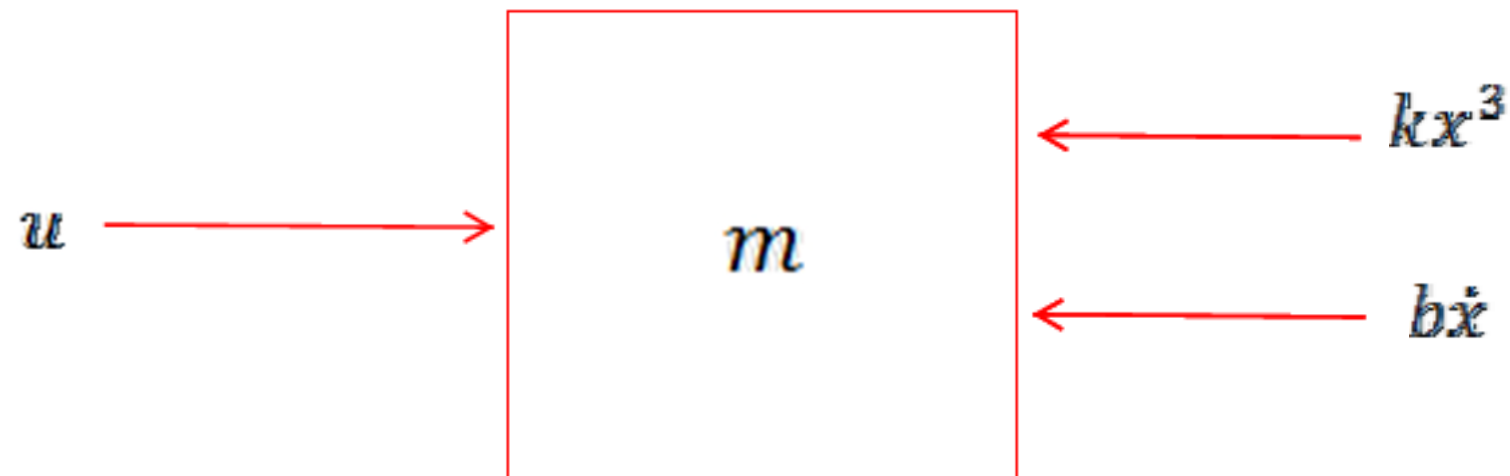


$$m\ddot{x} + b\dot{x} + kx^3 = u$$

$$u = \alpha v + \beta$$

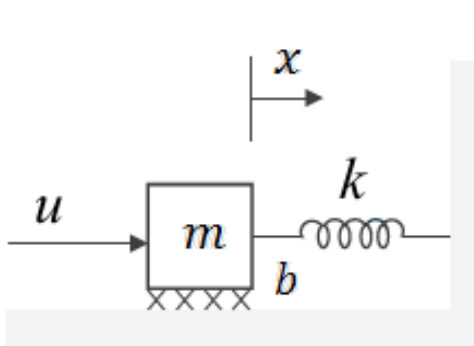


$$m\ddot{x} + b\dot{x} + kx^3 = u$$

$$u = \alpha v + \beta$$

$$\alpha = m$$

$$\beta = b\dot{x} + kx^3$$



$$\ddot{x} = v$$

$$v = \ddot{x}_d + k_v \dot{e} + k_p e$$

$$\ddot{e} + k_v \dot{e} + k_p e = 0$$

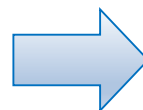
$$s^2 + k_v s + k_p = 0$$

How to set the control gains?

