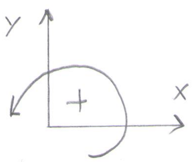
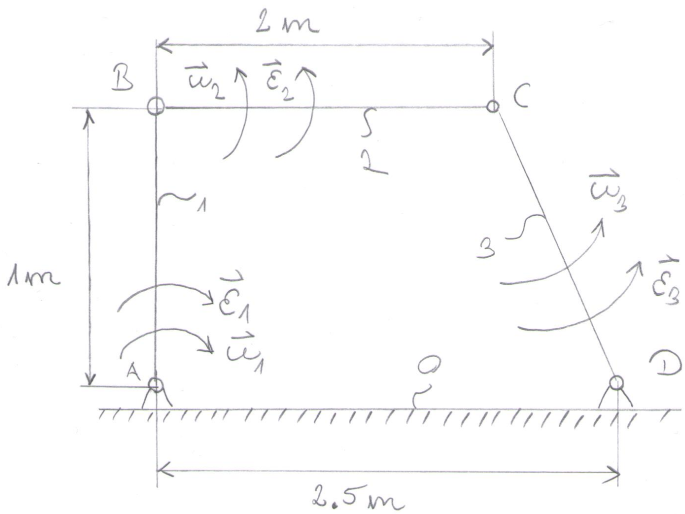
MECHANISMS

1. TYPE





DATA:

$$\vec{\omega}_1 = \begin{pmatrix} 0 \\ 0 \\ -1 \end{pmatrix} \frac{r}{s}$$

$$\vec{\varepsilon}_1 = \begin{pmatrix} 0 \\ 0 \\ -1 \end{pmatrix} \frac{r}{s^2}$$

POSITION VECTORS:

$$\vec{r}_{AB} = \begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix} m \quad \vec{r}_{BC} = \begin{pmatrix} 2 \\ 0 \\ 0 \end{pmatrix} m \quad \vec{r}_{DC} = \begin{pmatrix} -0.5 \\ 1 \\ 0 \end{pmatrix} m$$

VELOCITIES:

$$\left.\begin{aligned} \vec{v}_A &= \vec{0} \ \frac{m}{s} \\ \vec{v}_D &= \vec{0} \ \frac{m}{s} \end{aligned}\right\} \text{FIXED JOINTS}$$

$$\vec{v}_B = \vec{v}_A + \vec{\omega}_1 \times \vec{r}_{AB} = 0 + \begin{pmatrix} 0 \\ 0 \\ -1 \end{pmatrix} \times \begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix} = 0 + \begin{vmatrix} \overset{\oplus}{i} & \overset{\ominus}{j} & \overset{\oplus}{k} \\ 0 & 0 & -1 \\ 0 & 1 & 0 \end{vmatrix} = 0 + \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix} = \underline{\underline{\begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix} \frac{m}{s}}}$$

$$\vec{v}_C = \vec{v}_B + \vec{\omega}_2 \times \vec{r}_{BC} = \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ \omega_2 \end{pmatrix} \times \begin{pmatrix} 2 \\ 0 \\ 0 \end{pmatrix} = \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix} + \begin{vmatrix} \overset{\oplus}{i} & \overset{\ominus}{j} & \overset{\oplus}{k} \\ 0 & 0 & \omega_2 \\ 2 & 0 & 0 \end{vmatrix} = \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix} + \begin{pmatrix} 0 \\ 2\omega_2 \\ 0 \end{pmatrix} =$$

$$= \underline{\begin{pmatrix} 1 \\ 2\omega_2 \\ 0 \end{pmatrix} \frac{m}{s}}$$

$$\vec{v}_C = \vec{v}_D + \vec{\omega}_3 \times \vec{r}_{DC} = 0 + \begin{pmatrix} 0 \\ 0 \\ \omega_3 \end{pmatrix} \times \begin{pmatrix} -0.5 \\ 1 \\ 0 \end{pmatrix} = 0 + \begin{array}{c} \oplus \quad \ominus \quad \oplus \\ \begin{vmatrix} i & j & k \\ 0 & 0 & \omega_3 \\ -0.5 & 1 & 0 \end{vmatrix} \end{array} =$$

$$= 0 + \begin{pmatrix} -\omega_3 \\ -0.5\omega_3 \\ 0 \end{pmatrix} = \underline{\begin{pmatrix} -\omega_3 \\ -0.5\omega_3 \\ 0 \end{pmatrix} \frac{m}{s}}$$

$$\begin{pmatrix} 1 \\ 2\omega_2 \\ 0 \end{pmatrix} = \begin{pmatrix} -\omega_3 \\ -0.5\omega_3 \\ 0 \end{pmatrix}$$

$\longrightarrow 1 = -\omega_3 \Rightarrow \omega_3 = -1 \frac{r}{s} \Rightarrow \underline{\vec{\omega}_3 = \begin{pmatrix} 0 \\ 0 \\ -1 \end{pmatrix} \frac{r}{s}}$

$\longrightarrow 2\omega_2 = -0.5\,\omega_3$

$2\omega_2 = -0.5 \cdot (-1)$

$2\omega_2 = 0.5 \Rightarrow \omega_2 = 0.25 \frac{r}{s} \Rightarrow \underline{\vec{\omega}_2 = \begin{pmatrix} 0 \\ 0 \\ 0.25 \end{pmatrix} \frac{r}{s}}$

$$\vec{v}_C = \begin{pmatrix} 1 \\ 2 \cdot 0.25 \\ 0 \end{pmatrix} = \underline{\underline{\begin{pmatrix} 1 \\ 0.5 \\ 0 \end{pmatrix} \frac{m}{s}}}$$

ACCELERATIONS:

$$\left.\begin{aligned} \vec{a}_A &= \vec{0} \ \frac{m}{s^2} \\ \vec{a}_D &= \vec{0} \ \frac{m}{s^2} \end{aligned}\right\} \text{FIXED JOINTS}$$

$$\vec{a}_B = \vec{a}_A + \vec{\varepsilon}_1 \times \vec{r}_{AB} - \omega_1^2 \cdot \vec{r}_{AB} = 0 + \begin{pmatrix} 0 \\ 0 \\ -1 \end{pmatrix} \times \begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix} - (-1)^2 \cdot \begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix} =$$

$$= 0 + \begin{array}{c} \oplus \quad \ominus \quad \oplus \\ \begin{vmatrix} i & j & k \\ 0 & 0 & -1 \\ 0 & 1 & 0 \end{vmatrix} \end{array} - 1 \cdot \begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix} = 0 + \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix} - \begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix} = \underline{\underline{\begin{pmatrix} 1 \\ -1 \\ 0 \end{pmatrix} \frac{m}{s^2}}}$$

$$\vec{a}_C = \vec{a}_B + \vec{\varepsilon}_2 \times \vec{r}_{BC} - \omega_2^2 \cdot \vec{r}_{BC} = \begin{pmatrix} 1 \\ -1 \\ 0 \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ \varepsilon_2 \end{pmatrix} \times \begin{pmatrix} 2 \\ 0 \\ 0 \end{pmatrix} - 0.25^2 \cdot \begin{pmatrix} 2 \\ 0 \\ 0 \end{pmatrix} =$$

$$= \begin{pmatrix} 1 \\ -1 \\ 0 \end{pmatrix} + \begin{array}{c} \oplus \quad \ominus \quad \oplus \\ \begin{vmatrix} i & j & k \\ 0 & 0 & \varepsilon_2 \\ 2 & 0 & 0 \end{vmatrix} \end{array} - 0.0625 \cdot \begin{pmatrix} 2 \\ 0 \\ 0 \end{pmatrix} = \begin{pmatrix} 1 \\ -1 \\ 0 \end{pmatrix} + \begin{pmatrix} 0 \\ 2\varepsilon_2 \\ 0 \end{pmatrix} - \begin{pmatrix} 0.125 \\ 0 \\ 0 \end{pmatrix} =$$

$$= \underline{\begin{pmatrix} 0.875 \\ -1 + 2\varepsilon_2 \\ 0 \end{pmatrix} \frac{m}{s^2}}$$

$$\vec{a}_C = \vec{a}_D + \vec{\varepsilon}_3 \times \vec{r}_{DC} - \omega_3^2 \cdot \vec{r}_{DC} = 0 + \begin{pmatrix} 0 \\ 0 \\ \varepsilon_3 \end{pmatrix} \times \begin{pmatrix} -0.5 \\ 1 \\ 0 \end{pmatrix} - (-1)^2 \cdot \begin{pmatrix} -0.5 \\ 1 \\ 0 \end{pmatrix} =$$

