^2 + 2\zeta\omega_n s + \omega_n^2 = 0$$

$$\zeta < 1$$



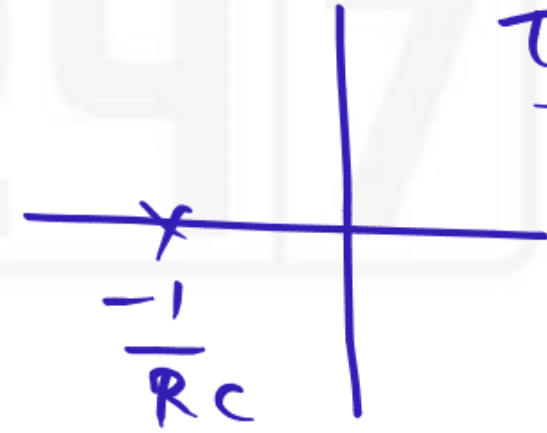
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$$G(s) \rightarrow \frac{1}{\underbrace{2s+1}_T}$$

$$\frac{1}{\underbrace{5RC+1}_T}$$

$T_s \rightarrow$ $\left| \frac{1}{\text{real part of the pole}} \right|$



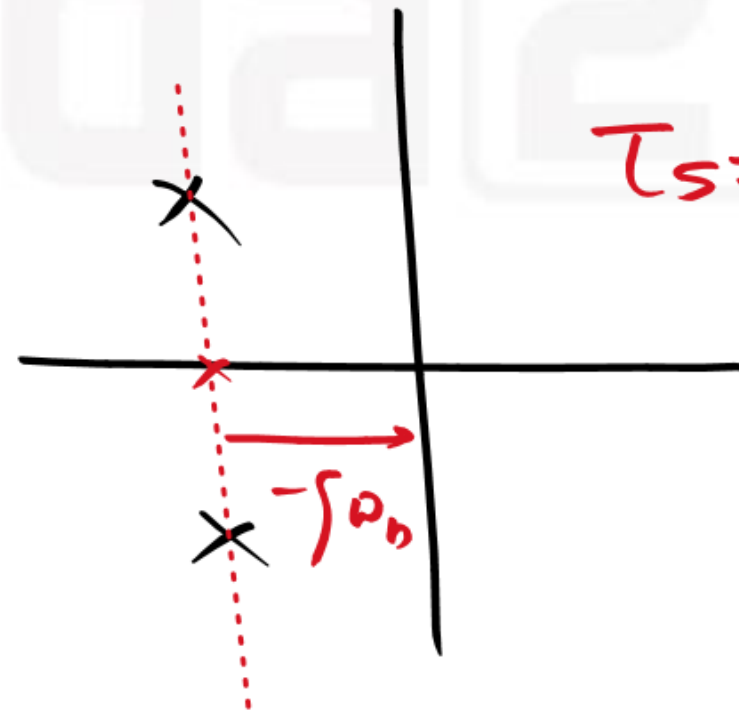
$$\begin{aligned} T_s &= 4RC \rightarrow 98\% \\ &= 5RC \rightarrow 99\% \\ &= 3RC \rightarrow \underline{95\%} \end{aligned}$$

$$T_s \rightarrow \frac{1}{|-1/RC|} \rightarrow \underline{RC}$$

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Char. eqⁿ $\rightarrow s^2 + 2\zeta\omega_n s + \omega_n^2 = 0$

