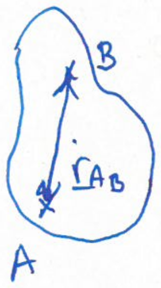
Dinamika 2. gyakorlat

Merev testek kinematikája

Elméleti összefoglaló



merev test, ha $|r_{AB}|$ = áll

Sebességáll.:

$[\underline{\omega}, v_A]_A$

$$\boxed{\underline{v}_B = \underline{v}_A + \underline{\omega} \times \underline{r}_{AB}}$$

$$\boxed{\underline{a}_B = \underline{a}_A + \underline{\varepsilon} \times \underline{r}_{AB} + \underline{\omega} \times (\underline{\omega} \times \underline{r}_{AB})}$$

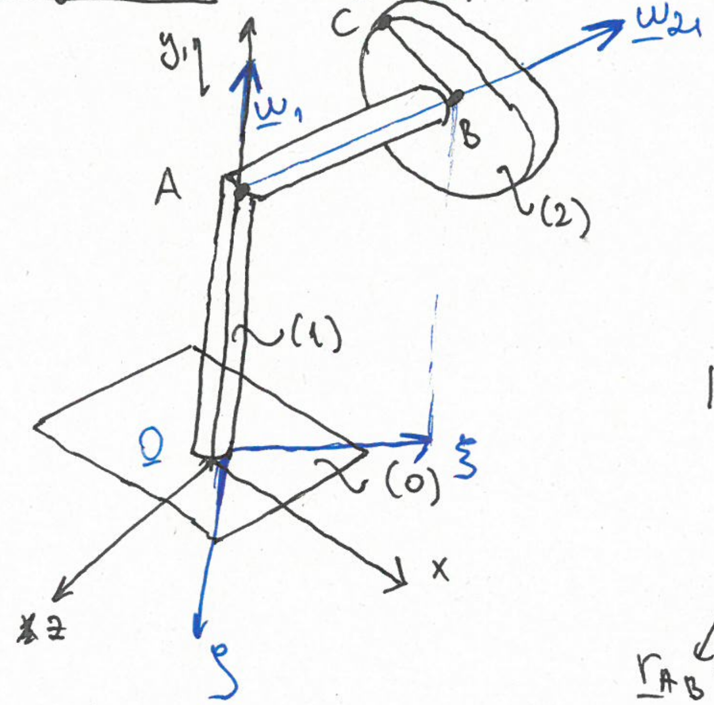
$\underline{\varepsilon}$ - szöggyorsulás

$\underline{\omega}$ - szögsebesség

$\Rightarrow \boxed{\underline{\varepsilon} = \dot{\underline{\omega}}}$

1. feladat

Robotkar



Adatok:

$\underline{\omega}_1 = \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}$ [rad/s] = áll

$|\underline{\omega}_{21}| = 2$ [rad/s] = áll

↳ A „2" es test „1"-hez viszonyított szögsebessége

$t_0 = 0$ s-ban!

$\underline{r}_{AB} = \begin{bmatrix} 0{,}8 \\ 0{,}6 \\ 0 \end{bmatrix}$ [m]

$r_{BC}(t_0 = 0) = \begin{bmatrix} -0{,}3 \\ 0{,}4 \\ 0 \end{bmatrix}$ [m]

Kérdések:

$\underline{v}_C(t_0 = 0) = ?$; $\underline{a}_C(t_0 = 0) = ?$

Koordináta rendszerek:

„0"-hoz kötött $\{x, y, z, \underline{O}\}$

„1"-hez kötött $\{\xi, \eta, \zeta, \underline{\Omega}\}$

↙

együtt forog az „1"es rúddal

A mi esetünkben

$\underline{O} = \underline{\Omega}$

$$\underline{\omega}_1 = \begin{bmatrix} 0 \\ \omega_1 \\ 0 \end{bmatrix} \qquad \underline{\omega}_{21} = \omega_{21} \cdot \underline{e} = \omega_{21} \cdot \frac{\underline{r}_{AB}}{|\underline{r}_{AB}|} = 2 \cdot \begin{bmatrix} 0{,}8 \\ 0{,}6 \end{bmatrix} = \begin{bmatrix} 1{,}6 \\ 1{,}2 \end{bmatrix} \left[\frac{rad}{s}\right]$$

