2010年度　ロボット工学Ⅰ
レポート解答例

東京海洋大学　海洋工学部
伊藤雅則　清水悦郎

2010/09/08

6.22

- Planet gearの角速度

$$\omega = \frac{40}{7}\pi \quad \text{[rad/s]（時計回り）}$$

- Planet gear中心の速度

$$v = 40\pi \quad \text{[in/s]}$$

6.35

- O点の角速度

$$\omega_O = -1.29 \text{ [rad/s]}$$

- A点の角速度

$$\omega_O = 4.83 \text{ [rad/s]}$$

6.44

- 質量mの上がる速度

$$v = 0.96 \text{ [m/s]}$$

6.45

- 問題の設定では解が得られず，釣り上げる速度を実現する角速度は解のようになる.

$$\omega_{AB} = 0 \quad \text{[rad/s]}$$

$$\omega_{BC} = 1.5 \quad \text{[rad/s]}$$

6.46

- C点の速度

$$v_c = \begin{bmatrix} 10.86 \\ 7.52 \\ 0 \end{bmatrix} \text{ [in/s]}$$

6.47

- 角速度は以下のようになる

$$\omega_{AB} = 0.18 \quad \text{[rad/s]}$$
$$\omega_{BC} = 0.20 \quad \text{[rad/s]}$$

6.50

- Sun gearの角速度

$$\omega = 52.0 \quad \text{[rad/s]}$$

- A点の速度

$$\omega = 5.2 \quad \text{[m/s]}$$

6.69

- (a)の場合

$$\vec{a}_A = \vec{a}_B + \alpha \times \vec{r}_{A/B} + \omega \times (\omega \times \vec{r}_{A/B})$$

より

$$\vec{a}_A = \begin{bmatrix} 0 \\ 0 \\ 30 \end{bmatrix} \times \begin{bmatrix} \sqrt{3} \\ 1 \\ 0 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 5 \end{bmatrix} \times \left(\begin{bmatrix} 0 \\ 0 \\ 5 \end{bmatrix} \times \begin{bmatrix} \sqrt{3} \\ 1 \\ 0 \end{bmatrix} \right) = \begin{bmatrix} -73.30 \\ 26.96 \\ 0 \end{bmatrix}$$

- (b)の場合

$$\vec{a}_A = \vec{a}_B + \alpha \times \vec{r}_{A/B} - \omega^2 \vec{r}_{A/B}$$

より

$$\vec{a}_A = \begin{bmatrix} 0 \\ 0 \\ 30 \end{bmatrix} \times \begin{bmatrix} \sqrt{3} \\ 1 \\ 0 \end{bmatrix} - 25 \begin{bmatrix} \sqrt{3} \\ 1 \\ 0 \end{bmatrix} = \begin{bmatrix} -73.30 \\ 26.96 \\ 0 \end{bmatrix}$$

6.71 その一

- (a)

$$v_A = v_B + \omega \times \vec{r}_{A/B} = \begin{bmatrix} 0 \\ 0 \\ \omega \end{bmatrix} \times \begin{bmatrix} 0 \\ 0.3 \\ 0 \end{bmatrix} = \begin{bmatrix} 6 \\ 0 \\ 0 \end{bmatrix}$$

$$\Rightarrow \omega = -20[\mathrm{rad/s}]$$

A点の加速度が与えられ，$a = r\alpha$ であることより

$$20 = -0.3\alpha \qquad \Rightarrow \begin{bmatrix} 0 \\ 0 \\ -66.7 \end{bmatrix} [\mathrm{rad/s^2}]$$