$$s_1, s_2 \rightarrow -\zeta\omega_n \pm j\omega_n\sqrt{1-\zeta^2}$$



$$T_s = \frac{1}{1-\zeta\omega_n} = \frac{1}{\zeta\omega_n}$$

$$\text{Setting time} = 4T_s = \frac{4}{\zeta\omega_n}$$

(i) $\zeta < 1 \rightarrow$ underdamp

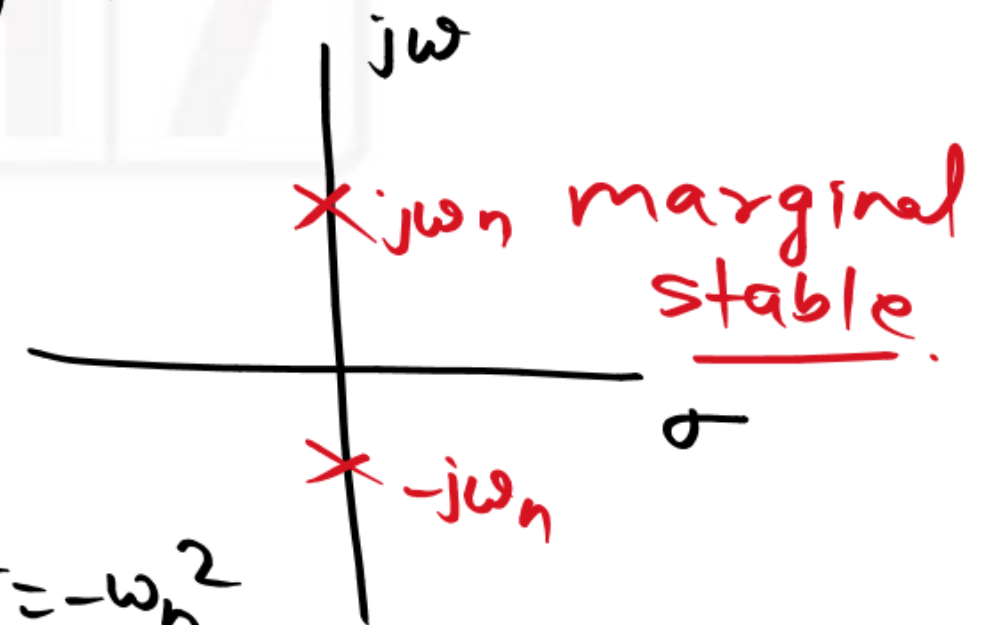
(ii) $\zeta = 0$

$$\frac{C(s)}{R(s)} = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

$$\frac{C(s)}{R(s)} = \frac{\omega_n^2}{s^2 + \omega_n^2}$$

$$s^2 + \omega_n^2 = 0 \Rightarrow s^2 = -\omega_n^2$$

$$s = \pm \sqrt{-\omega_n^2} = \pm j\omega_n$$



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type of damping

$$\zeta = 0$$

$$\frac{C(s)}{R(s)} = \frac{\omega_n^2}{s^2 + \omega_n^2}$$

$$c(t) = (1 - \cos(\omega_n t))$$

$$\zeta < 1$$

$$c(t) = 1 - \frac{e^{-\zeta \omega_n t}}{\sqrt{1-\zeta^2}} \left(\sin(\omega_n \sqrt{1-\zeta^2} t + \tan^{-1} \frac{\zeta \sqrt{1-\zeta^2}}{1-\zeta^2}) \right)$$