$$= 0 + \begin{array}{c} \oplus \quad \ominus \quad \oplus \\ \begin{vmatrix} i & j & k \\ 0 & 0 & \varepsilon_3 \\ -0.5 & 1 & 0 \end{vmatrix} \end{array} - 1 \cdot \begin{pmatrix} -0.5 \\ 1 \\ 0 \end{pmatrix} = 0 + \begin{pmatrix} -\varepsilon_3 \\ -0.5\varepsilon_3 \\ 0 \end{pmatrix} - \begin{pmatrix} -0.5 \\ 1 \\ 0 \end{pmatrix} = \underline{\begin{pmatrix} -\varepsilon_3 + 0.5 \\ -0.5\varepsilon_3 - 1 \\ 0 \end{pmatrix} \frac{m}{s^2}}$$

$$\begin{pmatrix}0.875\\-1+2\varepsilon_2\\0\end{pmatrix}=\begin{pmatrix}-\varepsilon_3+0.5\\-0.5\,\varepsilon_3-1\\0\end{pmatrix}\begin{matrix}\rightarrow 0.875=-\varepsilon_3+0.5 \Rightarrow \varepsilon_3=-0.375\,\frac{r}{s^2}\Rightarrow \vec{\varepsilon}_3=\begin{pmatrix}0\\0\\-0.375\end{pmatrix}\frac{r}{s^2}\\ \rightarrow -1+2\varepsilon_2=-0.5\,\varepsilon_3-1\end{matrix}$$

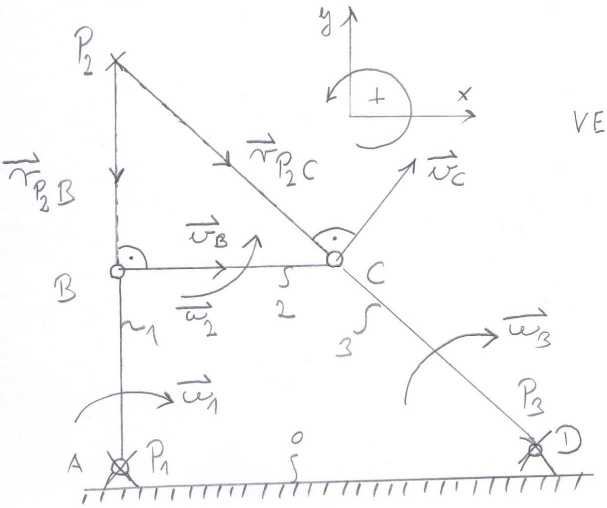
$$-1+2\varepsilon_2=-0.5\cdot(-0.375)-1$$

$$-1+2\varepsilon_2=0.1875-1$$

$$2\varepsilon_2=0.1875 \Rightarrow \varepsilon_2=0.09375\,\frac{r}{s^2}\Rightarrow \vec{\varepsilon}_2=\begin{pmatrix}0\\0\\0.09375\end{pmatrix}\frac{r}{s^2}$$

$$\vec{a}_C=\begin{pmatrix}0.875\\-1+2\cdot 0.09375\\0\end{pmatrix}=\begin{pmatrix}0.875\\-0.8125\\0\end{pmatrix}\frac{m}{s^2}$$

VELOCITY POLE:



VELOCITY POLE = CENTRE POINT OF A ROTATION MOTION

P_1 = A JOINT

P_3 = D JOINT

P_2: $\vec{v}_B=\vec{v}_{P_2}+\vec{\omega}_2\times\vec{r}_{P_2B}$ $\boxed{OR}$ $\vec{v}_C=\vec{v}_{P_2}+\vec{\omega}_2\times\vec{r}_{P_2C}$

$$\begin{pmatrix}1\\0\\0\end{pmatrix}=0+\begin{pmatrix}0\\0\\0.25\end{pmatrix}\times\begin{pmatrix}r_{P_2Bx}\\r_{P_2By}\\0\end{pmatrix} \qquad \begin{pmatrix}1\\0.5\\0\end{pmatrix}=0+\begin{pmatrix}0\\0\\0.25\end{pmatrix}\times\begin{pmatrix}r_{P_2Cx}\\r_{P_2Cy}\\0\end{pmatrix}$$

$$\begin{pmatrix}1\\0\\0\end{pmatrix}=0+\begin{vmatrix}\overset{+}{i} & \overset{-}{j} & \overset{+}{k}\\0&0&0.25\\r_{P_2Bx}&r_{P_2By}&0\end{vmatrix} \qquad \begin{pmatrix}1\\0.5\\0\end{pmatrix}=\begin{vmatrix}\overset{+}{i} & \overset{-}{j} & \overset{+}{k}\\0&0&0.25\\r_{P_2Cx}&r_{P_2Cy}&0\end{vmatrix}$$

$$\begin{pmatrix}1\\0\\0\end{pmatrix}=\begin{pmatrix}-0.25\,r_{P_2By}\\0.25\,r_{P_2Bx}\\0\end{pmatrix}\begin{matrix}\rightarrow r_{P_2By}=-4\,m\\ \rightarrow r_{P_2Bx}=0\,m\end{matrix} \qquad \begin{pmatrix}1\\0.5\\0\end{pmatrix}=\begin{pmatrix}-0.25\,r_{P_2Cy}\\0.25\,r_{P_2Cx}\\0\end{pmatrix}\begin{matrix}\rightarrow r_{P_2Cy}=-4\,m\\ \rightarrow r_{P_2Cx}=2\,m\end{matrix}$$

$$\vec{r}_{P_2B}=\begin{pmatrix}0\\-4\\0\end{pmatrix}m \qquad \vec{r}_{P_2C}=\begin{pmatrix}2\\-4\\0\end{pmatrix}m$$

EXPLANATION:

- THE 2 RESULT POSITION VECTOR GIVE US THE SAME P_2 POINT, THAT IS WHY WE CAN CALCULATE THE P_2 POINT FROM B and C JOINT AS WELL.
- THE POSITION VECTORS OF THE VELOCITY POLE ARE ALWAYS PERPENDICULAR TO THE VELOCITY VECTORS. FOR EXAMPLE $\vec{r}_{P_2B}$ POSITION VECTOR IS PERPENDICULAR TO $\vec{v}_B$ VELOCITY VECTOR AND $\vec{r}_{P_2C}$ IS ALSO PERPENDICULAR TO $\vec{v}_C$ VELOCITY VECTOR.
- THE VELOCITY OF THE VELOCITY VECTOR IS ALWAYS ZERO. $\vec{v}_{P_2} = \vec{0}\,\frac{m}{s}$

ACCELERATION POLE:

G_1 = A JOINT

G_3 = D JOINT

G_2:

$$\vec{a}_B = \vec{a}_{G_2} + \vec{\varepsilon}_2 \times \vec{r}_{G_2B} - \omega_2^2\, \vec{r}_{G_2B}$$

$\boxed{OR}$

$$\vec{a}_C = \vec{a}_{G_2} + \vec{\varepsilon}_2 \times \vec{r}_{G_2C} - \omega_2^2\, \vec{r}_{G_2C}$$

BOTH EQUATIONS CAN GIVE US THE G_2 ACCELERATION POLE.

$$\vec{a}_C = \vec{a}_{G_2} + \vec{\varepsilon}_2 \times \vec{r}_{G_2C} - \omega_2^2 \cdot \vec{r}_{G_2C}$$

$$\begin{pmatrix} 0.875 \\ -0.8125 \\ 0 \end{pmatrix} = 0 + \begin{pmatrix} 0 \\ 0 \\ 0.09375 \end{pmatrix} \times \begin{pmatrix} r_{G_2Cx} \\ r_{G_2Cy} \\ 0 \end{pmatrix} - 0.25^2 \cdot \begin{pmatrix} r_{G_2Cx} \\ r_{G_2Cy} \\ 0 \end{pmatrix}$$

$$\begin{pmatrix} 0.875 \\ -0.8125 \\ 0 \end{pmatrix} = 0 + \begin{vmatrix} \oplus & \ominus & \oplus \\ i & j & k \\ 0 & 0 & 0.09375 \\ r_{G_2Cx} & r_{G_2Cy} & 0 \end{vmatrix} - \begin{pmatrix} 0.0625 \cdot r_{G_2Cx} \\ 0.0625 \cdot r_{G_2Cy} \\ 0 \end{pmatrix}$$

$$\begin{pmatrix} 0.875 \\ -0.8125 \\ 0 \end{pmatrix} = \begin{pmatrix} -0.09375 \cdot r_{G_2Cy} \\ 0.09375 \cdot r_{G_2Cx} \\ 0 \end{pmatrix} - \begin{pmatrix} 0.0625 \cdot r_{G_2Cx} \\ 0.0625 \cdot r_{G_2Cy} \\ 0 \end{pmatrix}$$

