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I Mehansko nihanje in valovanje

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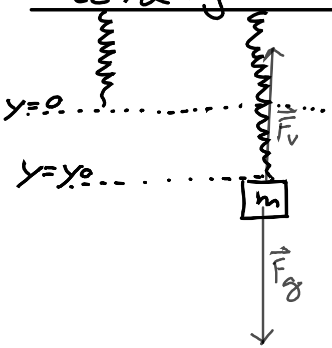
Utež na vijačni vzmeti



$$F_g = \begin{bmatrix} 0 \\ -mg_0 \\ 0 \end{bmatrix}$$ smer navzdol

$g_0 \approx 10\ m/s^2$

$$F_v = \begin{bmatrix} 0 \\ -ky_0 \\ 0 \end{bmatrix}$$ k... koeficient vzmeti N/m

$y_0 < 0$

$-ky_0 > 0 \Rightarrow$ smer je navzgor

neto sila

$$\vec{a} = 0 \iff \vec{F} = m\vec{a} = 0$$

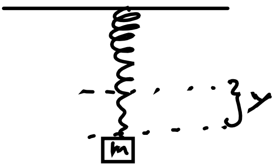
$$\vec{F}_g + \vec{F}_v = 0$$

$$-mg_0 - ky_0 = 0 \Rightarrow$$

$$mg_0 = -ky_0$$

$$y_0 = \frac{mg_0}{k}$$

$\vec{F}_g = -m g_0 \hat{e}_y$



$\vec{F}_v = -k y \hat{e}_y$

$\vec{F}_u$ .... sila upora

$\vec{F}_u = -\vec{c}\,\vec{v}$ (linearna sila upora) $v_y = \dot{y} = \frac{dy}{dt} \neq 0$

$c > 0$ sorazmerna z viskoznostjo tekočine in površino uteži

$\vec{F}_u = -c\dot{y}\hat{e}_y$

$\vec{F} = \vec{F}_g + \vec{F}_v + \vec{F}_u$

$\vec{F} = m \cdot \vec{a}$; $\vec{a} = \ddot{y}\hat{e}_y$

$$-c\dot{y}\hat{e}_y - ky\hat{e}_y - mg_0\hat{e}_y = m\ddot{y}\hat{e}_y$$

$$(\underbrace{\ddot{y} + \frac{c}{m}\dot{y} + \frac{k}{m}y + g_0}_{=0})\hat{e}_y = 0$$

Vpeljemo $\beta := \frac{c}{m}$ $[\beta] = s^{-1}$

$\omega_0^2 = \frac{k}{m}$ $[\omega_0^2] = s^{-2}$

$$\ddot{y} + \beta\dot{y} + \omega_0^2 y + g_0 = 0$$

$y_0 = \frac{mg_0}{k}$

$g_0 = \frac{y_0 k}{m} = y_0\omega^2$

$$\ddot{y} + \beta\dot{y} + \omega_0^2(y - y_0) = 0$$

$$\dot{y} + \beta y + \omega_0^2 y = \omega_0^2 y_0$$

- diferencialna enačba za y 2. reda
- linearna enačba
- konstantni koeficienti
- nehomogena (pogojno, ker jo lahko z lahkoto prevedemo v homogeno)

$y' := y - y_0$

$\dot{y}' = (\dot{y - y_0}) = \dot{y}$

$\ddot{y}' = \ddot{y}$

Dobimo: $\ddot{y}' + \beta\dot{y}' + \omega_0^2 y' = 0$

je homogena :)

$$\ddot{y}' + \beta \dot{y}' + \omega_0^2 y = 0$$

Nastavek: $y' = Ae^{\lambda t}$, A, λ konstanti

$[\lambda] = s^{-1}$

$[A] = m$

$\dot{y}' = \lambda y$

$\ddot{y}' = \lambda^2 y$

$$(\lambda^2 + \beta\lambda + \omega_0^2)\underset{\neq 0 \text{ ko } A \neq 0}{Ae^{\lambda t}} = 0 \quad \text{za } \forall t$$