Először a „B" pont sebességét tudjuk számolni

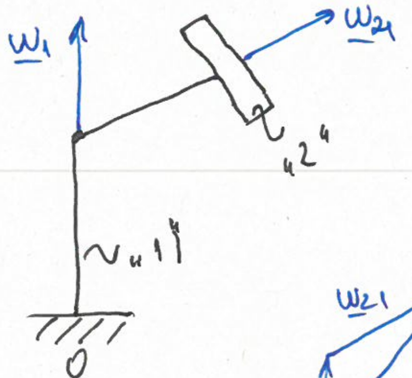
$$\underline{v}_B = \underline{v}_A + \underline{\omega}_1 \times \underline{r}_{AB} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix} \times \begin{bmatrix} 0{,}8 \\ 0{,}6 \\ 0 \end{bmatrix} = \begin{vmatrix} i & j & k \\ 0 & 1 & 0 \\ 0{,}8 & 0{,}6 & 0 \end{vmatrix} =$$

$$\underline{v}_B = \begin{bmatrix} 0 \\ 0 \\ -0{,}8 \end{bmatrix} \left[\frac{m}{s}\right] \qquad \left(\begin{vmatrix} i & j & k \\ 0 & \omega_1 & 0 \\ r_{ABx} & r_{ABy} & 0 \end{vmatrix} = \begin{bmatrix} 0 \\ 0 \\ -r_{ABx}\,\omega_1 \end{bmatrix} \right)$$

Ha ki akarjuk számolni $\underline{v}_C$-t

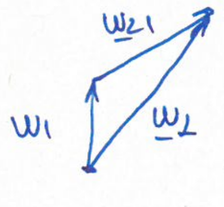
$$\underline{v}_C = \underline{v}_B + \underline{\omega}_2 \times \underline{r}_{BC}$$

↳ a 2es test „0"-hoz vett szögsebessége

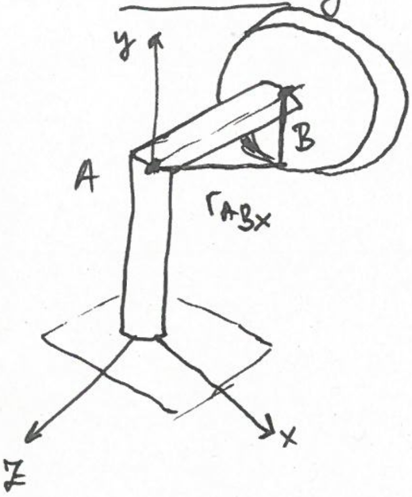


⇒ A szögsebességvektorok összeadhatóak:

$$\underline{\omega}_2 = \underline{\omega}_{21} + \underline{\omega}_{21} = \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix} + \begin{bmatrix} 1{,}6 \\ 1{,}2 \\ 0 \end{bmatrix} = \begin{bmatrix} 1{,}6 \\ 2{,}2 \\ 0 \end{bmatrix} \left[\frac{rad}{s}\right]$$



Érdekesség



A „B" pont $r_{ABx} = 0,8\,[m]$ sugarú körön mozog

↓ A sebessége érintőirányú

⇓ $-\underline{k}$ irányú

$$v_B = \omega_1 r_{ABx} = 0,8 \left[\frac{m}{s}\right] \rightarrow \underline{v_B} = \begin{bmatrix} 0 \\ 0 \\ -0,8 \end{bmatrix} \frac{m}{s}$$

Most már számolható $\underline{v_C}$

$$\underline{v_C} = \underline{v_B} + \underline{\omega_2} \times \underline{r_{BC}} = \begin{bmatrix} 0 \\ 0 \\ v_B \end{bmatrix} + \begin{vmatrix} \underline{i} & \underline{j} & \underline{k} \\ \omega_{2x} & \omega_{2y} & 0 \\ r_{BCx} & r_{BCy} & 0 \end{vmatrix} = \begin{bmatrix} 0 \\ 0 \\ v_B + \omega_{2x} r_{BCy} - \omega_{2y} r_{BCx} \end{bmatrix}$$

$$= \begin{bmatrix} 0 \\ 0 \\ -0,8 + 1,6 \cdot (-0,1) - 2,2 \cdot (-0,3) \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0,5 \end{bmatrix} \left[\frac{m}{s}\right]$$

$\underline{a}_C$ gyorsulás számítása

↳ „2es" testen $\underline{a}_C \rightarrow \underline{a}_B$-re van szükség!