6.71 その二

- (b)

$$\vec{a}_A = \vec{a}_B + \alpha \times \vec{r}_{A/B} - \omega^2 \vec{r}_{A/B}$$

より

$$\vec{a}_B = \begin{bmatrix} 20 \\ 0 \\ 0 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ -66.7 \end{bmatrix} \times \begin{bmatrix} 0 \\ -0.3 \\ 0 \end{bmatrix} - 400 \begin{bmatrix} 0 \\ -0.3 \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ 120 \\ 0 \end{bmatrix} [\mathrm{m/s^2}]$$

$$\vec{a}_C = \begin{bmatrix} 20 \\ 0 \\ 0 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ -66.7 \end{bmatrix} \times \begin{bmatrix} -0.3 \\ 0 \\ 0 \end{bmatrix} - 400 \begin{bmatrix} -0.3 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 140 \\ 20 \\ 0 \end{bmatrix} [\mathrm{m/s^2}]$$

$$\begin{aligned} \vec{a}_D &= \begin{bmatrix} 20 \\ 0 \\ 0 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ -66.7 \end{bmatrix} \times \begin{bmatrix} -\frac{0.3\sqrt{2}}{2} \\ \frac{0.3\sqrt{2}}{2} \\ 0 \end{bmatrix} - 400 \begin{bmatrix} -\frac{0.3\sqrt{2}}{2} \\ \frac{0.3\sqrt{2}}{2} \\ 0 \end{bmatrix} \\ &= \begin{bmatrix} 118.7 \\ -98.7 \\ 0 \end{bmatrix} [\mathrm{m/s^2}] \end{aligned}$$

6.72 その一

- $\vec{v}_A = \vec{v}_B + \omega \times \vec{r}_{A/B}$

  より

$$\vec{v}_A = \begin{bmatrix} 0 \\ 0 \\ 2 \end{bmatrix} \times \begin{bmatrix} -6\sqrt{2} \\ -6\sqrt{2} \\ 0 \end{bmatrix} = \begin{bmatrix} 12\sqrt{2} \\ -12\sqrt{2} \\ 0 \end{bmatrix} [\mathrm{in/s}]$$

$$\vec{v}_C = \begin{bmatrix} 12\sqrt{2} \\ -12\sqrt{2} \\ 0 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ \omega_{CA} \end{bmatrix} \times \begin{bmatrix} 24 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 12\sqrt{2} \\ -12\sqrt{2} + 24\omega_{CA} \\ 0 \end{bmatrix} [\mathrm{in/s}]$$

$$\begin{aligned} \vec{v}_D &= \begin{bmatrix} 12\sqrt{2} \\ -12\sqrt{2} + 24\omega_{CA} \\ 0 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ \omega_{DC} \end{bmatrix} \times \begin{bmatrix} 10\sqrt{2} \\ 10\sqrt{2} \\ 0 \end{bmatrix} \\ &= \begin{bmatrix} 12\sqrt{2} - 10\sqrt{2}\omega_{DC} \\ -12\sqrt{2} + 24\omega_{CA} + 10\sqrt{2}\omega_{DC} \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} [\mathrm{in/s}] \end{aligned}$$

$$\Rightarrow \omega_{DC} = \frac{6}{5}[\mathrm{rad/s}], \omega_{CA} = 0[\mathrm{rad/s}]$$

6.72 その二

- $\vec{a}_A = \vec{a}_B + \alpha \times \vec{r}_{A/B} - \omega^2 \vec{r}_{A/B}$

  より

$$\vec{a}_A = \begin{bmatrix} 0 \\ 0 \\ 10 \end{bmatrix} \times \begin{bmatrix} -6\sqrt{2} \\ -6\sqrt{2} \\ 0 \end{bmatrix} - 4 \begin{bmatrix} -6\sqrt{2} \\ -6\sqrt{2} \\ 0 \end{bmatrix} = \begin{bmatrix} 84\sqrt{2} \\ -36\sqrt{2} \\ 0 \end{bmatrix} [\mathrm{in/s^s}]$$