$$\lambda^2 + \beta\lambda + \omega_0^2 = 0$$

$$D = \beta^2 - 4\omega_0^2 =: -4\omega^2$$

$$(\omega^2 := \omega_0^2 - (\tfrac{\beta}{2})^2)$$

$D < 0 \Rightarrow 4\omega^2 > 0$: podkritično dušenje

$$\sqrt{D} = \sqrt{-4\omega^2} = \sqrt{-1}\, 2\omega \quad ; \omega = +\sqrt{\omega^2}$$

$$\Rightarrow \lambda_{1,2} = \frac{-\beta \pm \sqrt{D}}{2} = \frac{-\beta}{2} \pm \omega i$$

$$y_1' = A_1 e^{\lambda_1 t} = A_1 \exp(-\tfrac{\beta}{2} + i\omega)t) =$$

$$= A_1 \exp(-\tfrac{\beta}{2}t)\exp(i\omega t)$$

$$y_2' = A_2 \exp\{-\tfrac{\beta}{2}t)\exp(-i\omega t)$$

$$\left.\begin{aligned} \ddot{y}_1' + \beta\dot{y}_1' + \omega_0^2 y_1' &= 0 \\ \ddot{y}_2' + \beta\dot{y}_2' + \omega_0^2 y' &= 0 \end{aligned}\right\} +$$

$$(\ddot{y}_1' + \ddot{y}_2') + \beta(\dot{y}_1' + \dot{y}_2') + \omega_0(y_1' - y') = 0$$

$$\Rightarrow y' = \exp\{-\tfrac{\beta}{2}t\}\left(A_1\exp(i\omega t) + A_2\exp\{-i\omega t\}\right)$$

Eulerjeva enačba

$$\exp\{\pm i\omega t\} = \cos\{\omega t\} \pm i\sin(\omega t)$$

$$\Rightarrow y' = \exp\{-\tfrac{\beta}{2}t\}\{(A_1 + A_2)\cos(\omega t) + i(A_1 - A_2)\sin\omega t$$

$$= e^{-\frac{\beta}{2}t}\left(B_1\cos(\omega t) + B_2\sin(\omega t)\right)$$

$$= B e^{-\frac{\beta}{2}t}\sin(\omega t + \delta)$$ ← Fazni zamik

$B > 0$; δ = fazni zamik

$$B e^{-\frac{\beta}{2}t}(\sin\omega t\sin\delta + \cos\omega t\sin\delta)$$

$$= e^{-\frac{\beta}{2}t}(B\sin\delta\cos(\omega t) + B\cos\omega t\sin\delta)$$

$$B_1 = B\sin\delta$$

$$B_2 = B\cos\delta$$

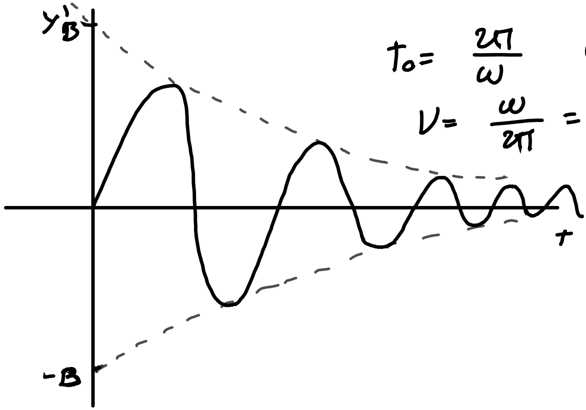
$$\tan\delta = \frac{B_1}{B_2}$$

$$B^2 = B_1^2 + B_2^2$$

$$B = \sqrt{B_1^2 + B_2^2}$$

Primer:

$$\delta = 0 \Rightarrow y' = B\, e^{-\frac{\beta}{2}t} \sin(\omega t)$$



$$t_0 = \frac{2\pi}{\omega} \qquad \omega = 2\pi\nu$$

$$\nu = \frac{\omega}{2\pi} = \frac{1}{t_0}$$

$\delta = \frac{\pi}{2}$

$$y'(t) = Be^{-\frac{\beta}{2}t} \sin\left(\omega t + \frac{\pi}{2}\right) = \sin\omega t \cos\frac{\pi}{2} + \cos\omega t \sin\frac{\pi}{2}$$