$$\underline{a}_B = \underbrace{\underline{a}_A}_{\underline{0}} + \underbrace{\underline{\varepsilon}_1 \times \underline{r}_{AB}}_{\underline{0}} + \underline{\omega} \times (\underline{\omega} \times \underline{r}_{AB}) =$$

$\underline{\varepsilon}_1 = \dot{\underline{\omega}}_1 = 0$

↳ mert állandó

$$= \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix} \times \begin{bmatrix} 0 \\ 0 \\ -0,8 \end{bmatrix} = \begin{vmatrix} \underline{i} & \underline{j} & \underline{k} \\ 0 & 1 & 0 \\ 0 & 0 & -0,8 \end{vmatrix} = \begin{bmatrix} -0,8 \\ 0 \\ 0 \end{bmatrix} \left[\frac{m}{s^2}\right]$$

Másik úton

A „B" pont állandó sebességgel körpályán mozog

$$\underline{a}_B = \underbrace{\underline{a}_{Bt}}_{=0\,!!} + \underline{a}_{Bn} = a_{Bn}\cdot \underbrace{\underline{e}_n}_{=\boxed{-\underline{i}}}$$

$$a_{Bn} = \frac{v_B^2}{\rho_B} = \frac{v_B^2}{r_{ABx}} = \frac{r_{ABx}^2\,\omega_1^2}{r_{ABx}} = \underline{\underline{r_{ABx}\,\omega_1^2}} = 0{,}8\ \frac{m}{s^2}$$

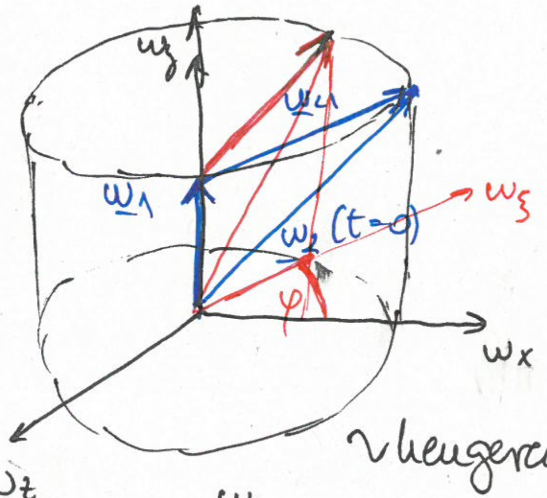
$$\underline{a}_B = a_{Bn}\cdot(-\underline{i}) = \underline{\underline{\begin{bmatrix}-0{,}8\\0\\0\end{bmatrix}\frac{m}{s^2}}}$$

Most számolhatjuk $\underline{a}_C$-t

$$\underline{a}_C = \underline{a}_B + \underbrace{\underline{\varepsilon}_2}_{\text{ismeretlen}}\times r_{BC} + \underline{\omega}_2\times(\underline{\omega}_2\times \underline{r}_{BC})$$

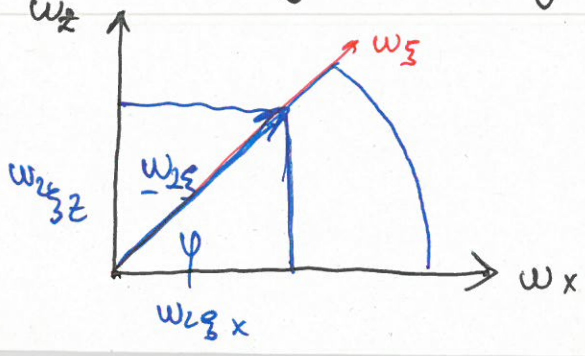
$$\underline{\varepsilon}_2 = \dot{\underline{\omega}}_2 = (\omega_1 + \omega_{21})^{\cdot} = \underbrace{\dot{\underline{\omega}}_1}_{=0} + \dot{\omega}_{21}$$

↳ ennek a hossza nem változik csak az iránya



Az „1"-es test elforog

hengeren mozognak a pontok



$$|\underline{\omega}_{2\xi}| = |\underline{\omega}_{2\xi}(t_0)| = |\underline{\omega}_{21x}(t_0)| = 1{,}6\left[\frac{rad}{s}\right]$$

$$\underline{\omega}_2(t) = \begin{bmatrix} \omega_{2\xi x}(t) \\ \omega_1 + \omega_{21y} \\ \omega_{2\xi z}(t) \end{bmatrix}$$