$$\vec{a}_C = \begin{bmatrix} 84\sqrt{2} \\ -36\sqrt{2} \\ 0 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ \alpha_{CA} \end{bmatrix} \times \begin{bmatrix} 24 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 84\sqrt{2} \\ -36\sqrt{2} + 24\alpha_{CA} \\ 0 \end{bmatrix} [\mathrm{in/s^2}]$$

$$\begin{aligned} \vec{a}_D &= \begin{bmatrix} 84\sqrt{2} \\ -36\sqrt{2} + 24\alpha_{CA} \\ 0 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ \alpha_{DC} \end{bmatrix} \times \begin{bmatrix} 10\sqrt{2} \\ 10\sqrt{2} \\ 0 \end{bmatrix} - \frac{36}{25} \begin{bmatrix} 10\sqrt{2} \\ 10\sqrt{2} \\ 0 \end{bmatrix} \\ &= \begin{bmatrix} 84\sqrt{2} - 10\sqrt{2}\alpha_{DC} - \frac{72}{5}\sqrt{2} \\ -36\sqrt{2} + 24\alpha_{CA} + 10\sqrt{2}\alpha_{DC} - \frac{72}{5}\sqrt{2} \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} [\mathrm{in/s^2}] \end{aligned}$$

$$\Rightarrow \alpha_{DC} = 6.96[\mathrm{rad/s^2}], \alpha_{CA} = -1.13[\mathrm{rad/s^2}]$$

6.74

- Diskの中心の速度を求める

$$\vec{v}_o = \begin{bmatrix} 4 \\ 0 \\ 0 \end{bmatrix} [\mathrm{in/s^s}]$$

球面中心の速度，加速度を求め，それよりA，Bの加速度を求める

$$\vec{v}_o = \begin{bmatrix} 4 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ \omega \end{bmatrix} \times \begin{bmatrix} 0 \\ 16 \\ 0 \end{bmatrix} = \begin{bmatrix} -16\omega \\ 0 \\ 0 \end{bmatrix} \quad \Rightarrow \omega = -0.25[\mathrm{rad/s}]$$

$$\vec{a}_o = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} \times \begin{bmatrix} 0 \\ 16 \\ 0 \end{bmatrix} - \omega^2 \begin{bmatrix} 0 \\ 16 \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ -1 \\ 0 \end{bmatrix} [\mathrm{in/s^2}]$$

$$\vec{a}_A = \begin{bmatrix} 0 \\ -1 \\ 0 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} \times \begin{bmatrix} 0 \\ 4 \\ 0 \end{bmatrix} - \omega^2 \begin{bmatrix} 0 \\ 4 \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ -5 \\ 0 \end{bmatrix} [\mathrm{in/s^2}]$$

$$\vec{a}_B = \begin{bmatrix} 0 \\ -1 \\ 0 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} \times \begin{bmatrix} 0 \\ -4 \\ 0 \end{bmatrix} - \omega^2 \begin{bmatrix} 0 \\ -4 \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ 3 \\ 0 \end{bmatrix} [\mathrm{in/s^2}]$$

6.75

- x軸方向の加速度の釣り合いより求める

$$a_{Ax} = -200[\mathrm{in/s^2}]$$
$$a_{Bx} = 0[\mathrm{in/s^2}] \qquad \Rightarrow \alpha_P = -14.3[\mathrm{rad/s^2}]$$

6.76

- x軸方向の速度，加速度の釣り合いより求める

$$v_{Ax} = -80[\text{in/s}] \quad v_{Bx} = 0[\text{in/s}] \qquad \Rightarrow \omega_{PB} = -\frac{40}{7}[\text{rad/s}^2]$$

$$v_{Px} = -40 = -27\omega_{PO}[\text{in/s}] \qquad \Rightarrow \omega_{PO} = \frac{40}{27}[\text{rad/s}^2]$$

$$a_{Ax} = 240[\text{in/s}^2] \quad a_{Bx} = 0[\text{in/s}^2] \qquad \Rightarrow \alpha_{PB} = \frac{120}{7}[\text{rad/s}^2]$$