$$= Be^{-\frac{\beta}{2}t} \cos(\omega t)$$

$$\ddot{y}' + \beta \dot{y}' + \omega_0^2 y' = 0$$

$y' = y - y_0 \rightarrow$ odmik doremenjene vzmeti v ravnovesni legi

$\hookrightarrow$ odmik od konca neobremenjene vzmeti

$$\omega_0^2 = \frac{k}{m} \ (>0)$$

$$\beta \propto c \propto \eta$$

sorazmerno

Nastavek $y' = Ae^{\lambda t}$

$$\Rightarrow \lambda^2 + \beta\lambda + \omega_0^2 = 0$$

$$D = \beta^2 - 4\omega_0^2 = -4\omega^2 \qquad \omega^2 = \omega_0^2 - \left(\frac{\beta}{2}\right)^2$$

a) $D < 0 \Rightarrow (\omega^2 > 0)$

$$y' = Be^{-\frac{\beta}{2}t} \sin(\omega t + \delta) \ ; \ \omega = \sqrt{\omega^2} =$$

$$= \sqrt{\omega_0^2 - \left(\frac{\beta}{2}\right)^2}$$

Zelo šibko dušenje $\left(\frac{\beta}{2}\right)^2 \ll \omega_0 \Rightarrow$

$$t_0 = \frac{2\pi}{\sqrt{\omega_0^2}} = 2\pi\sqrt{\frac{m}{k}}$$

Primer:

$m = 500\,g = 0{,}5\,kg$

$k y_0 = -m g_0$

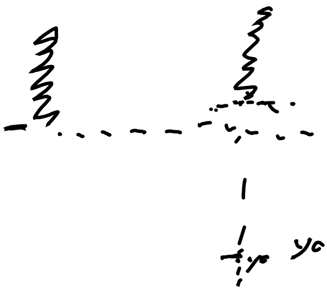
$$k = -\frac{m g_0}{y_0} \Rightarrow \frac{m}{k} = -\frac{y_0}{g_0}$$

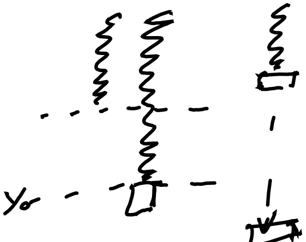
$y_0 = -0{,}4\ m$

$$\frac{m}{k} = \frac{0{,}4\,m}{10\,m/s^2} = 0{,}04\,s^2 =$$

$$\sqrt{\frac{m}{k}} = 2\cdot 10^{-1} = 0{,}2\,s$$

$$\Rightarrow t_0 = 2\pi\cdot 0{,}2\,s \cong 1{,}2\,s$$





B in δ dobimo iz začetnih pogojev

$$y' = B e^{-\frac{\beta}{2}t} \sin(\omega t + \delta)$$

$$\dot{y}' = -\frac{\beta}{2} B e^{-\frac{\beta}{2}t} \sin(\omega t + \delta) + \omega B e^{-\frac{\beta}{2}t} \cos(\omega t + \delta)$$

$$\dot{y}'(0) = -\frac{\beta}{2} B \sin\delta + \omega B \cos\delta =$$

$$= B\left(-\frac{\beta}{2}\sin\delta + \omega\cos\delta\right)$$

$$y'(0) = B\sin\delta$$

$$r = \frac{y'(0)}{\dot{y}'(0)} = \frac{\sin\delta}{\omega\cos\delta - \frac{\beta}{2}\sin\delta} = \frac{\tan\delta}{\omega - \frac{\beta}{2}\tan\delta}$$

$$\Rightarrow \delta = \arctan\left(\frac{r\omega}{1 + \frac{r\beta}{2}}\right)$$