Az y irányú szögsebesség állandóak

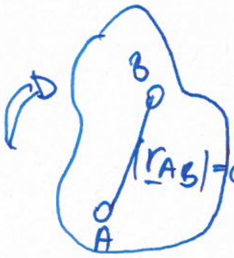
$$\boxed{\varphi = \omega_1 \cdot t}$$

$$\underline{\omega}_2(t) = \begin{bmatrix} \omega_{2t_0} \cdot \cos(\omega_1 t) \\ \omega_1 + \omega_{21y} \\ -\omega_{2t_0} \cdot \sin(\omega_1 t) \end{bmatrix} \rightarrow \underline{\varepsilon}_2 = \dot{\underline{\omega}}_2$$

$$\underline{\varepsilon}_2 = \begin{bmatrix} \omega_{2t_0} \cdot (-\sin(\omega_1 t) \cdot \omega_1) \\ 0 \\ -\omega_{2t_0} \cos(\omega_1 t) \cdot \omega_1 \end{bmatrix} \Rightarrow \underline{\varepsilon}_2(t_0 = 0) = \begin{bmatrix} 0 \\ 0 \\ -\omega_1 \cdot \omega_{2t_0} \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ -1{,}6 \end{bmatrix} \left[\frac{rad}{s^2}\right]$$

Másik megközelítés:

$|r_{AB}| = áll$ de forog.



$|r_{AB}| = áll$ $\quad \dot{r}_{AB} = \underline{v}_{AB} = \underline{v}_B - \underline{v}_A = \underline{\omega} \times \underline{r}_{AB}$

Nálunk

$|\underline{\omega}_2| = áll$ de forog $\underline{\omega}_1$ szögsebességgel

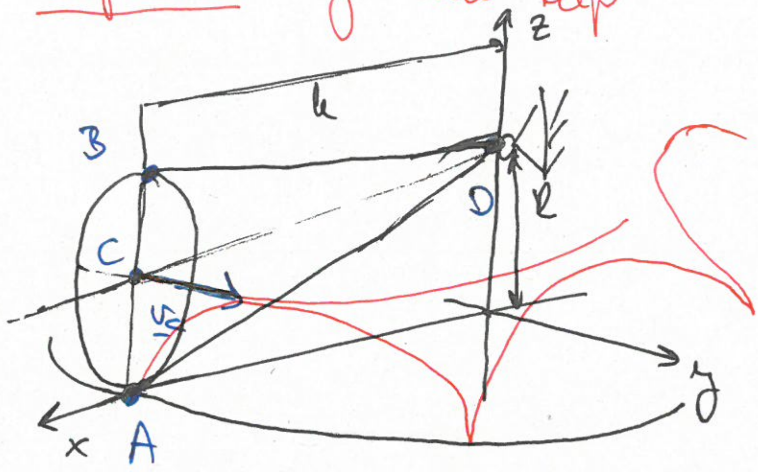
$$\underline{\varepsilon}_2 = \dot{\underline{\omega}}_2 = \dot{\underline{\omega}}_{21} = \underline{\omega}_1 \times \underline{\omega}_{21} = \begin{vmatrix} i & j & k \\ 0 & \omega_1 & 0 \\ \omega_{21x} & \omega_{21y} & 0 \end{vmatrix} = \begin{bmatrix} 0 \\ 0 \\ -\omega_1 \omega_{21x} \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ -1{,}6 \end{bmatrix} \left[\frac{rad}{s^2}\right]$$

Ezzel a_C számolható

$$\underline{a}_C = \underline{a}_B + \underline{\varepsilon}_2 \times \underline{r}_{BC} + \underline{\omega}_2 \times (\underline{\omega}_2 \times \underline{r}_{BC})$$

$$\begin{bmatrix} -0{,}8 \\ 0 \\ 0 \end{bmatrix} + \begin{vmatrix} i & j & k \\ 0 & 0 & -1{,}6 \\ -0{,}3 & 0{,}4 & 0 \end{vmatrix} + \begin{vmatrix} i & j & k \\ 1{,}6 & 2{,}2 & 0 \\ 0 & 0 & 1{,}3 \end{vmatrix} = \begin{bmatrix} -0{,}8 + 0{,}64 + 2{,}86 \\ 0 + 0{,}48 - 2{,}08 \\ 0 \end{bmatrix} = \begin{bmatrix} 2{,}7 \\ -1{,}6 \\ 0 \end{bmatrix} \left(\frac{m}{s^2}\right)$$