$$a_{Px} = 120 = -27\alpha_{PO}[\text{in/s}^2] \qquad \Rightarrow \alpha_{PO} = -\frac{120}{27}[\text{rad/s}^2]$$

$$\begin{aligned} \vec{a}_P &= \vec{a}_O + \alpha_{PO} \times \vec{r}_{P/O} - \omega_{PO}^2 \vec{r}_{P/O} \\ &= \begin{bmatrix} 120 \\ -\frac{1600}{27} \\ 0 \end{bmatrix} \end{aligned} \qquad \Rightarrow |\vec{a}_P| = 133.8[\text{in/s}^2]$$

6.78

- *P*点の*y*軸方向の速度，加速度が0となることより求める

$$
\begin{aligned}
\vec{v}_P &= \vec{v}_B + \omega_{PB} \times \vec{r}_{P/B} \\
&= \begin{bmatrix} 41.8 \\ -41.8 \\ 0 \end{bmatrix} + \begin{bmatrix} 2\omega_{PB} \\ 6\omega_{PB} \\ 0 \end{bmatrix} = \begin{bmatrix} 55.8 \\ 0 \\ 0 \end{bmatrix} [\mathrm{in/s}]
\end{aligned}
$$

$$(\omega_{PB} = 7.0[\mathrm{rad/s}])$$

$$
\begin{aligned}
\vec{a}_P &= \vec{a}_B + \alpha_{PB} \times \vec{r}_{P/B} - \omega_{PB}^2 \vec{r}_{P/B} \\
&= \begin{bmatrix} -1167.6 \\ -775.6 \\ 0 \end{bmatrix} + \begin{bmatrix} 2\alpha_{PB} \\ 6\alpha_{PB} \\ 0 \end{bmatrix} = \begin{bmatrix} -909.0 \\ 0 \\ 0 \end{bmatrix} [\mathrm{in/s^2}]
\end{aligned}
$$

$$\left(\alpha_{PB} = 129.3[\mathrm{rad/s^2}]\right)$$

6.82

- C点のy軸方向の速度，加速度が0となることより求める

$$
\begin{aligned}
\vec{v}_C &= \vec{v}_B + \omega_{BC} \times \vec{r}_{C/B} \\
&= \begin{bmatrix} 24 \\ -24 \\ 0 \end{bmatrix} + \begin{bmatrix} 7\omega_{BC} \\ 10\omega_{BC} \\ 0 \end{bmatrix} = \begin{bmatrix} 40.8 \\ 0 \\ 0 \end{bmatrix} [\mathrm{in/s}]
\end{aligned}
$$

$$(\omega_{BC} = 2.4[\mathrm{rad/s}])$$

$$
\begin{aligned}
\vec{a}_C &= \vec{a}_B + \alpha_{BC} \times \vec{r}_{C/B} - \omega_{BC}^2 \vec{r}_{C/B} \\
&= \begin{bmatrix} -121.6 \\ -183.7 \\ 0 \end{bmatrix} + \begin{bmatrix} 7\alpha_{BC} \\ 10\alpha_{BC} \\ 0 \end{bmatrix} = \begin{bmatrix} 7.2 \\ 0 \\ 0 \end{bmatrix} [\mathrm{in/s^2}]
\end{aligned}
$$

$$\left(\alpha_{PB} = 18.4[\mathrm{rad/s^2}]\right)$$

6.85

$$
\begin{aligned}
\vec{a}_B &= \vec{a}_A + \alpha_{AB} \times \vec{r}_{B/A} - \omega_{AB}^2 \vec{r}_{B/A} \\
&= \begin{bmatrix} -19.8 \\ -9.6 \\ 0 \end{bmatrix} [\mathrm{m/s^2}]
\end{aligned}
$$