$$\Rightarrow B = \frac{y'(0)}{\sin\delta}$$

$$\dot{y}'(0) = B\omega\sin\delta$$

$$\Rightarrow B = \frac{\dot{y}'(0)}{\pm\omega} = \frac{|\dot{y}'(0)|}{\omega}$$

Energija nihala

$$W_k = \frac{1}{2}mv^2 = \frac{1}{2}m\dot{y}^2$$

$$W_{pr} = \frac{1}{2}ky^2 = \frac{1}{2}k(y' + y_0)^2$$

$$W_p = mg_0(y' + y_0)$$

Skupna $\boxed{W = W_k + W_p + W_{pr}}$

a) W za zelo šibko dušenje ?

$$\frac{\beta}{2}t \ll 1$$

$$\left(\frac{\beta}{2}\right)^2 \ll \omega_0^2 \Rightarrow \omega \simeq \omega_0 = \sqrt{\frac{k}{m}}$$

$$y' = B\sin(\omega_0 t + \delta)$$

$$\dot{y}' = \omega_0 B\cos(\omega_0 t + \delta)$$

$$W_k = \frac{1}{2}m\omega_0^2 B^2\cos^2(\omega_0 t + \delta) =$$

$$= \frac{1}{2}\cancel{m}\frac{k}{\cancel{m}}B^2\cos^2(\omega_0 t + \delta)$$

$$W_{pr} = \frac{1}{2}kB^2\sin^2(\omega_0 t + \delta) + \frac{1}{2}ky_0^2 + ky_0 B\sin(\omega_0 t + \delta)$$

$$W_p = mg_0 B\sin(\omega_0 t + \delta) + mg_0 y_0$$

$$W = \frac{1}{2}kB^2\underbrace{\left(\sin^2(\omega_0 t + \delta) + \cos^2(\omega_0 t + \delta)\right)}_{1}$$

$$+ (ky_0 + mg_0)B\sin(\omega t + \delta) +$$

$$+ \frac{1}{2}ky_0^2 + mg_0 y_0$$

$$= \frac{1}{2}kB^2 + \frac{1}{2}ky_0^2 + mg_0 y_0 = \text{konst.}$$

b) kritično dušenje

$D = 0 \quad (\omega = 0)$ (kritično dušenje

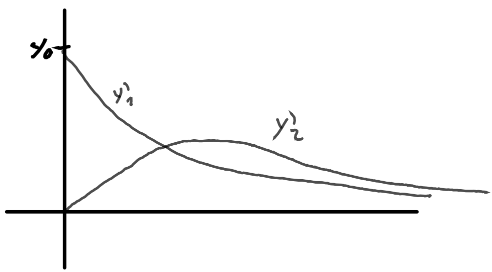
$D = \beta^2 - 4\omega_0^2 \Rightarrow \omega_0 = \frac{\beta}{2}$

$\lambda_{1,2} = \frac{-\beta \pm \sqrt{D}}{2} = -\frac{\beta}{2}$

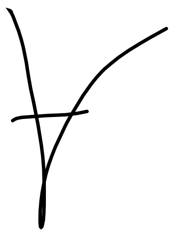
$\Rightarrow y_1' = B_1 e^{-\frac{\beta}{2}t}$

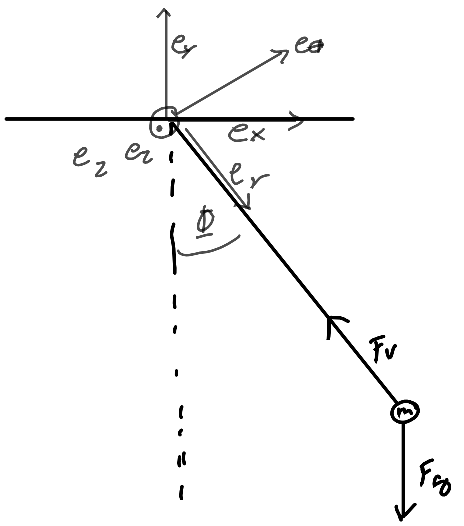
$y_2' = B_2 t e^{-\frac{\beta}{2}t}$ je tudi rešitev (DN)