$$\left.\begin{aligned} 0.875 &= -0.09375 \cdot r_{G_2Cy} - 0.0625 \cdot r_{G_2Cx} \\ -0.8125 &= 0.09375 \cdot r_{G_2Cx} - 0.0625 \cdot r_{G_2Cy} \end{aligned}\right\} /\cdot 1{,}5$$

$$\left.\begin{aligned} 1.3125 &= -0.140625 \cdot r_{G_2Cy} - 0.09375\, r_{G_2Cx} \\ -0.8125 &= 0.09375 \cdot r_{G_2Cx} - 0.0625 \cdot r_{G_2Cy} \end{aligned}\right\} +$$

$$0.5 = -0.203125 \cdot r_{G_2Cy}$$

$$\underline{r_{G_2Cy} = -2.462}$$

$$0.875 = -0.09375 \cdot (-2.462) - 0.0625 \cdot r_{G_2Cx}$$

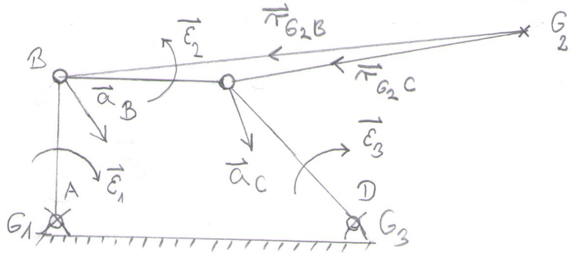
$$0.875 = 0.2308 - 0.0625 \cdot r_{G_2Cx}$$

$$\underline{r_{G_2Cx} = -10.3}$$

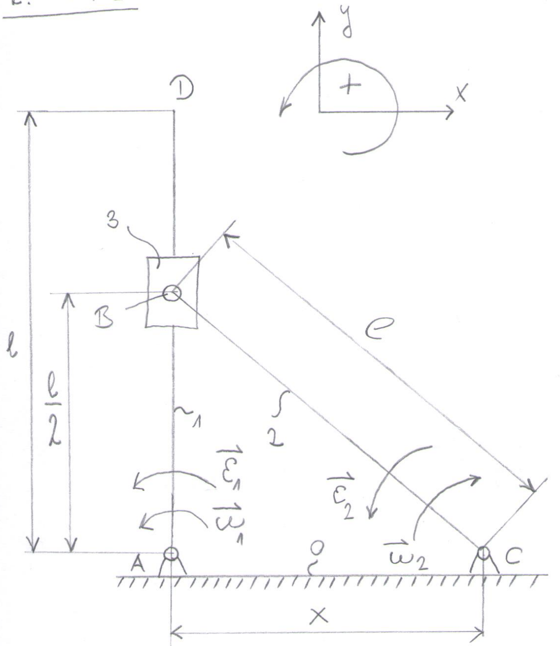
$$\vec{r}_{G_2C} = \begin{pmatrix} -10.3 \\ -2.462 \\ 0 \end{pmatrix} m$$

EXPLANATION:

- IN CASE OF ACCELERATION POLE, WE DETERMINE THE VALUES OF THE POSITION VECTOR, WHICH POINTS FROM THE ACCELERATION POLE TO THE RIGHT ACCELERATION VECTOR. FOR EXAMPLE $\vec{r}_{G_2B}$ OR $\vec{r}_{G_2C}$.
- THE ACCELERATION OF ACCELERATION POLE IS ALWAYS ZERO: $\vec{a}_G = \vec{0} \ \frac{m}{s^2}$
- FIXED JOINTS CAN BE ACCELERATION POLES.



2. TYPE



DATA:

$l = 0.4\,m$

$\vec{\omega}_2 = \begin{pmatrix} 0 \\ 0 \\ -2 \end{pmatrix} \frac{r}{s}$

$\vec{\varepsilon}_2 = \begin{pmatrix} 0 \\ 0 \\ 3 \end{pmatrix} \frac{r}{s^2}$

CALCULATION OF X:

$$x^2 + \left(\frac{l}{2}\right)^2 = l^2$$

$$x^2 + 0.2^2 = 0.4^2$$

$$x^2 + 0.04 = 0.16$$

$$x^2 = 0.12$$

$$x = 0.346 \approx 0.35\,m$$

POSITION VECTORS:

$\vec{r}_{AB} = \begin{pmatrix} 0 \\ 0.2 \\ 0 \end{pmatrix} m$

$\vec{r}_{CB} = \begin{pmatrix} -0.35 \\ 0.2 \\ 0 \end{pmatrix} m$

$\vec{r}_{AD} = \begin{pmatrix} 0 \\ 0.4 \\ 0 \end{pmatrix} m$

VELOCITIES:

$\left.\begin{array}{l} \vec{v}_A = \vec{0}\ \frac{m}{s} \\ \vec{v}_D = \vec{0}\ \frac{m}{s} \end{array}\right\}$ FIXED JOINTS.

$\boxed{\vec{v}_B:}$

GEOMETRICAL CONNECTION:

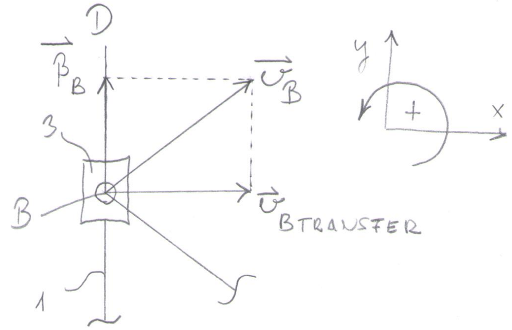
THE GEOMETRICAL CONNECTION REFERS TO THE SEGMENT 2, BECAUSE BC IS A SIMPLE JOINT-SEGMENT-JOINT CONNECTION. THAT IS WHY WE CAN USE THE SIMPLE FORMULE OF VELOCITY CALCULATION.

$$\vec{v}_B = \vec{v}_C + \vec{\omega}_2 \times \vec{r}_{CB} = 0 + \begin{pmatrix}0\\0\\-2\end{pmatrix} \times \begin{pmatrix}-0.35\\0.2\\0\end{pmatrix} = 0 + \begin{vmatrix}\overset{\oplus}{i} & \overset{\ominus}{j} & \overset{\oplus}{k}\\ 0 & 0 & -2\\ -0.35 & 0.2 & 0\end{vmatrix} = \underline{\begin{pmatrix}0.4\\0.7\\0\end{pmatrix} \frac{m}{s}}$$

RELATIVE CONNECTION:

RELATIVE CONNECTION REFERS TO THE SEGMENT 1, BECAUSE AB IS A JOINT-SEGMENT-SLIDE CONNECTION. THAT IS WHY WE HAVE TO DECOMPOSE THE $\vec{v}_B$ VELOCITY INTO COMPONENTS.

$$\vec{v}_B = \vec{v}_{B\,TRANSFER} + \vec{\beta}_B$$



$\vec{v}_{B\,TRANSFER}$: TRANSFER VELOCITY, IT REFERS TO THE B JOINT.

$\vec{\beta}_B$: RELATIVE VELOCITY, IT REFERS TO THE SLIDE.

$$\vec{v}_{B\,TRANSFER} = \vec{v}_A + \vec{\omega}_1 \times \vec{r}_{AB} = 0 + \begin{pmatrix}0\\0\\\omega_1\end{pmatrix} \times \begin{pmatrix}0\\0.2\\0\end{pmatrix} = 0 + \begin{vmatrix}\overset{\oplus}{i} & \overset{\ominus}{j} & \overset{\oplus}{k}\\ 0 & 0 & \omega_1\\ 0 & 0.2 & 0\end{vmatrix} = \underline{\begin{pmatrix}-0.2\,\omega_1\\0\\0\end{pmatrix} \frac{m}{s}}$$

$$\underline{\vec{\beta}_B = \begin{pmatrix}0\\\beta_B\\0\end{pmatrix} \frac{m}{s}}$$

$$\vec{v}_B = \begin{pmatrix}-0.2\,\omega_1\\0\\0\end{pmatrix} + \begin{pmatrix}0\\\beta_B\\0\end{pmatrix}$$

$$\underline{\vec{v}_B = \begin{pmatrix}-0.2\,\omega_1\\\beta_B\\0\end{pmatrix} \frac{m}{s}}$$