$$
\begin{aligned}
\vec{a}_C &= \vec{a}_B + \alpha_{BC} \times \vec{r}_{C/B} - \omega_{BC}^2 \vec{r}_{C/B} \\
&= \begin{bmatrix} -19.8 \\ -9.6 \\ 0 \end{bmatrix} + \begin{vmatrix} i & j & k \\ 0 & 0 & -4 \\ 2.3 & -0.5 & 0 \end{vmatrix} + \begin{bmatrix} -2.3 \\ 0.5 \\ 0 \end{bmatrix} \\
&= \begin{bmatrix} -24.1 \\ -18.3 \\ 0 \end{bmatrix} [\mathrm{m/s^2}]
\end{aligned}
$$

6.86

$$\begin{aligned}\vec{v}_C &= \vec{v}_B + \omega_{BC} \times \vec{r}_{C/B} \\ &= \omega_{AB} \times \vec{r}_{B/A} + \omega_{BC} \times \vec{r}_{C/B}\end{aligned}$$

$$\begin{aligned}\vec{a}_C &= \vec{a}_B + \alpha_{BC} \times \vec{r}_{C/B} - \omega_{BC}^2 \vec{r}_{C/B} \\ &= \alpha_{AB} \times \vec{r}_{B/A} - \omega_{AB}^2 \vec{r}_{B/A} + \alpha_{BC} \times \vec{r}_{C/B} - \omega_{BC}^2 \vec{r}_{C/B}\end{aligned}$$

$$\Rightarrow \quad \begin{aligned}\omega_{AB} &= -0.88[\mathrm{rad/s}] \\ \omega_{BC} &= -1.15[\mathrm{rad/s}] \\ \alpha_{AB} &= -1.06[\mathrm{rad/s^2}] \\ \alpha_{BC} &= -2.40[\mathrm{rad/s^2}]\end{aligned}$$

6.89

$$\begin{aligned}\vec{v}_D &= \omega_{AB} \times \vec{r}_{B/A} + \omega_{BC} \times \vec{r}_{C/B} + \omega_{CD} \times \vec{r}_{D/C} \\ &= [0 \quad 0 \quad 0]^T\end{aligned}$$

$$\begin{aligned}\vec{a}_D &= \alpha_{AB} \times \vec{r}_{B/A} - \omega_{AB}^2 \vec{r}_{B/A} + \alpha_{BC} \times \vec{r}_{C/B} - \omega_{BC}^2 \vec{r}_{C/B} \\ &\quad + \alpha_{CD} \times \vec{r}_{D/C} - \omega_{CD}^2 \vec{r}_{D/C} \\ &= [0 \quad 0 \quad 0]^T\end{aligned}$$

$$\Rightarrow \quad \begin{aligned}\omega_{BC} &= -5.33[\text{rad/s}] \\ \omega_{CD} &= 4.57[\text{rad/s}] \\ \alpha_{BC} &= 410.53[\text{rad/s}^2] \\ \alpha_{CD} &= 278.31[\text{rad/s}^2]\end{aligned}$$

6.92

$$\begin{aligned}
\vec{a}_D &= \vec{a}_C \\
&= -\omega_{AB}^2 \vec{r}_{B/A} - \omega_{BC}^2 \vec{r}_{C/B} \\
&= \begin{bmatrix} -0.135 \\ -0.144 \\ 0 \end{bmatrix} [\mathrm{m/s^2}]
\end{aligned}$$