$$\zeta = 0$$

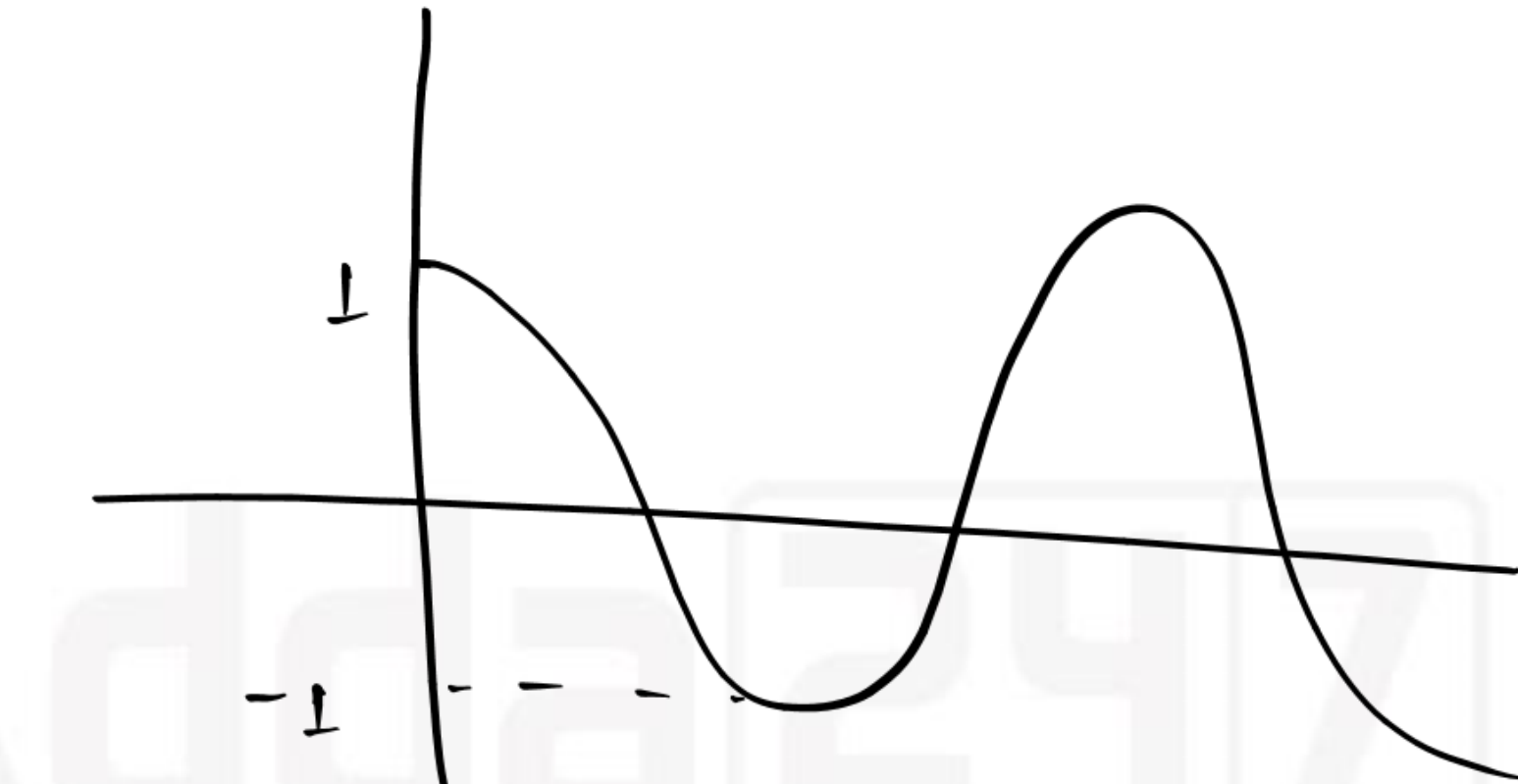
$$c(t) = 1 - \sin(\omega_n t + 90^\circ)$$