GEOMETRICAL CONNECTION = RELATIVE CONNECTION

$$\begin{pmatrix}0.4\\0.7\\0\end{pmatrix} = \begin{pmatrix}-0.2\,\omega_1\\\beta_B\\0\end{pmatrix} \begin{array}{l} \rightarrow 0.4 = -0.2\,\omega_1 \Rightarrow \omega_1 = -2\,\frac{r}{s} \Rightarrow \underline{\vec{\omega}_1 = \begin{pmatrix}0\\0\\-2\end{pmatrix}\frac{r}{s}} \\ \rightarrow 0.7 = \beta_B \Rightarrow \underline{\vec{\beta}_B = \begin{pmatrix}0\\0.7\\0\end{pmatrix}\frac{m}{s}} \end{array}$$

$$\vec{v}_D = \vec{v}_A + \vec{\omega}_1 \times \vec{r}_{AD} = 0 + \begin{pmatrix}0\\0\\-2\end{pmatrix} \times \begin{pmatrix}0\\0.4\\0\end{pmatrix} = 0 + \begin{vmatrix}\overset{\oplus}{i} & \overset{\ominus}{j} & \overset{\oplus}{k}\\ 0 & 0 & -2\\ 0 & 0.4 & 0\end{vmatrix} = \underline{\underline{\begin{pmatrix}0.8\\0\\0\end{pmatrix} \frac{m}{s}}}$$

ACCELERATIONS:

$$\left.\begin{array}{l}\vec{a}_A = \vec{0}\ \frac{m}{s^2} \\ \vec{a}_D = \vec{0}\ \frac{m}{s^2}\end{array}\right\}\text{FIXED JOINTS}$$

$\boxed{\vec{a}_B}$

GEOMETRICAL CONNECTION:

THE GEOMETRICAL CONNECTION REFERS TO THE SEGMENT 2, BECAUSE BC IS A SIMPLE JOINT-SEGMENT-JOINT CONNECTION. THAT IS WHY WE CAN USE THE SIMPLE FORMULE OF ACCELERATION CALCULATION.

$$\vec{a}_B = \vec{a}_C + \vec{\varepsilon}_2 \times \vec{r}_{CB} - \omega_2^2 \cdot \vec{r}_{CB} = 0 + \begin{pmatrix}0\\0\\3\end{pmatrix} \times \begin{pmatrix}-0.35\\0.2\\0\end{pmatrix} - (-2)^2 \cdot \begin{pmatrix}-0.35\\0.2\\0\end{pmatrix} =$$

$$= 0 + \begin{vmatrix} \oplus & \ominus & \oplus \\ i & j & k \\ 0 & 0 & 3 \\ -0.35 & 0.2 & 0 \end{vmatrix} - 4 \cdot \begin{pmatrix}-0.35\\0.2\\0\end{pmatrix} = 0 + \begin{pmatrix}-0.6\\-1.05\\0\end{pmatrix} - \begin{pmatrix}-1.4\\0.8\\0\end{pmatrix} = \underline{\underline{\begin{pmatrix}0.8\\-1.85\\0\end{pmatrix} \frac{m}{s^2}}}$$

RELATIVE CONNECTION:

RELATIVE CONNECTION REFERS TO THE SEGMENT 1, BECAUSE AB IS A JOINT-SEGMENT-SLIDE CONNECTION. THAT IS WHY WE HAVE TO DECOMPOSE THE $\vec{a}_B$ ACCELERATION INTO COMPONENTS.

$$\vec{a}_B = \vec{a}_{B\,TRANSFER} + \vec{\alpha}_B + \vec{a}_{B\,CORIOLIS}$$

$\vec{a}_{B\,TRANSFER}$: TRANSFER ACCELERATION, IT REFERS TO THE B JOINT.

$\vec{\alpha}_B$: RELATIVE ACCELERATION, IT REFERS TO THE SLIDE.

$\vec{a}_{B\,CORIOLIS}$: CORIOLIS ACCELERATION.

$$\vec{a}_{B\,TRANSFER} = \vec{a}_A + \vec{\varepsilon}_1 \times \vec{r}_{AB} - \omega_1^2 \cdot \vec{r}_{AB} = 0 + \begin{pmatrix}0\\0\\\varepsilon_1\end{pmatrix} \times \begin{pmatrix}0\\0.2\\0\end{pmatrix} - (-2)^2 \cdot \begin{pmatrix}0\\0.2\\0\end{pmatrix} =$$

$$= 0 + \begin{vmatrix} \oplus & \ominus & \oplus \\ i & j & k \\ 0 & 0 & \varepsilon_1 \\ 0 & 0.2 & 0 \end{vmatrix} - 4 \cdot \begin{pmatrix}0\\0.2\\0\end{pmatrix} = 0 + \begin{pmatrix}-0.2\,\varepsilon_1\\0\\0\end{pmatrix} - \begin{pmatrix}0\\0.8\\0\end{pmatrix} = \underline{\begin{pmatrix}-0.2\,\varepsilon_1\\-0.8\\0\end{pmatrix} \frac{m}{s^2}}$$

$$\underline{\vec{\alpha}_B = \begin{pmatrix}0\\\alpha_B\\0\end{pmatrix} \frac{m}{s^2}}$$

$$\vec{a}_{B\,CORIOLIS} = 2 \cdot \vec{\omega}_1 \times \vec{\beta}_B = 2 \cdot \begin{pmatrix}0\\0\\-2\end{pmatrix} \times \begin{pmatrix}0\\0.7\\0\end{pmatrix} = 2 \cdot \begin{vmatrix} \oplus & \ominus & \oplus \\ i & j & k \\ 0 & 0 & -2 \\ 0 & 0.7 & 0 \end{vmatrix} = 2 \cdot \begin{pmatrix}1.4\\0\\0\end{pmatrix} = \underline{\begin{pmatrix}2.8\\0\\0\end{pmatrix} \frac{m}{s^2}}$$

$$\vec{a}_B = \vec{a}_{B_{TRANSFER}} + \vec{\alpha}_B + \vec{a}_{B_{CORIOLIS}} = \begin{pmatrix} -0.2\varepsilon_1 \\ -0.8 \\ 0 \end{pmatrix} + \begin{pmatrix} 0 \\ \alpha_B \\ 0 \end{pmatrix} + \begin{pmatrix} 2.8 \\ 0 \\ 0 \end{pmatrix} = \underline{\begin{pmatrix} -0.2\varepsilon_1 + 2.8 \\ -0.8 + \alpha_B \\ 0 \end{pmatrix} \frac{m}{s^2}}$$

GEOMETRICAL CONNECTION = RELATIVE CONNECTION

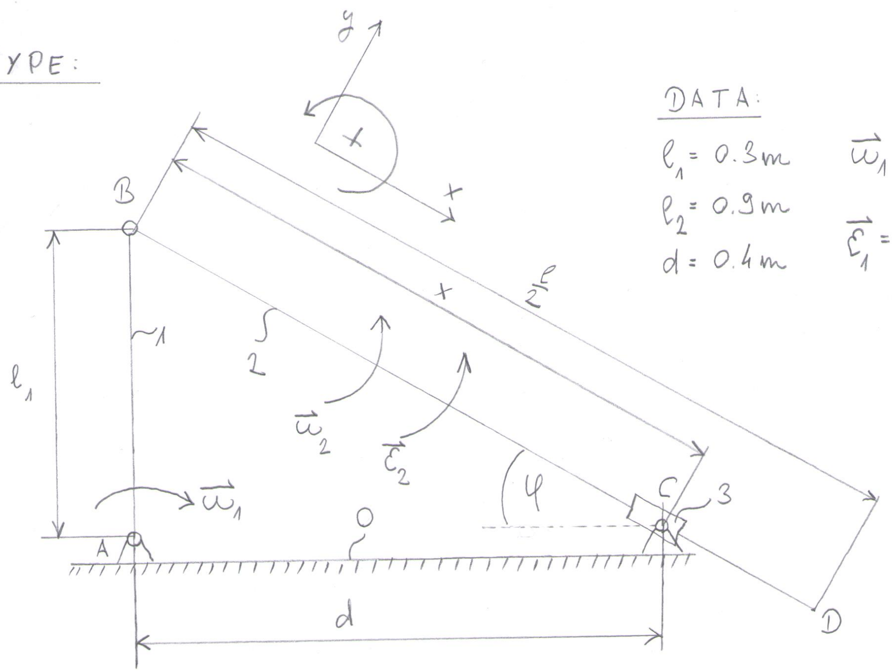
$$\begin{pmatrix} 0.8 \\ -1.85 \\ 0 \end{pmatrix} = \begin{pmatrix} -0.2\varepsilon_1 + 2.8 \\ -0.8 + \alpha_B \\ 0 \end{pmatrix} \begin{matrix} \longrightarrow 0.8 = -0.2\varepsilon_1 + 2.8 \Rightarrow \varepsilon_1 = 10 \frac{r}{s^2} \Rightarrow \underline{\vec{\varepsilon}_1 = \begin{pmatrix} 0 \\ 0 \\ 10 \end{pmatrix} \frac{r}{s^2}} \\ \longrightarrow -1.85 = -0.8 + \alpha_B \Rightarrow \alpha_B = -1.05 \frac{m}{s^2} \Rightarrow \underline{\vec{\alpha}_B = \begin{pmatrix} 0 \\ -1.05 \\ 0 \end{pmatrix} \frac{m}{s^2}} \end{matrix}$$