2. példa Gördülő kúp



Adatok:

$|\underline{v}_C| = v_C = 10 \left[\frac{m}{s}\right] = \text{áll}$

$r = 2\,[m]$

$h = 4\,[m]$

A kúp tengelye ∥ x tengellyel

Kérdés t_0-ban

$\underline{\omega},\ \underline{\varepsilon},\ \underline{v}_B,\ \underline{a}_B,\ \underline{a}_A$

Hogyan fog mozog C pont

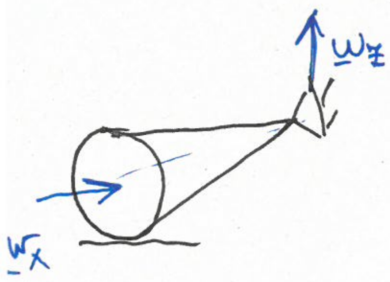
↳ köríven ⇒ ∀ ρ_C sugarú körpályán

Hogyan mozog az A pont $\overline{DA} = \text{áll} = \sqrt{r^2 + h^2}$ ⇒ gömbre írt általános pálya

gördülő kerék általános

Szögsebesség:

$\underline{v}_C = v_C \cdot \underline{j} = \begin{bmatrix} 0 \\ 10 \\ 0 \end{bmatrix} \left[\frac{m}{s}\right]$ $\quad \underline{r}_{DC} = \begin{bmatrix} h \\ 0 \\ 0 \end{bmatrix}$



$\underline{\omega} = \begin{bmatrix} -\omega_x \\ 0 \\ \omega_z \end{bmatrix}$

↳ A pillanatnyi forgástengely AD egyenes

$\underline{\omega} \parallel \underline{r}_{AD} \Rightarrow \underline{\omega} = \omega \cdot \underline{e}_{AD}$

$$\underline{v}_C = \underset{\underset{\underline{0}}{\shortparallel}}{\underline{v}_D} + \underline{\omega} \times \underline{r}_{DC} = \begin{vmatrix} \underline{i} & \underline{j} & \underline{k} \\ \omega_x & 0 & \omega_z \\ h & 0 & 0 \end{vmatrix} = \begin{bmatrix} 0 \\ \omega_z \cdot h \\ 0 \end{bmatrix}$$

a gördülés miatt

$$\underline{v}_C = \begin{bmatrix} 0 \\ v_C \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ \omega_z \cdot h \\ 0 \end{bmatrix} \rightarrow \omega_z = \frac{v_C}{h} = \underline{\underline{2,5 \left[\frac{rad}{s}\right]}}$$

$$\underline{v}_C = \underset{=\underline{0}}{\underline{v}_A} + \underline{\omega} \times \underline{r}_{AC} = \begin{vmatrix} \underline{i} & \underline{j} & \underline{k} \\ -\omega_x & 0 & \omega_z \\ 0 & 0 & \ell \end{vmatrix} = \begin{bmatrix} 0 \\ \omega_x \ell \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ v_C \\ 0 \end{bmatrix}$$

$$\omega_x = \frac{v_C}{\ell} = 5 \left[\frac{rad}{s}\right]$$

$$\underline{\omega} = \begin{bmatrix} -\omega_x \\ 0 \\ \omega_z \end{bmatrix} = \underline{\underline{\begin{bmatrix} -5 \\ 0 \\ 2,5 \end{bmatrix} \left[\frac{rad}{s}\right]}}$$

<u>Szöggyorsulás</u>

$$\underline{a}_C = \underset{\underset{\underline{0}}{\shortparallel}}{\underline{a}_{Ct}} + \underline{a}_{Cn} = \frac{v_C^2}{\rho_C} \cdot \underline{e}_n = \frac{v_C^2}{h} (-\underline{i}) = \underline{\underline{\begin{bmatrix} -25 \\ 0 \\ 0 \end{bmatrix} \left[\frac{m}{s^2}\right]}}$$

ment állandó sebességgel forog

Másik lehetőség:

$$\underline{a}_C = \underset{=\underline{0}}{\underline{a}_D} + \underline{\varepsilon} \times \underline{r}_{DC} + \underline{\omega} \times \overbrace{(\underline{\omega} \times \underline{r}_{DC})}^{v_C} = \begin{vmatrix} \underline{i} & \underline{j} & \underline{k} \\ \varepsilon_x & \varepsilon_y & \varepsilon_z \\ h & 0 & 0 \end{vmatrix} + \begin{vmatrix} \underline{i} & \underline{j} & \underline{k} \\ \omega_x & 0 & \omega_z \\ 0 & v_C & 0 \end{vmatrix}$$

$$\underline{a}_C = \begin{bmatrix} 0 & -\omega_z v_C \\ h\,\varepsilon_z & 0 \\ -h\,\varepsilon_y & -\omega_x v_C \end{bmatrix}$$