$$c(t) = (1 - \cos \omega_n t) u(t)$$

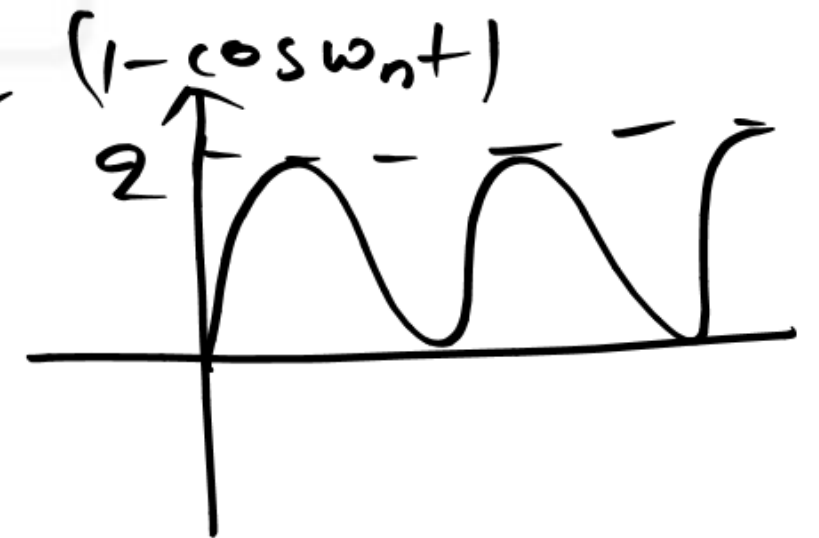
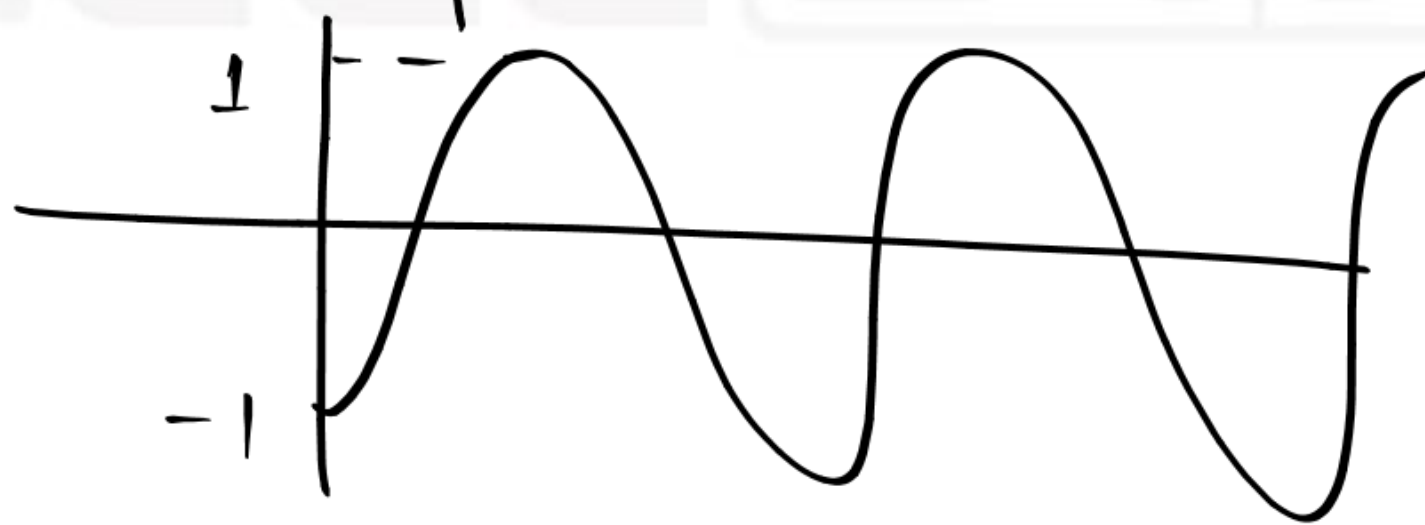