$$\vec{a}_D = \vec{a}_A + \vec{\varepsilon}_1 \times \vec{r}_{AD} - \omega_1^2 \cdot \vec{r}_{AD} = 0 + \begin{pmatrix} 0 \\ 0 \\ 10 \end{pmatrix} \times \begin{pmatrix} 0.4 \\ 0 \\ 0 \end{pmatrix} - (-2)^2 \cdot \begin{pmatrix} 0.4 \\ 0 \\ 0 \end{pmatrix} =$$

$$= 0 + \begin{vmatrix} \oplus & \ominus & \oplus \\ i & j & k \\ 0 & 0 & 10 \\ 0 & 0.4 & 0 \end{vmatrix} - 4 \cdot \begin{pmatrix} 0 \\ 0.4 \\ 0 \end{pmatrix} = 0 + \begin{pmatrix} -4 \\ 0 \\ 0 \end{pmatrix} - \begin{pmatrix} 0 \\ 1.6 \\ 0 \end{pmatrix} = \underline{\underline{\begin{pmatrix} -4 \\ -1.6 \\ 0 \end{pmatrix} \frac{m}{s^2}}}$$

MECHANISMS

3. TYPE:



DATA:

$l_1 = 0.3\,m$ $\quad \vec{\omega}_1 = \begin{pmatrix} 0 \\ 0 \\ -4 \end{pmatrix} \frac{r}{s}$

$l_2 = 0.9\,m$

$d = 0.4\,m$ $\quad \vec{\varepsilon}_1 = \vec{0}\ \frac{r}{s^2}$

CALCULATIONS:

$$\cos\varphi = \frac{l_1}{d} \qquad l_1^2 + d^2 = x^2 \qquad \sin\varphi = \frac{0.3}{0.5} = \underline{0.6}$$

$$\cos\varphi = \frac{0.3}{0.4} \qquad 0.3^2 + 0.4^2 = x^2 \qquad \cos\varphi = \frac{0.3}{0.4} = \underline{0.8}$$

$$0.25 = x^2$$

$$\underline{\varphi = 41.4^\circ} \qquad \underline{x = 0.5\,m}$$

POSITION VECTORS:

$$\vec{r}_{AB} = \begin{pmatrix} -\sin\varphi \cdot l_1 \\ \cos\varphi \cdot l_1 \\ 0 \end{pmatrix} = \underline{\begin{pmatrix} -0.18 \\ 0.24 \\ 0 \end{pmatrix} m} \qquad \vec{r}_{BC} = \underline{\begin{pmatrix} 0.5 \\ 0 \\ 0 \end{pmatrix} m} \qquad \vec{r}_{CD} = \underline{\begin{pmatrix} 0.4 \\ 0 \\ 0 \end{pmatrix} m}$$

VELOCITIES:

$$\vec{v}_A = \vec{0}\ \frac{m}{s}$$

$$\vec{v}_B = \vec{v}_A + \vec{\omega}_1 \times \vec{r}_{AB} = 0 + \begin{pmatrix} 0 \\ 0 \\ -4 \end{pmatrix} \times \begin{pmatrix} -0.18 \\ 0.24 \\ 0 \end{pmatrix} = 0 + \begin{vmatrix} \oplus & \ominus & \oplus \\ i & j & k \\ 0 & 0 & -4 \\ -0.18 & 0.24 & 0 \end{vmatrix} = \underline{\underline{\begin{pmatrix} 0.96 \\ 0.72 \\ 0 \end{pmatrix} \frac{m}{s}}}$$

$\boxed{\vec{v}_C}$

GEOMETRICAL CONNECTION:

THE GEOMETRICAL CONNECTION REFERS TO THE BC JOINT-SEGMENT-JOINT CONNECTION. IN THIS CASE WE CAN USE THE SIMPLE FORMULE OF VELOCITY CALCULATION.

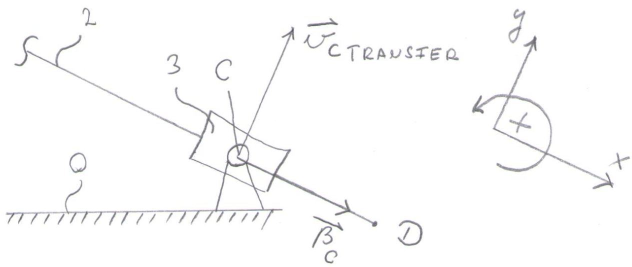
$$\vec{v}_C = \vec{v}_B + \vec{\omega}_2 \times \vec{r}_{BC} = \begin{pmatrix} 0.96 \\ 0.72 \\ 0 \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ \omega_2 \end{pmatrix} \times \begin{pmatrix} 0.5 \\ 0 \\ 0 \end{pmatrix} = \begin{pmatrix} 0.96 \\ 0.72 \\ 0 \end{pmatrix} + \begin{vmatrix} \oplus & \ominus & \oplus \\ i & j & k \\ 0 & 0 & \omega_2 \\ 0.5 & 0 & 0 \end{vmatrix} =$$

$$= \begin{pmatrix} 0.96 \\ 0.72 \\ 0 \end{pmatrix} + \begin{pmatrix} 0 \\ 0.5\omega_2 \\ 0 \end{pmatrix} = \begin{pmatrix} 0.96 \\ 0.72+0.5\omega_2 \\ 0 \end{pmatrix} \frac{m}{s}$$

RELATIVE CONNECTION:

RELATIVE CONNECTION REFERS TO THE SLIDE. THAT IS WHY WE HAVE TO DECOMPOSE THE $\vec{v}_C$ VELOCITY INTO COMPONENTS.

$$\vec{v}_C = \vec{v}_{C_{TRANSFER}} + \vec{\beta}_C$$



$\vec{v}_{C_{TRANSFER}}$: TRANSFER VELOCITY

$\vec{\beta}_C$: RELATIVE VELOCITY

$\vec{v}_{C_{TRANSFER}} = \vec{0}\ \frac{m}{s}$ BECAUSE THE SLIDE IS FIXED AND THERE IS NO MOTION IN DIRECTION OF Y.

$$\vec{v}_C = \vec{\beta}_C = \begin{pmatrix} \beta_C \\ 0 \\ 0 \end{pmatrix} \frac{m}{s}$$

GEOMETRICAL CONNECTION = RELATIVE CONNECTION

$$\begin{pmatrix} 0.96 \\ 0.72+0.5\omega_2 \\ 0 \end{pmatrix} = \begin{pmatrix} \beta_C \\ 0 \\ 0 \end{pmatrix}$$

$\rightarrow 0.96 = \beta_C \Rightarrow \vec{\beta}_C = \begin{pmatrix} 0.96 \\ 0 \\ 0 \end{pmatrix} \frac{m}{s}$

$\rightarrow 0.72 + 0.5\omega_2 = 0$

$0.5\omega_2 = -0.72 \Rightarrow \omega_2 = -1.44\ \frac{r}{s} \Rightarrow \vec{\omega}_2 = \begin{pmatrix} 0 \\ 0 \\ -1.44 \end{pmatrix} \frac{r}{s}$

$$\vec{v}_C = \begin{pmatrix} 0.96 \\ 0.72+0.5\cdot(-1.44) \\ 0 \end{pmatrix} = \begin{pmatrix} 0.96 \\ 0 \\ 0 \end{pmatrix} \frac{m}{s}$$

$$\vec{v}_D = \vec{v}_C + \vec{\omega}_2 \times \vec{r}_{CD} \quad \boxed{OR} \quad \vec{v}_B + \vec{\omega}_2 \times \vec{r}_{BD}$$

$$\vec{v}_D = \vec{v}_C + \vec{\omega}_2 \times \vec{r}_{CD} = \begin{pmatrix} 0.96 \\ 0 \\ 0 \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ -1.44 \end{pmatrix} \times \begin{pmatrix} 0.4 \\ 0 \\ 0 \end{pmatrix} = \begin{pmatrix} 0.96 \\ 0 \\ 0 \end{pmatrix} + \begin{vmatrix} \oplus & \ominus & \oplus \\ i & j & k \\ 0 & 0 & -1.44 \\ 0.4 & 0 & 0 \end{vmatrix} =$$

$$= \begin{pmatrix} 0.96 \\ 0 \\ 0 \end{pmatrix} + \begin{pmatrix} 0 \\ -0.576 \\ 0 \end{pmatrix} = \underline{\underline{\begin{pmatrix} 0.96 \\ -0.576 \\ 0 \end{pmatrix}}} \frac{m}{s}$$