Összesítve:

$$\begin{bmatrix} -25 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} a_{Cn} \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} -\frac{v_C^2}{h} \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} -\omega_z v_C \\ h\,\varepsilon_z \\ -\varepsilon_y \cdot h - \omega_x v_C \end{bmatrix}$$

$$\Rightarrow \varepsilon_z = 0 \left[\frac{rad}{s^2}\right]$$

$$\Rightarrow \varepsilon_y = \frac{-\omega_x v_C}{h} = -12{,}5 \left[\frac{rad}{s^2}\right]$$

Hasonlóan

$$\underline{a}_A = \underset{\underline{0}}{\underset{\parallel}{\underline{a}_D}} + \underline{\varepsilon} \times \underline{r}_{DA} + \underline{\omega} \times \underbrace{(\underline{\omega} \times \underline{r}_{DA})}_{\underline{\omega} \parallel r_{DA} \Rightarrow = \underline{0}} = \begin{vmatrix} i & j & k \\ \varepsilon_x & \varepsilon_y & \varepsilon_z \\ h & 0 & -R \end{vmatrix} = \begin{bmatrix} -R\,\varepsilon_y \\ h\,\varepsilon_z + R\,\varepsilon_x \\ -h\,\varepsilon_y \end{bmatrix}$$

$$\Downarrow$$

$$\underline{a}_A = \begin{bmatrix} a_{Ax} \\ a_{Ay} \\ a_{Az} \end{bmatrix} = \begin{bmatrix} -R\,\varepsilon_y \\ h\,\varepsilon_z + R\,\varepsilon_x \\ -h\,\varepsilon_y \end{bmatrix}$$

$\rightarrow a_{Ax} = 25 \left[\frac{m}{s^2}\right]$

$\rightarrow 0 = 0 + R\,\varepsilon_x \rightarrow \varepsilon_x = 0 \left[\frac{rad}{s^2}\right]$

$a_{Ay} = 0$ a gördülés miatt

$\rightarrow a_{Az} = -h \cdot \varepsilon_y = 50 \left[\frac{m}{s^2}\right]$

$$\underline{a}_A = \begin{bmatrix} 25 \\ 0 \\ 50 \end{bmatrix} \left[\frac{m}{s^2}\right] \;; \quad \underline{\varepsilon} = \begin{bmatrix} 0 \\ -12{,}5 \\ 0 \end{bmatrix} \left[\frac{rad}{s^2}\right]$$

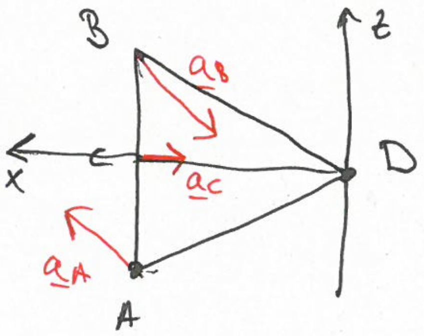
Ami kell még $\underline{v}_B$; $\underline{a}_A$

$$\hookrightarrow \underline{v}_B = \underset{\underset{\underline{0}}{\parallel}}{\underline{v}_A} + \underline{\omega} \times \underline{r}_{AB} = \underline{\omega} \times 2\underline{r}_{AC} = 2(\overbrace{\underline{\omega} \times \underline{r}_{AC}}^{v_C}) = \begin{bmatrix} 0 \\ 20 \\ 0 \end{bmatrix} \left[\frac{m}{s}\right]$$

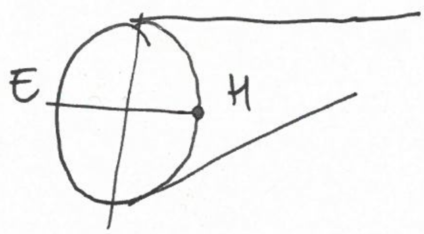
$$\hookrightarrow \underline{a}_B = \underline{a}_C + \underline{\varepsilon} \times \underline{r}_{CB} + \underline{\omega} \times (\overbrace{\underline{\omega} \times \underline{r}_{CB}}^{v_C}) =$$

$$= \begin{bmatrix} a_{Cn} \\ 0 \\ 0 \end{bmatrix} + \begin{vmatrix} i & j & k \\ 0 & \varepsilon_y & 0 \\ 0 & 0 & r \end{vmatrix} + \begin{vmatrix} i & j & k \\ -\omega_x & 0 & \omega_z \\ 0 & v_C & 0 \end{vmatrix} =$$