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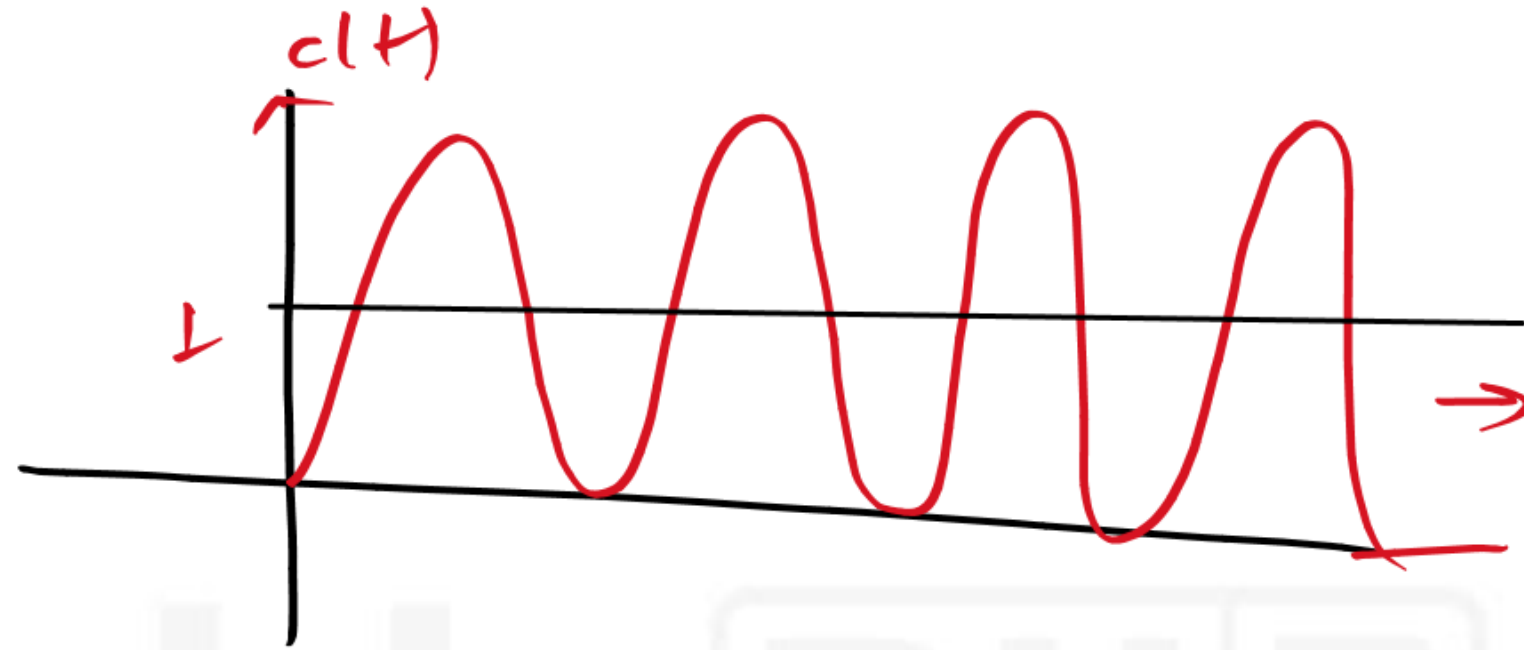
$\cos \omega_n t$