ACCELERATIONS:

$\vec{a}_A = \vec{0} \ \frac{m}{s^2} \rightarrow$ FIXED JOINT.

$$\vec{a}_B = \vec{a}_A + \vec{\varepsilon}_1 \times \vec{r}_{AB} - \omega_1^2 \cdot \vec{r}_{AB} = 0 + \begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix} \times \begin{pmatrix} -0.18 \\ 0.24 \\ 0 \end{pmatrix} - (-4)^2 \cdot \begin{pmatrix} -0.18 \\ 0.24 \\ 0 \end{pmatrix} =$$

$$= 0 + 0 - 16 \cdot \begin{pmatrix} -0.18 \\ 0.24 \\ 0 \end{pmatrix} = \underline{\underline{\begin{pmatrix} 2.88 \\ -3.84 \\ 0 \end{pmatrix}}} \frac{m}{s^2}$$

$\boxed{\vec{a}_C}$

GEOMETRICAL CONNECTION:

THE GEOMETRICAL CONNECTION REFERS TO THE BC JOINT-SEGMENT-JOINT CONNECTION. IN THIS CASE WE CAN USE THE SIMPLE FORMULE OF ACCELERATION CALCULATION.

$$\vec{a}_C = \vec{a}_B + \vec{\varepsilon}_2 \times \vec{r}_{BC} - \omega_2^2 \cdot \vec{r}_{BC} = \begin{pmatrix} 2.88 \\ -3.84 \\ 0 \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ \varepsilon_2 \end{pmatrix} \times \begin{pmatrix} 0.5 \\ 0 \\ 0 \end{pmatrix} - (-1.44)^2 \begin{pmatrix} 0.5 \\ 0 \\ 0 \end{pmatrix} =$$

$$= \begin{pmatrix} 2.88 \\ -3.84 \\ 0 \end{pmatrix} + \begin{vmatrix} \oplus & \ominus & \oplus \\ i & j & k \\ 0 & 0 & \varepsilon_2 \\ 0.5 & 0 & 0 \end{vmatrix} - \begin{pmatrix} 1.3 \\ 0 \\ 0 \end{pmatrix} = \begin{pmatrix} 2.88 \\ -3.84 \\ 0 \end{pmatrix} + \begin{pmatrix} 0 \\ 0.5\varepsilon_2 \\ 0 \end{pmatrix} - \begin{pmatrix} 1.03 \\ 0 \\ 0 \end{pmatrix} = \underline{\begin{pmatrix} 1.85 \\ 0.5\varepsilon_2 - 3.84 \\ 0 \end{pmatrix} \frac{m}{s^2}}$$

RELATIVE CONNECTION:

RELATIVE CONNECTION REFERS TO THE SLIDE. THAT IS WHY WE HAVE TO DECOMPOSE THE $\vec{a}_C$ INTO COMPONENTS.

$$\vec{a}_C = \vec{a}_{C\,TRANSFER} + \vec{\alpha}_C + \vec{a}_{C\,CORIOLIS}$$

$\vec{a}_{C\,TRANSFER}$: TRANSFER ACCELERATION.

$\vec{\alpha}_C$: RELATIVE ACCELERATION.

$\vec{a}_{C\,CORIOLIS}$: CORIOLIS ACCELERATION.

$$\vec{a}_{C\,TRANSFER} = \underline{\vec{0}\ \frac{m}{s^2}}$$

$$\vec{\alpha}_C = \underline{\begin{pmatrix} \alpha_C \\ 0 \\ 0 \end{pmatrix}} \frac{m}{s^2}$$

$$\vec{a}_{C\,CORIOLIS} = 2 \cdot \vec{\omega}_2 \times \vec{\beta}_C = 2 \cdot \begin{pmatrix} 0 \\ 0 \\ -1.44 \end{pmatrix} \times \begin{pmatrix} 0.96 \\ 0 \\ 0 \end{pmatrix} = 2 \cdot \begin{vmatrix} \oplus i & \ominus j & \oplus k \\ 0 & 0 & -1.44 \\ 0.96 & 0 & 0 \end{vmatrix} = 2 \cdot \begin{pmatrix} 0 \\ -1.38 \\ 0 \end{pmatrix} = \underline{\begin{pmatrix} 0 \\ -2.76 \\ 0 \end{pmatrix} \frac{m}{s}}$$

$$\vec{a}_C = \vec{a}_{C\,TRANSFER} + \vec{\alpha}_C + \vec{a}_{C\,CORIOLIS} = 0 + \begin{pmatrix} \alpha_C \\ 0 \\ 0 \end{pmatrix} + \begin{pmatrix} 0 \\ -2.76 \\ 0 \end{pmatrix} = \underline{\begin{pmatrix} \alpha_C \\ -2.76 \\ 0 \end{pmatrix} \frac{m}{s^2}}$$

GEOMETRICAL CONNECTION = RELATIVE CONNECTION

$$\begin{pmatrix} 1.85 \\ 0.5\,\varepsilon_2 - 3.84 \\ 0 \end{pmatrix} = \begin{pmatrix} \alpha_C \\ -2.76 \\ 0 \end{pmatrix}$$

$$\rightarrow 1.85 = \alpha_C \Rightarrow \underline{\vec{\alpha}_C = \begin{pmatrix} 1.85 \\ 0 \\ 0 \end{pmatrix} \frac{m}{s^2}}$$

$$\rightarrow 0.5\varepsilon_2 - 3.84 = -2.76 \Rightarrow \varepsilon_2 = 2.16\ \frac{r}{s} \Rightarrow \underline{\vec{\varepsilon}_2 = \begin{pmatrix} 0 \\ 0 \\ 2.16 \end{pmatrix} \frac{r}{s^2}}$$

$$\downarrow$$

$$\vec{a}_C = \begin{pmatrix} 1.85 \\ 0.5\varepsilon_2 - 3.84 \\ 0 \end{pmatrix} = \underline{\begin{pmatrix} 1.85 \\ -2.76 \\ 0 \end{pmatrix} \frac{m}{s^2}}$$

$$\vec{a}_D = \vec{a}_C + \vec{\varepsilon}_2 \times \vec{r}_{CD} - \omega_2^2 \cdot \vec{r}_{CD} \quad \boxed{OR} \quad \vec{a}_B + \vec{\varepsilon}_2 \times \vec{r}_{BD} - \omega_2^2 \cdot \vec{r}_{BD}$$

$$\vec{a}_D = \begin{pmatrix} 1.85 \\ -2.76 \\ 0 \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ 2.16 \end{pmatrix} \times \begin{pmatrix} 0.4 \\ 0 \\ 0 \end{pmatrix} - (-1.44)^2 \cdot \begin{pmatrix} 0.4 \\ 0 \\ 0 \end{pmatrix} = \begin{pmatrix} 1.85 \\ -2.76 \\ 0 \end{pmatrix} + \begin{vmatrix} \oplus i & \ominus j & \oplus k \\ 0 & 0 & 2.16 \\ 0.4 & 0 & 0 \end{vmatrix} - \begin{pmatrix} 0.829 \\ 0 \\ 0 \end{pmatrix} =$$

$$= \begin{pmatrix} 1.85 \\ -2.76 \\ 0 \end{pmatrix} + \begin{pmatrix} 0 \\ 0.864 \\ 0 \end{pmatrix} - \begin{pmatrix} 0.829 \\ 0 \\ 0 \end{pmatrix} = \underline{\underline{\begin{pmatrix} 1.021 \\ -1.896 \\ 0 \end{pmatrix} \frac{m}{s^2}}}$$

4. TYPE:

DATA:

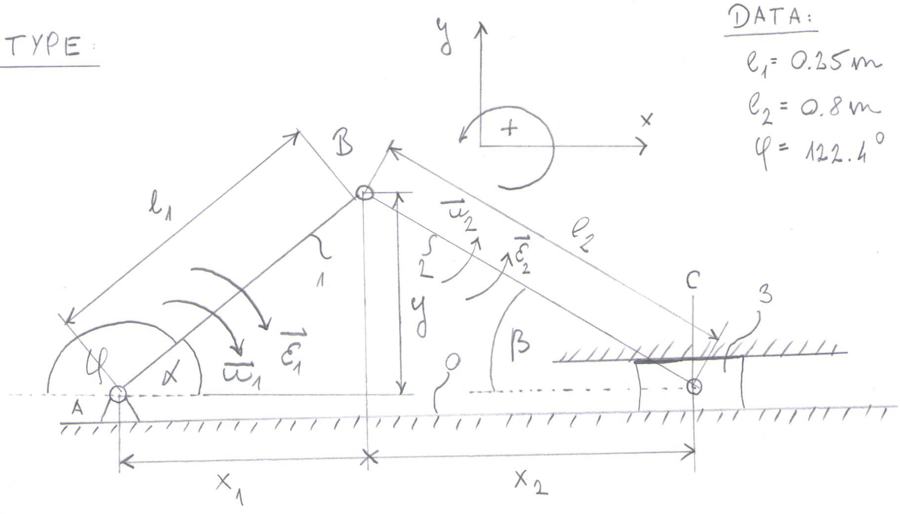
$l_1 = 0.25\,m$

$l_2 = 0.8\,m$

$\varphi = 122.4^\circ$

$\vec{\omega}_1 = \begin{pmatrix} 0 \\ 0 \\ -2 \end{pmatrix} \frac{r}{s}$

$\vec{\varepsilon}_1 = \begin{pmatrix} 0 \\ 0 \\ -3 \end{pmatrix} \frac{r}{s^2}$



CALCULATIONS:

$\alpha = 180^\circ - \varphi = 180^\circ - 122.4^\circ = \underline{57{,}6^\circ}$

$\sin\alpha = \frac{y}{l_1}$ $\quad\cos\alpha = \frac{x_1}{l_1}$

$\sin 57{,}6^\circ = \frac{y}{0.25}$ $\quad\cos 57{,}6^\circ = \frac{x_1}{0.25}$

$\underline{y = 0.21\,m}$ $\quad\underline{x_1 = 0.13\,m}$

$\sin\beta = \frac{y}{l_2}$ $\quad\cos\beta = \frac{x_2}{l_2}$

$\sin\beta = \frac{0.21}{0.8}$ $\quad\cos 15.21^\circ = \frac{x_2}{0.8}$

$\underline{\beta = 15.21^\circ}$ $\quad\underline{x_2 = 0.77\,m}$

POSITION VECTORS:

$\vec{r}_{AB} = \begin{pmatrix} x_1 \\ y \\ 0 \end{pmatrix} = \underline{\begin{pmatrix} 0.13 \\ 0.21 \\ 0 \end{pmatrix}}\,m$ $\qquad \vec{r}_{BC} = \begin{pmatrix} x_2 \\ -y \\ 0 \end{pmatrix} = \underline{\begin{pmatrix} 0.77 \\ -0.21 \\ 0 \end{pmatrix}}\,m$

VELOCITIES:

$\vec{v}_A = \vec{0}\ \frac{m}{s} \rightarrow$ FIXED JOINT.

$$\vec{v}_B = \vec{v}_A + \vec{\omega}_1 \times \vec{r}_{AB} = 0 + \begin{pmatrix} 0 \\ 0 \\ -2 \end{pmatrix} \times \begin{pmatrix} 0.13 \\ 0.21 \\ 0 \end{pmatrix} = 0 + \begin{vmatrix} \oplus & \ominus & \oplus \\ i & j & k \\ 0 & 0 & -2 \\ 0.13 & 0.21 & 0 \end{vmatrix} = \underline{\underline{\begin{pmatrix} 0.42 \\ -0.26 \\ 0 \end{pmatrix}}}\,\frac{m}{s}$$

$$\vec{v}_C = \vec{v}_B + \vec{\omega}_2 \times \vec{r}_{BC} = \begin{pmatrix} 0.42 \\ -0.26 \\ 0 \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ \omega_2 \end{pmatrix} \times \begin{pmatrix} 0.77 \\ -0.21 \\ 0 \end{pmatrix} = \begin{pmatrix} 0.42 \\ -0.26 \\ 0 \end{pmatrix} + \begin{vmatrix} \overset{\oplus}{i} & \overset{\ominus}{j} & \overset{\oplus}{k} \\ 0 & 0 & \omega_2 \\ 0.77 & -0.21 & 0 \end{vmatrix} =$$

$$= \begin{pmatrix} 0.42 \\ -0.26 \\ 0 \end{pmatrix} + \begin{pmatrix} 0.21 \cdot \omega_2 \\ 0.77\omega_2 \\ 0 \end{pmatrix} = \underline{\begin{pmatrix} 0.42 + 0.21\omega_2 \\ -0.26 + 0.77\omega_2 \\ 0 \end{pmatrix} \frac{m}{s}}$$

BECAUSE OF THE PISTON, THE $\vec{v}_C$ VELOCITY HAS ONLY X DIRECTION COMPONENT.

$$\underline{\vec{v}_C = \begin{pmatrix} v_{Cx} \\ 0 \\ 0 \end{pmatrix} \frac{m}{s}}$$

$$\begin{pmatrix} v_{Cx} \\ 0 \\ 0 \end{pmatrix} = \begin{pmatrix} 0.42 + 0.21\omega_2 \\ -0.26 + 0.77\omega_2 \\ 0 \end{pmatrix} \longrightarrow 0 = -0.26 + 0.77\omega_2$$

$$\omega_2 = 0.33 \frac{r}{s}$$

$$\underline{\vec{\omega}_2 = \begin{pmatrix} 0 \\ 0 \\ 0.33 \end{pmatrix} \frac{r}{s}}$$

$$v_{Cx} = 0.42 + 0.21\omega_2$$

$$v_{Cx} = 0.42 + 0.21 \cdot 0.33$$

$$v_{Cx} = 0.49 \frac{m}{s}$$

$$\underline{\underline{\vec{v}_C = \begin{pmatrix} 0.49 \\ 0 \\ 0 \end{pmatrix} \frac{m}{s}}}$$

ACCELERATIONS:

$\vec{a}_A = \vec{0} \frac{m}{s^2} \longrightarrow$ FIXED JOINT.

$$\vec{a}_B = \vec{a}_A + \vec{\varepsilon}_1 \times \vec{r}_{AB} - \omega_1^2 \cdot \vec{r}_{AB} = 0 + \begin{pmatrix} 0 \\ 0 \\ -3 \end{pmatrix} \times \begin{pmatrix} 0.13 \\ 0.21 \\ 0 \end{pmatrix} - (-2)^2 \cdot \begin{pmatrix} 0.13 \\ 0.21 \\ 0 \end{pmatrix} =$$

$$= 0 + \begin{vmatrix} \overset{\oplus}{i} & \overset{\ominus}{j} & \overset{\oplus}{k} \\ 0 & 0 & -3 \\ 0.13 & 0.21 & 0 \end{vmatrix} - 4 \cdot \begin{pmatrix} 0.13 \\ 0.21 \\ 0 \end{pmatrix} = 0 + \begin{pmatrix} 0.63 \\ -0.39 \\ 0 \end{pmatrix} - \begin{pmatrix} 0.52 \\ 0.84 \\ 0 \end{pmatrix} = \underline{\underline{\begin{pmatrix} 0.11 \\ -1.23 \\ 0 \end{pmatrix} \frac{m}{s^2}}}$$

$$\vec{a}_C = \vec{a}_B + \vec{\varepsilon}_2 \times \vec{r}_{BC} - \omega_2^2 \cdot \vec{r}_{BC} = \begin{pmatrix} 0.11 \\ -1.23 \\ 0 \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ \varepsilon_2 \end{pmatrix} \times \begin{pmatrix} 0.77 \\ -0.21 \\ 0 \end{pmatrix} - 0.33^2 \cdot \begin{pmatrix} 0.77 \\ -0.21 \\ 0 \end{pmatrix} =$$

$$= \begin{pmatrix} 0.11 \\ -1.23 \\ 0 \end{pmatrix} + \begin{vmatrix} \overset{\oplus}{i} & \overset{\ominus}{j} & \overset{\oplus}{k} \\ 0 & 0 & \varepsilon_2 \\ 0.77 & -0.21 & 0 \end{vmatrix} - 0.1089 \cdot \begin{pmatrix} 0.77 \\ -0.21 \\ 0 \end{pmatrix} = \begin{pmatrix} 0.11 \\ -1.23 \\ 0 \end{pmatrix} + \begin{pmatrix} 0.21\varepsilon_2 \\ 0.77\varepsilon_2 \\ 0 \end{pmatrix} - \begin{pmatrix} 0.08 \\ -0.13 \\ 0 \end{pmatrix} =$$

$$= \begin{pmatrix} 0.11 + 0.21 \cdot \varepsilon_2 - 0.08 \\ -1.23 + 0.77\varepsilon_2 - (-0.13) \\ 0 \end{pmatrix} = \underline{\begin{pmatrix} 0.03 + 0.21\varepsilon_2 \\ -1.1 + 0.77 \cdot \varepsilon_2 \\ 0 \end{pmatrix} \frac{m}{s^2}}$$