$\Longrightarrow y' = y_1' + y_2' = (B_1 + Bt) e^{-\frac{\beta}{2}t}$



20.2





e_ϕ, e_z, e_r ... cilindrične koordinate

$$\vec{F} = \vec{F}_g + \vec{F}_v = m\vec{a}$$

$$F_g = -mg_0 \hat{e}_y$$

$$F_v = -F_v \hat{e}_r$$

$$\vec{r} = l \cdot \vec{e}_r$$

$$\vec{r} \times \vec{F} = l\vec{e}_r \times (-mg_0 \hat{e}_y - F_v \hat{e}_r) =$$

$$= -mg_0 l \, \hat{e}_r \times \hat{e}_y - \underbrace{lF_v \, \hat{e}_r \times \vec{e}_r}_{=0}$$

$$= -mg_0 l \hat{e}_r \times (\hat{e}_r \cos\phi + \hat{e}_\phi \sin\phi)$$

$$= -mg_0 l \sin\Phi \, \hat{e}_r \times \hat{e}_\phi =$$

$$= -mg_0 l \sin\Phi \, \hat{e}_z$$

$$\vec{r} \times \vec{F} = m \cdot \vec{r} \times \vec{a} = m \cdot l \hat{e}_r \times (a \hat{e}_\phi) =$$

$$\vec{a} = a \cdot e_\Phi \qquad = mal \, \hat{e}_z$$

$$a = a_t = l\ddot{\Phi}$$

$$mg_0 l \sin\phi \, e_z = m l \ddot{\Phi} e_z$$

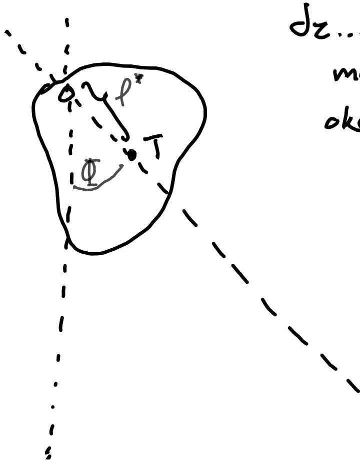
$$ml(l\ddot{\Phi} + g_0 \sin\Phi) e_z = 0 \quad (e_z \neq \vec{0})$$

$$-l\ddot{\Phi} = g_0 \sin\Phi$$

$$\ddot{\Phi} + \frac{g_0}{l} \sin\Phi = 0$$

$$\approx \ddot{\Phi} + \underbrace{\frac{g_0}{l}}_{\omega_0^2} \Phi = 0$$

$$\ddot{\Phi} + \omega_0^2 \Phi = 0$$



J_z.... vstrajnostni moment za vrtenje okrog fiksne osi

primer: palica

$J_z = \frac{1}{3} m l^2 \quad l^* = \frac{l}{2}$

$\sin\Phi \approx \Phi$

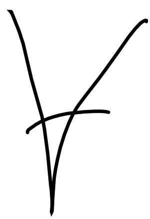
$\Rightarrow \ddot{\Phi} + \omega_0^2 \Phi = 0$

$$\omega_0^2 = \frac{m g l^*}{J_z} = \frac{3 m g l}{2 m l^2} = \frac{3}{2}\frac{g_0}{l}$$

Nihalo:

$J_z = m l^2 \quad l^* = l$

$$\omega_0^2 = \frac{m g_0 l}{m l^2} = \frac{g_0}{l}$$



21.2

Nismë e shkele

$F = F_0 \sin(\omega_v t)$ $\qquad \omega_v = 2\pi\nu_v$

$$\ddot{y}' + \beta\dot{y}' + \omega_0^2 y' = \frac{F_0}{m}\sin(\omega_v t)$$

$\omega_0^2 = \frac{k}{m}$ $\qquad \beta = \frac{C}{m}$ $\qquad y' = y - y_0$ raztezek ko je obtežena vzmet mirna