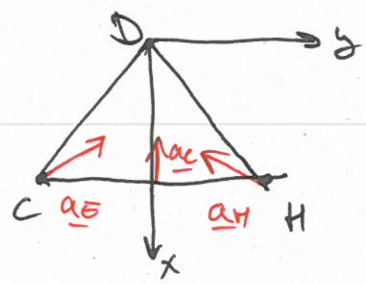
$$= \begin{bmatrix} a_{Cn} + \varepsilon_y r - \omega_z v_C \\ 0 + 0 + 0 \\ 0 + 0 - \omega_x v_C \end{bmatrix} = \underline{\underline{\begin{bmatrix} -75 \\ 0 \\ -50 \end{bmatrix} \left[\frac{m}{s^2}\right]}}$$



Hasonlóan



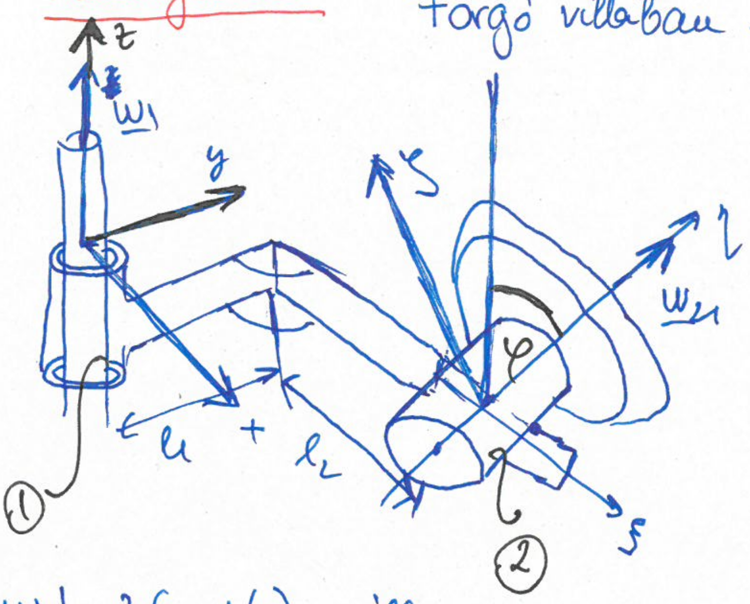
$$\underline{a}_E = \begin{bmatrix} -25 \\ 6,25 \\ 0 \end{bmatrix} \left[\frac{m}{s^2}\right]$$

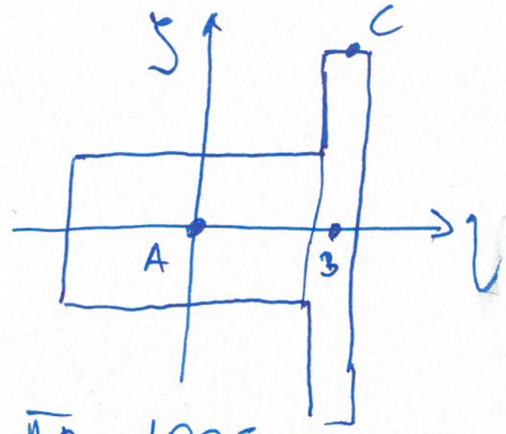


$$\underline{a}_H = \begin{bmatrix} -25 \\ -6,25 \\ 0 \end{bmatrix} \left[\frac{m}{s^2}\right]$$

Plusszfeladat

Forgó villában elforduló rotor





$|\underline{\omega}_1| = 3\ [\mathrm{rad/s}] = \text{áll}$

$|\underline{\omega}_{21}| = 8\ [\mathrm{rad/s}] = \text{áll}$

$\overline{AB} = 100\ (\mathrm{mm})$

$\overline{BC} = 100\ (\mathrm{mm})$

$l_1 = l_2 = 200\ (\mathrm{mm})$

$\varphi = 60°$

Feladat: $\underline{a}_C,\ \underline{\omega},\ \underline{\varepsilon}$

Megoldás:

- $$\underline{\omega}_1 = \begin{bmatrix} 0 \\ 0 \\ \omega_1 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 3 \end{bmatrix} \left[\frac{\mathrm{rad}}{\mathrm{s}}\right]; \quad \underline{\omega}_{21} = \begin{bmatrix} 0 \\ \omega_{21} \cdot \sin\varphi \\ \omega_{21} \cos\varphi \end{bmatrix} = \underline{\underline{\begin{bmatrix} 0 \\ 4\sqrt{3} \\ 4 \end{bmatrix}}} \left[\frac{\mathrm{rad}}{\mathrm{s}}\right]$$

$$\underline{\omega}_2 = \underline{\omega}_1 + \underline{\omega}_{21} = \begin{bmatrix} 0 \\ \omega_{21} \sin\varphi \\ \omega_1 + \omega_{21} \cos\varphi \end{bmatrix} = \underline{\underline{\begin{bmatrix} 0 \\ 6{,}93 \\ 7 \end{bmatrix}}} \left[\frac{\mathrm{rad}}{\mathrm{s}}\right]$$

- $$\underline{\varepsilon} = \underline{\dot{\omega}} = \dot{\overline{(\underline{\omega}_1 + \underline{\omega}_{21})}} = \underbrace{\underline{\dot{\omega}}_1}_{=0} + \underline{\dot{\omega}}_{21} = \underline{\dot{\omega}}_{21} \rightarrow$$ állandó a hossza és ω_1 szögsebességgel forog

$$\underline{\dot{\omega}}_{21} = \underline{\omega}_1 \times \underline{\omega}_{21} = \begin{vmatrix} \underline{i} & \underline{j} & \underline{k} \\ 0 & 0 & \omega_1 \\ 0 & \omega_{21} \sin\varphi & \omega_{21} \cos\varphi \end{vmatrix} = \begin{bmatrix} -\omega_1 \omega_{21} \sin\varphi \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} -20{,}78 \\ 0 \\ 0 \end{bmatrix} \left[\frac{\mathrm{rad}}{\mathrm{s}^2}\right]$$

- $\underline{a}_C$

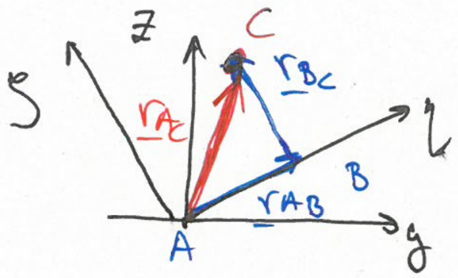
$$\underline{a}_C = \underline{a}_A + \underline{\varepsilon}_2 \times \underline{r}_{AC} + \underline{\omega}_2 \times (\underline{\omega}_2 \times \underline{r}_{AC})$$

Ekkor kell még

$$\underline{a}_A = \underset{\underline{0}}{\underset{\parallel}{\underline{a}_0}} + \underset{\underline{0}}{\underset{\parallel}{\underline{\varepsilon}_1}} \times \underline{r}_{OA} + \underline{\omega}_1 \times (\underline{\omega}_1 \times \underline{r}_{OA}) = -\omega_1^2 \underline{r}_{OA} =$$

$$= -\omega_1^2 \begin{bmatrix} l_2 \\ l_1 \\ 0 \end{bmatrix} = \begin{bmatrix} -1{,}8 \\ -1{,}8 \\ 0 \end{bmatrix} \left[\frac{m}{s^2}\right]$$

$$\underline{r}_{AC} = \underline{r}_{AB} + \underline{r}_{BC}$$



$$= \begin{bmatrix} 0 \\ \overline{AB}\sin\varphi - \overline{BC}\cos\varphi \\ \overline{AB}\cos\varphi + \overline{BC}\sin\varphi \end{bmatrix}$$

$$= \begin{bmatrix} 0 \\ 0{,}0366 \\ 0{,}1366 \end{bmatrix} [m]$$

Ezt már vissza lehet helyettesíteni $\underline{a}_C$ egyenletébe:

$\Downarrow$ behelyettesítés után

$$\underline{a}_C = \begin{bmatrix} -1{,}8 \\ 5{,}87 \\ -5{,}56 \end{bmatrix} \left[\frac{m}{s^2}\right] \qquad |\underline{a}_C| = 8{,}275 \left[\frac{m}{s^2}\right]$$