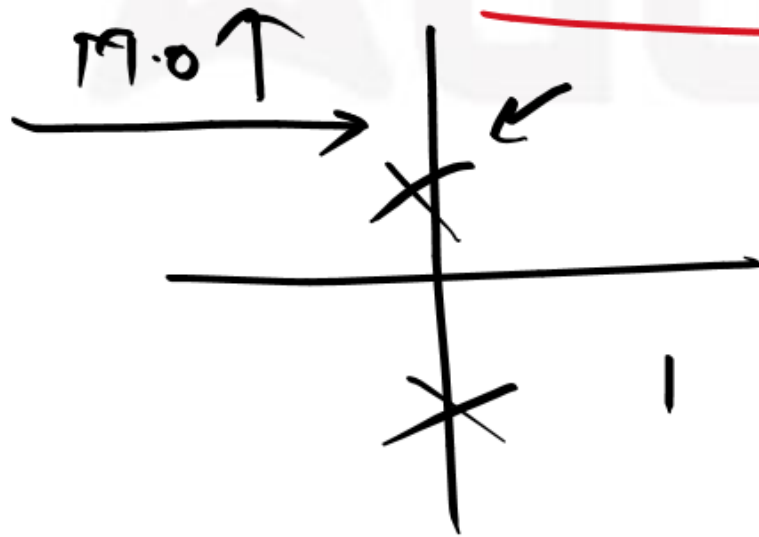
$-\cos \omega_n t$



$\zeta = 0$



undamped

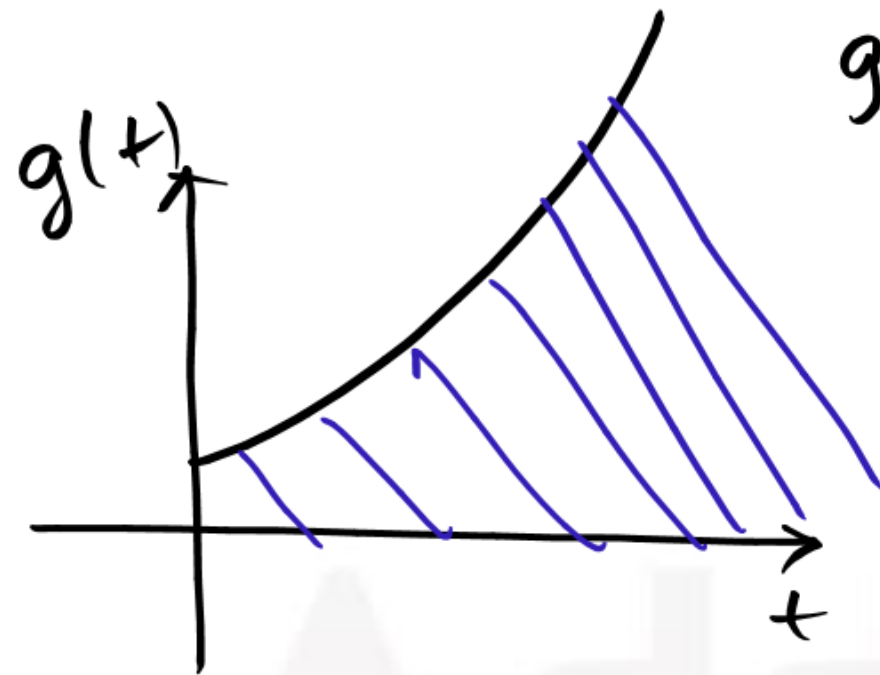


Max^m overshoot $\rightarrow ?$

$$M.O \rightarrow e^{\frac{-\zeta \pi}{\sqrt{1-\zeta^2}}} \times 100 = 100\%$$

$$M.O = \frac{c(t)_{max} - c(t)_{des}}{c(t)_{des}} = \frac{2-1}{1} \times 100 = 100\%$$

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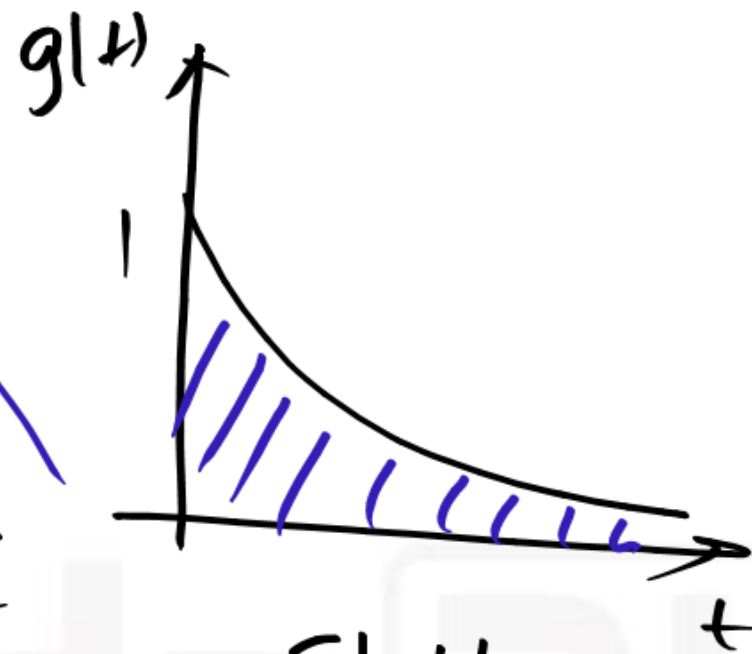


unstable

$$g(t) \rightarrow \infty \quad t \rightarrow \infty$$

$$\int |g(t)| dt = \infty$$

unst.