$y' = y'_h + y'_p$ ← partikularna rešitev

homogena

$$y'_p = B\sin(\omega t - \delta_p)$$

$$B_p\{(\omega_0^2-\omega_v^2)[\cos\delta_p \sin(\omega_v t) - \sin\delta_p \sin(\omega_v t)]$$
$$+\, \omega_v\beta[\cos\delta_p\cos(\omega_v t) + \sin\delta_p\sin(\omega_v t)]\}$$
$$= \frac{F_0}{m}\sin(\omega_v t) \quad \text{za } \forall t$$

a) $t_1 = 0 \Rightarrow \sin\omega_v t = 0$, $\cos\omega_v t = 1$

$$B_p\{-(\omega_0^2-\omega_v^2)\sin\delta_p + \omega_v\beta\cos\delta_p\} = 0$$

$$\Rightarrow \tan\delta_p = \frac{\omega_v\beta}{\omega_0^2-\omega_v^2}$$

$$\cos\delta_p = \pm\frac{(\omega_0^2-\omega_v^2)}{\sqrt{(\omega_0^2-\omega_v^2)^2+\omega_v^2\beta^2}}$$

$$\sin\delta_p = \pm\frac{\omega_v\beta}{\sqrt{\quad}}$$

$\omega_v \to 0 \Rightarrow \tan\delta_p \to +0 \Rightarrow \delta_p \to 0$

$\omega_v \to \uparrow\omega_0 \Rightarrow \tan\delta_p \to +\infty \Rightarrow \delta_p \to \uparrow\frac{\pi}{2}$

$\omega_v \to \downarrow\omega_0 \Rightarrow \tan\delta_p \to -\infty \Rightarrow \delta_p \to \downarrow\frac{\pi}{2}$

$\omega_v \to \infty \Rightarrow \tan\delta_p \to -0 \Rightarrow \delta_p \to \pi$

$\omega_v \to 0 \Rightarrow \delta_p \to 0 \Rightarrow \cos\delta_p \to +1$

$\cos\delta_p \to \frac{\pm\omega_0^2}{\sqrt{\omega_0^4}} = \pm 1$ očitno mora biti +

b) $t_2 = \frac{\pi}{2\omega_v} \Rightarrow \omega_v t_2 = \frac{\pi}{2} \Rightarrow \sin(\omega_v t) = 1$

$\cos(\omega_v t) = 0$

$$B_p\{(\omega_0^2-\omega_v^2)\cos\delta_p + \omega_v\beta\sin\delta_p\} = \frac{F_0}{m}$$

$$B_p\left\{\frac{(\omega_0^2-\omega_v^2)^2+\omega_v^2\beta^2}{\sqrt{(\omega_0^2-\omega_v^2)^2+\omega_v^2\beta}}\right\} = \frac{F_0}{m}$$

$$\Rightarrow B_p = \frac{F_0}{m}\cdot\frac{1}{\sqrt{(\omega_0^2-\omega_v^2)^2+\omega_v^2\beta^2}}$$

$\omega_v \to 0 \Rightarrow B_p \to \frac{F_0}{m}\cdot\frac{1}{\omega_0^2} = \frac{F_0 \cdot m}{m \cdot k} = \frac{F_0}{k}$

$\omega_v \to \infty \Rightarrow B_p \to 0$

$B_p(\omega_v) = max$

Kdaj dosežen maksimum?
Takrat kadar je v resonanci?

Ko je imenovalec najmanjši

$(\omega_0^2 - \omega_v^2)^2 + \beta^2 \omega_v^2$ je najmanjši

$$\frac{d}{d\omega_v}\left((\omega_0^2-\omega_v^2)^2 + \beta^2\omega_v^2\right) = 0$$