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

$$\zeta \geq 1$$

$$\omega_n \leq 0.5\omega_{res}$$



$$k_v = 2\zeta\omega_n$$

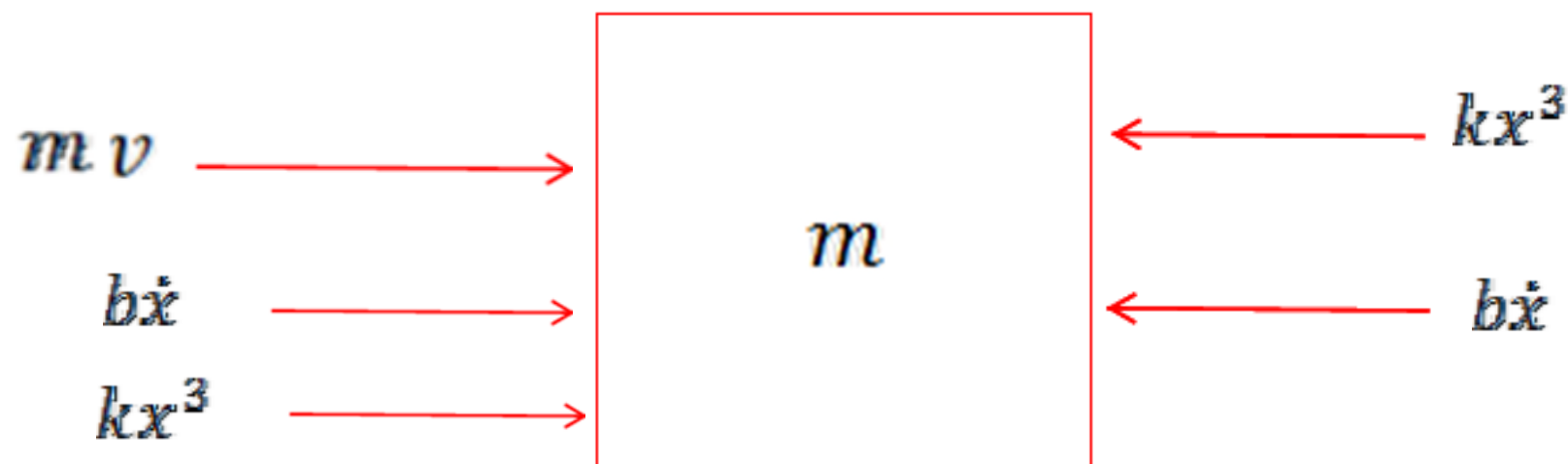
$$k_p = \omega_n^2$$

$$m\ddot{x} + b\dot{x} + kx^3 = u$$

$$u = \alpha v + \beta$$

$$\alpha = m$$

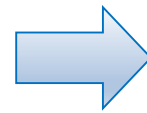
$$\beta = b\dot{x} + kx^3$$



$$m\ddot{x} + b\dot{x} + kx^3 = u$$

$$\ddot{x} = v$$

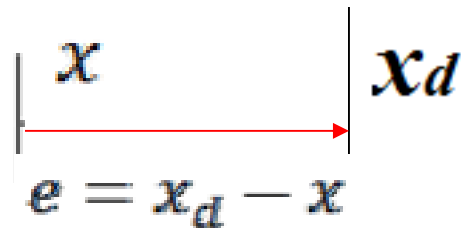
$$u = \alpha v + \beta$$



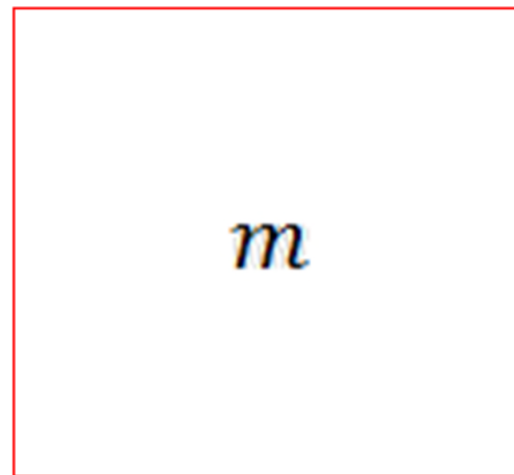
$$v = \ddot{x}_d + k_v \dot{e} + k_p e$$

$$\alpha = m$$

$$\beta = b\dot{x} + kx^3$$



$$m v \longrightarrow$$

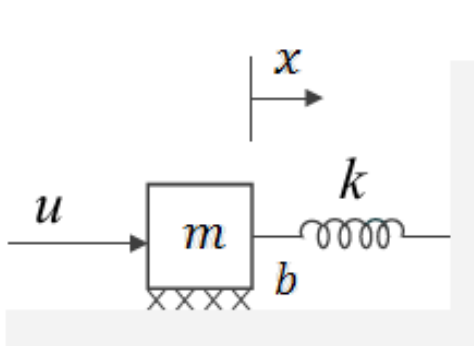


$$m\ddot{x} + b\dot{x} + kx^3 = u$$

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$$\beta = b\dot{x} + kx^3$$



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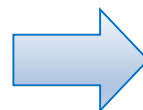
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How to set the control gains?

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$$\omega_n \leq 0.5\omega_{res}$$



$$k_v = 2\zeta\omega_n$$

$$k_p = \omega_n^2$$

$$\underline{k_v = 2\zeta w_n} \quad \underline{k_p = w_n^2}$$

3 types of response

example

1. under-damped

$$\underline{k_p = 4}, \quad \underline{k_v = 2} \quad \underline{w_n = 2} \quad \underline{\zeta = 0.5}$$

2. overdamped

$$k_p = 4, \quad k_v = 8 \quad w_n = 2 \quad \zeta = 2$$

3. critically damped

$$k_p = 4, \quad k_v = 4 \quad w_n = 2 \quad \zeta = 1$$