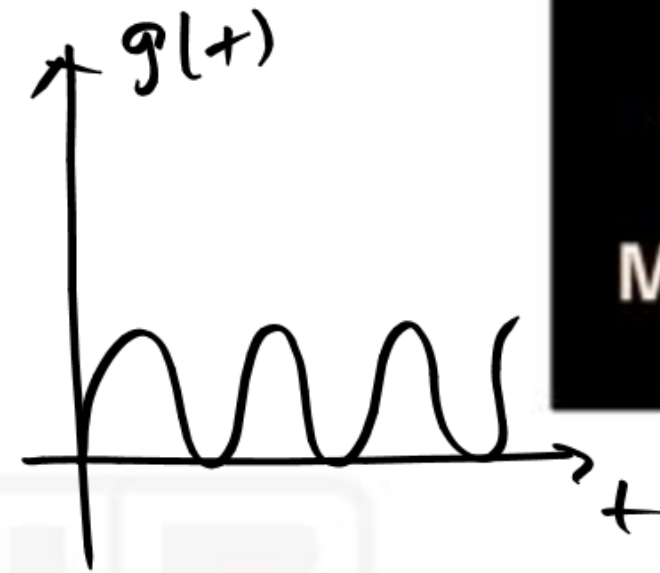


Stable

$$g(t) \neq \infty \text{ at any } t$$

$$\int g(t) dt < \infty$$

Stable




marginally stable.

$$g(t) \neq \infty \text{ at any } t$$


$$\int |g(t)| dt = \infty$$

marginally stable

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$\zeta < 1$  \rightarrow underdamped

$\zeta = 0$  \rightarrow marginal stable / undamped

$\zeta = 1$ \rightarrow  \rightarrow critically damped

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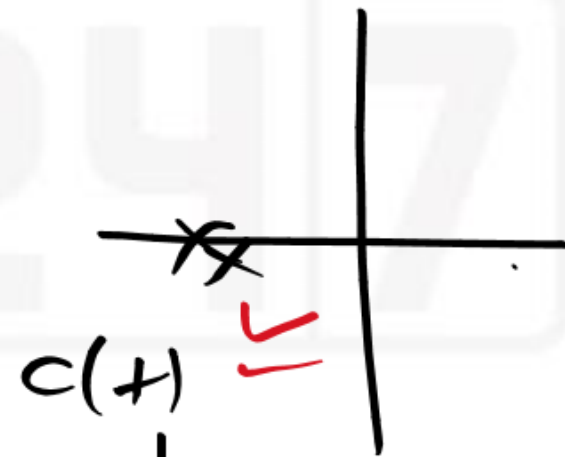
$$\zeta = 1$$