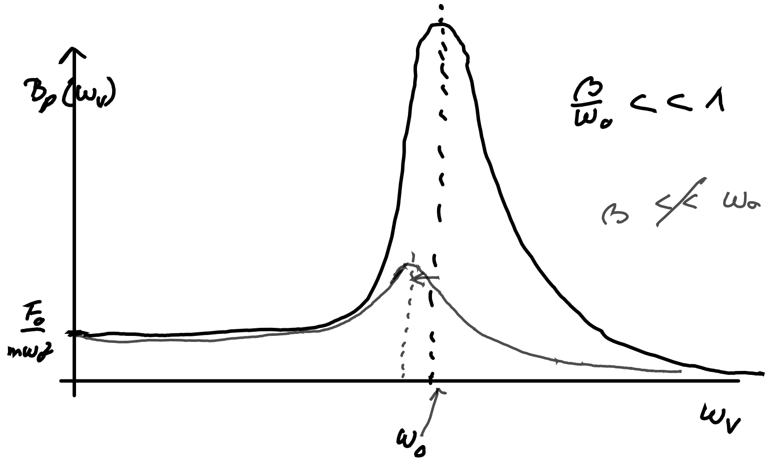
$$2(\omega_0^2 - \omega_v^2)(-2\omega_v) + 2\omega_v\beta^2 = 0$$

$$-2(\omega_0^2 - \omega_v) + \beta^2 = 0$$

$$\omega_v^2 = \omega_0^2 - \frac{\beta^2}{2}$$

$$\omega_v = +\sqrt{\omega_0^2 - \frac{\beta^2}{2}} = \omega_0\sqrt{1 - \frac{\beta^2}{2\omega_0^2}}$$

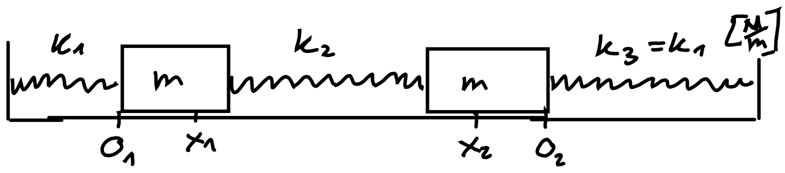
$$\beta << \omega_0 \Rightarrow \omega_v = \omega_0$$



$B_p(\omega_v)$
$\frac{F_0}{m\omega_0^2}$
$\frac{\beta}{\omega_0} << 1$
$\beta \not\ll \omega_0$
ω_0
ω_v

Sklopljeno nihanje

- $\beta \longrightarrow 0$ dušenje pošljemo proti 0
- za začetek: simetrični primer



"z drugo vzmetjo, ki ji bomo rekli tretja vzmet

$\vec{F}_{1\to 1,r}$ ... sila prve vzmeti na prvi voziček ko je v ravnovesni legi

$$\vec{F}_{1\to 1,r} = -k_1 \Delta l_{1,r}\hat{e}_x$$
$$\vec{F}_{2\to 1,r} = +k_2 \Delta l_{2,r}\hat{e}_x$$
} + = 0

v ravnovesju

$$F_{2\to 2,r} = -k_2 \Delta l_{2,r}\hat{e}_x$$
$$F_{3\to 2,r} = +\underset{k_3}{k_1} \Delta l_{3,r}\hat{e}_x$$
} + = 0

$$\vec{F}_{1\to 1} = \vec{F}_{1\to 1,r} - k_1 x_1 \hat{e}_x$$
$$\vec{F}_{2\to 1} = \vec{F}_{2\to 1,r} - k_2(x_1 - x_2)\hat{e}_x$$
$$\vec{F}_{2\to 2} = \vec{F}_{2\to 2,r} + k_2(x_1 - x_2)\hat{e}_x$$
$$\vec{F}_{3\to 2} = \vec{F}_{3\to 2,r} - k_1 x_2 \hat{e}_x$$
$$\vec{F}_{1\to 1} + \vec{F}_{2\to 1} = m\ddot{x}_1\hat{e}_x$$
$$\cancel{F_{1\to 1,r}} - k_1 x_1 \hat{e}_x + \cancel{F_{2\to 1,r}} - k_2(x_1 - x_2)\hat{e}_x = $$
$$= m\ddot{x}_1\hat{e}_x$$

$$m\ddot{x}_1 + k_1 x_1 + k_2(x_1 - x_2) = 0$$
$$\ddot{x}_1 + \omega_1^2 x_1 + \omega_2^2(x_1 - x_2) = 0$$
$$\omega_1^2 = \frac{k_1}{m} \qquad \omega_2^2 = \frac{k_2}{m}$$