BECAUSE OF THE PISTON, THE $\vec{a}_C$ ACCELERATION HAS ONLY X DIRECTION COMPONENT.

$$\underline{\vec{a}_C = \begin{pmatrix} a_{Cx} \\ 0 \\ 0 \end{pmatrix} \frac{m}{s}}$$

$$\begin{pmatrix} a_{Cx} \\ 0 \\ 0 \end{pmatrix} = \begin{pmatrix} 0.03 + 0.21\varepsilon_2 \\ -1.1 + 0.77\varepsilon_2 \\ 0 \end{pmatrix}$$

$\rightarrow 0 = -1.1 + 0.77\varepsilon_2$

$\varepsilon_2 = 1.43 \ \frac{r}{s^2}$

$$\underline{\vec{\varepsilon}_2 = \begin{pmatrix} 0 \\ 0 \\ 1.43 \end{pmatrix} \frac{r}{s^2}}$$

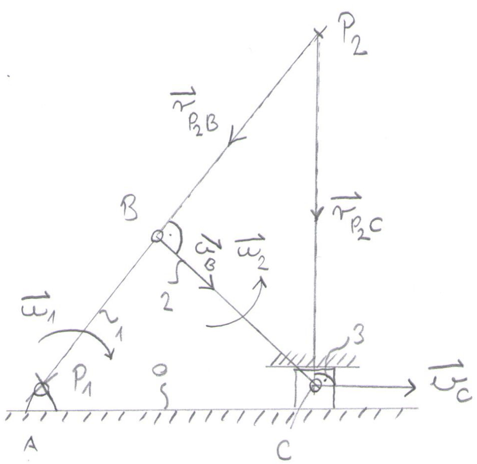
$a_{Cx} = 0.03 + 0.21\varepsilon_2$

$a_{Cx} = 0.03 + 0.21 \cdot 1.43$

$a_{Cx} = 0.33 \ \frac{m}{s^2}$

$$\underline{\underline{\vec{a}_C = \begin{pmatrix} 0.33 \\ 0 \\ 0 \end{pmatrix} \frac{m}{s^2}}}$$

VELOCITY POLE:



VELOCITY POLE = CENTRE POINT OF A ROTATION MOTION

P_1 = A JOINT

$\boxed{P_2}$ $\vec{v}_B = \vec{v}_{P_2} + \vec{\omega}_2 \times \vec{r}_{P_2B}$ $\boxed{OR}$ $\vec{v}_C = \vec{v}_{P_2} + \vec{\omega}_2 \times \vec{r}_{P_2C}$

$$\begin{pmatrix} 0.42 \\ -0.26 \\ 0 \end{pmatrix} = 0 + \begin{pmatrix} 0 \\ 0 \\ 0.33 \end{pmatrix} \times \begin{pmatrix} r_{P_2Bx} \\ r_{P_2By} \\ 0 \end{pmatrix}$$

$$\begin{pmatrix} 0.42 \\ -0.26 \\ 0 \end{pmatrix} = \begin{vmatrix} \oplus & \ominus & \oplus \\ i & j & k \\ 0 & 0 & 0.33 \\ r_{P_2Bx} & r_{P_2By} & 0 \end{vmatrix}$$

$$\begin{pmatrix} 0.42 \\ -0.26 \\ 0 \end{pmatrix} = \begin{pmatrix} -r_{P_2By} \cdot 0.33 \\ r_{P_2Bx} \cdot 0.33 \\ 0 \end{pmatrix}$$

$0.42 = -r_{P_2By} \cdot 0.33 \rightarrow r_{P_2By} = \underline{-1.27\ m}$

$-0.26 = r_{P_2Bx} \cdot 0.33 \rightarrow r_{P_2Bx} = \underline{-0.78\ m}$

$$\vec{r}_{P_2B} = \underline{\underline{\begin{pmatrix} -0.78 \\ -1.27 \\ 0 \end{pmatrix} m}}$$

EXPLANATION:

- THE 2 RESULT POSITION VECTOR GIVE US THE SAME P_2 POINT, THAT IS WHY WE CAN CALCULATE THE P_2 POINT FROM B AND C JOINT AS WELL.
- THE POSITION VECTORS OF THE VELOCITY POLE ARE ALWAYS PERPENDICULAR TO THE VELOCITY VECTORS. FOR EXAMPLE $\vec{r}_{P_2B}$ POSITION VECTOR IS PERPENDICULAR TO $\vec{v}_B$ VELOCITY VECTOR AND $\vec{r}_{P_2C}$ IS ALSO PERPENDICULAR TO THE $\vec{v}_C$ VELOCITY VECTOR.
- THE VELOCITY OF THE VELOCITY VECTOR IS ALWAYS ZERO. $\vec{v}_{P_2} = \vec{0}\ \frac{m}{s}$

ACCELERATION POLE:

G_1 = A JOINT

$\boxed{G_2}$ $\vec{a}_B = \vec{a}_{G_2} + \vec{\varepsilon}_2 \times \vec{r}_{G_2B} - \omega_2^2 \cdot \vec{r}_{G_2B}$ $\boxed{OR}$ $\vec{a}_C = \vec{a}_{G_2} + \vec{\varepsilon}_2 \times \vec{r}_{G_2C} - \omega_2^2 \cdot \vec{r}_{G_2C}$

$$\vec{a}_B = \vec{a}_{G_2} + \vec{\varepsilon}_2 \times \vec{r}_{G_2B} - \omega_2^2 \cdot \vec{r}_{G_2B}$$

$$\begin{pmatrix} 0.11 \\ -1.23 \\ 0 \end{pmatrix} = 0 + \begin{pmatrix} 0 \\ 0 \\ 1.43 \end{pmatrix} \times \begin{pmatrix} r_{G_2Bx} \\ r_{G_2By} \\ 0 \end{pmatrix} - 0.33^2 \cdot \begin{pmatrix} r_{G_2Bx} \\ r_{G_2By} \\ 0 \end{pmatrix}$$

$$\begin{pmatrix} 0.11 \\ -1.23 \\ 0 \end{pmatrix} = 0 + \begin{vmatrix} \oplus & \ominus & \oplus \\ i & j & k \\ 0 & 0 & 1.43 \\ r_{G_2Bx} & r_{G_2By} & 0 \end{vmatrix} - 0.1089 \cdot \begin{pmatrix} r_{G_2Bx} \\ r_{G_2By} \\ 0 \end{pmatrix}$$

$$\begin{pmatrix} 0.11 \\ -1.23 \\ 0 \end{pmatrix} = \begin{pmatrix} -1.43\, r_{G_2By} \\ 1.43\, r_{G_2Bx} \\ 0 \end{pmatrix} - \begin{pmatrix} 0.1089\, r_{G_2Bx} \\ 0.1089\, r_{G_2By} \\ 0 \end{pmatrix}$$

$$\left.\begin{aligned} 0.11 &= -1.43\, r_{G_2By} - 0.1089\, r_{G_2Bx} \\ -1.23 &= 1.43\, r_{G_2Bx} - 0.1089\, r_{G_2By} \end{aligned}\right\} / \cdot 13.13$$

$$\left.\begin{aligned} 1.443 &= -18.7759\, r_{G_2By} - 1.43\, r_{G_2Bx} \\ -1.23 &= 1.43\, r_{G_2Bx} - 0.1089\, r_{G_2By} \end{aligned}\right\} +$$

$$0.2143 = -18.8848\, r_{G_2By}$$

$$18.8848\, r_{G_2By} = -0.2143$$

$$\underline{r_{G_2By} = -0.01\,m}$$

$$-1.23 = 1.43\, r_{G_2Bx} - 0.1089 \cdot (-0.01)$$

$$-1.23 = 1.43\, r_{G_2Bx} + 1.089 \cdot 10^{-3}$$

$$-1.231 = 1.43\, r_{G_2Bx}$$

$$\underline{r_{G_2Bx} = -0.86\,m}$$

$$\underline{\underline{\vec{r}_{G_2B} = \begin{pmatrix} -0.86 \\ -0.01 \\ 0 \end{pmatrix} m}}$$

EXPLANATION:

- IN CASE OF ACCELERATION POLE, WE DETERMINE THE VALUES OF THE POSITION VECTOR, WHICH POINTS FROM THE ACCELERATION POLE TO THE RIGHT ACCELERATION VECTOR. FOR EXAMPLE $\vec{r}_{G_2B}$ OR $\vec{r}_{G_2C}$.
- THE ACCELERATION OF ACCELERATION POLE IS ALWAYS ZERO: $\vec{a}_{G_2} = \vec{0}\ \frac{m}{s^2}$
- FIXED JOINTS CAN BE ACCELERATION POLES.