$$* \frac{C(s)}{R(s)} = \frac{\omega_n^2}{s^2 + 2\omega_n s + \omega_n^2}$$

$$\Rightarrow \frac{\omega_n^2}{(s + \omega_n)^2}$$

for unit step I/P

$$C(s) = \frac{1}{s} \times \frac{\omega_n^2}{(s + \omega_n)^2}$$



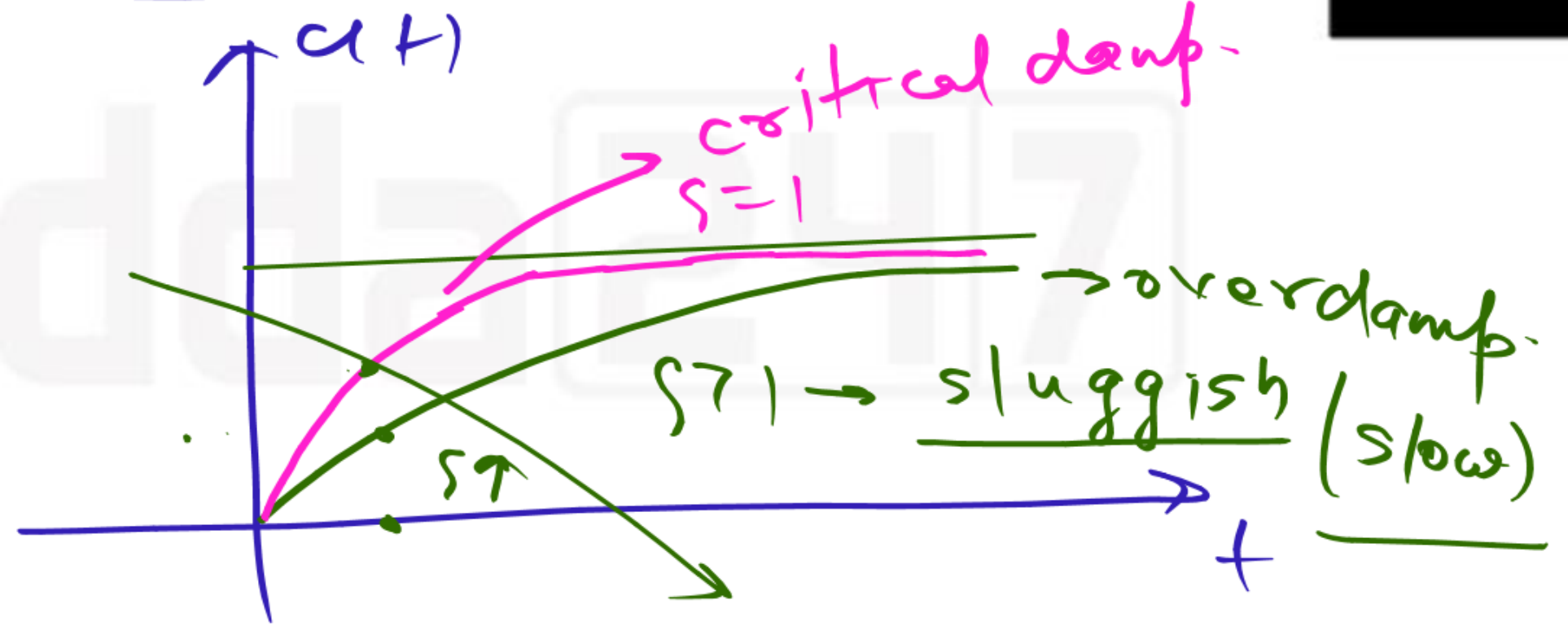
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overdamped system

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$$= \frac{R}{2} \sqrt{\frac{K}{L}}$$

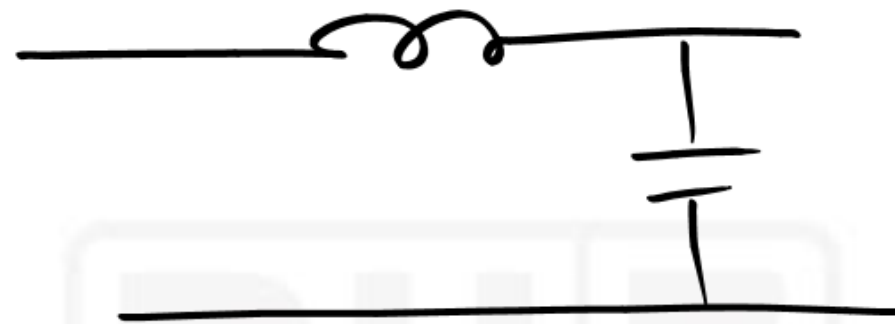
$R \rightarrow$



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$$\frac{V_o(s)}{V_i(s)} = \frac{1/c_s}{R + Ls + \frac{1}{c_s}}$$



$$\frac{V_o(s)}{V_i(s)} = \frac{1/c_s}{sL + \frac{1}{c_s}} \Rightarrow \frac{1}{Lc_s^2 + 1}$$

$$\frac{1/c_c}{s^2 + \frac{1}{Lc}}$$

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