Zelo podobno $\ddot{x}_2 + \omega_1^2 x_2 - \omega_2^2(x_1 - x_2) =$

$$x_a = x_1 + x_2$$
$$x_b = x_1 - x_2$$
$$\Rightarrow x_1 = \frac{x_a + x_b}{2} \qquad x_2 = \frac{x_a - x_b}{2}$$

seštejemo enačbi

$$\ddot{x}_1 + \ddot{x}_2 + \omega_1^2 x_1 + \omega_1^2 x_2 = 0$$
$$(\ddot{x_1 + x_2}) + \omega_1^2(x_1 + x_2) = 0$$
$$\ddot{x}_a + \omega_a^2 x_a = 0$$
$$\ddot{x}_b + \omega_b^2 x_b = 0$$

$\omega_a = \omega_1$
$\omega_b = \sqrt{\omega_1^2 + 2\omega_2^2}$

$$x_a = B_a \sin(\omega_a t + \delta_a)$$
$$x_b = B_b \sin(\omega_b t + \delta_b)$$

$$\Rightarrow x_1 = \underbrace{\frac{B_a}{2}}_{B_1}\sin(\omega_a t + \delta_a) + \underbrace{\frac{B_b}{2}}_{B_2}\sin(\omega_b t + \delta_b)$$

$$x_2 = B_1\sin(\omega_a t + \delta_a) - B_2 \sin(\omega_b t + \delta_b)$$

$B_1, B_2, \delta_a, \delta_b = ?$

začetni pogoji: $x_1(t=0)$ $\dot{x}_1(t=0)$
$x_2(t=0)$ $\dot{x}_2(t=0)$

iz tega izvemo

Primer

$x_1(t=0)=x_0 \quad (>0) \qquad \dot{x}_1(t=0)=0$

$x_2(t=0)=0 \qquad \dot{x}_2(t=0)=0$

$$\dot{x}_1 = B_1\omega_a\cos(\omega_a t+\delta_a)+B_2\omega_b\cos(\omega_b t+\delta_b)$$

$$x_2 = B_1\omega_a\cos(\omega_a t+\delta_a)-B_2\omega_b\cos(\omega_b t+\delta_b)$$

$$\left.\begin{aligned} x_0 &= B_1\sin\delta_a + B_2\sin(\delta_b) \\ 0 &= B_1\sin\delta_a - B_2\sin\delta_b \end{aligned}\right\} +,\ -$$

$$\left.\begin{aligned} 0 &= B_1\omega_a\cos(\delta_a)+B_2\omega_b\cos(\delta_b) \\ 0 &= B_1\omega_a\cos(\delta_a)-B_2\omega_b\cos(\delta_b) \end{aligned}\right\} +,\ -$$

$$x_0 = 2B_1\sin\delta_a = 2B_2\sin\delta_B$$

$$2B_1\omega_a\cos\delta_a = 0 \Rightarrow \cos\delta_a = 0$$

$$\delta_a = \pm\frac{\pi}{2}$$

$$\Rightarrow \quad B_1 = B_2 = \frac{x_0}{2} \qquad \Rightarrow \quad \delta_b = +\frac{\pi}{2}$$

7.3

mentalna
odsotna

lastna nihanja sestavljenega nihala

$$x_1 = B\sin(\omega_a t + \delta_a) + B_2 \sin(\omega_b t + \delta_b)$$
$$x_2 = \ldots$$

$$\begin{cases} x_1 = B_1 \sin(\omega_i t + \delta_1) \\ x_2 = B_2 \sin(\omega_i t + \delta_2) \end{cases}$$

$$\ddot{x}_1 + \omega_1^2 x_1 + \omega_2^2 (x_1 - x_2) = 0$$
$$\ddot{x}_2 + \omega_2^2 x_2 - \omega_2^2 (x_1 - x_2) = 0$$