6.93

$$\begin{aligned}
\vec{v}_D &= \vec{v}_C + \omega_{CD} \times \vec{r}_{D/C} \\
&= \omega_{AB} \times \vec{r}_{B/A} + \omega_{BC} \times \vec{r}_{C/B} + \omega_{CD} \times \vec{r}_{D/C} \\
&= \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} \qquad \Rightarrow \qquad \begin{aligned} \omega_{BC} &= -0.53[\mathrm{rad/s}] \\ \omega_{CD} &= -0.84[\mathrm{rad/s}] \end{aligned}
\end{aligned}$$

$$\begin{aligned}
\vec{a}_D &= \vec{a}_C + \alpha_{CD} \times \vec{r}_{D/C} - \omega_{CD}^2 \vec{r}_{D/C} \\
&= -\omega_{AB}^2 \vec{r}_{B/A} + \alpha_{BC} \times \vec{r}_{C/B} - \omega_{BC}^2 \vec{r}_{C/B} \\
&\quad + \alpha_{CD} \times \vec{r}_{D/C} - \omega_{CD}^2 \vec{r}_{D/C} \\
&= \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} \qquad \Rightarrow \qquad \begin{aligned} \alpha_{BC} &= 0.02[\mathrm{rad/s^2}] \\ \alpha_{CD} &= 1.20[\mathrm{rad/s^2}] \end{aligned}
\end{aligned}$$

6.96

- x軸方向の加速度の釣り合いより求める

$$a_{Cx} = -0.58 \cdot 10 = -5.8[\mathrm{m/s^2}]$$

$$0.14\alpha_P = -5.8$$

$$\Rightarrow \alpha_P = -41.43[\mathrm{rad/s^2}]$$

$$0.48\alpha_P = -0.24\alpha_S$$

$$\Rightarrow \alpha_S = -82.86[\mathrm{rad/s^2}]$$

6.97

- x軸方向の速度，加速度よりA点の角速度，角加速度を求める

$$v_{Px} = -0.58 \cdot 4 = -2.32 = 0.14\omega_P$$
$$\Rightarrow \omega_P = -16.57[\mathrm{rad/s}]$$
$$v_{Ax} = -0.2\omega_P = 3.31 = -0.92\omega_A$$
$$\Rightarrow \omega_A = -3.60[\mathrm{rad/s}]$$

$$a_{Px} = 0.58 \cdot 12 = 6.96 = 0.14\alpha_P$$
$$\Rightarrow \alpha_P = 49.71[\mathrm{rad/s^2}]$$
$$a_{Ax} = -0.2\alpha_P = -9.94 = -0.92\alpha_A$$
$$\Rightarrow \alpha_A = 10.80[\mathrm{rad/s^2}]$$

$$\begin{aligned} a_A &= \alpha_A \times \vec{r}_{A/O} - \omega_A^2 \vec{r}_{A/O} \\ &= \begin{bmatrix} -9.94 \\ -11.92 \\ 0 \end{bmatrix} [\mathrm{m/s^2}] \end{aligned}$$
$$\Rightarrow |\vec{a}_A| = 15.52[\mathrm{m/s^2}]$$

6.98

- x軸方向の速度，加速度よりB点の角速度，角加速度を求める

$$v_{Bx} = -14 \cdot 2 = -28 = -4\omega_B$$
$$\Rightarrow \omega_B = 7[\mathrm{rad/s}]$$
$$a_{Bx} = -14 \cdot 4 = -56 = -4\alpha_B$$
$$\Rightarrow \alpha_B = 14[\mathrm{rad/s^2}]$$

$$v_E = v_B + \omega_B \times \vec{r}_{C/B} + \omega_C \times \vec{r}_{D/C} + \omega_D \times \vec{r}_{E/D}$$
$$\Rightarrow \quad \omega_C = -3[\mathrm{rad/s}]$$
$$\omega_D = 2[\mathrm{rad/s}]$$
$$\begin{aligned} a_E &= a_B + \alpha_B \times \vec{r}_{C/B} - \omega_B^2 \vec{r}_{C/B} + \alpha_C \times \vec{r}_{D/C} - \omega_C^2 \vec{r}_{D/C} \\ &\quad + \alpha_D \times \vec{r}_{E/C} - \omega_D^2 \vec{r}_{E/D} \end{aligned}$$
$$\Rightarrow \quad \alpha_C = -22.96[\mathrm{rad/s^2}]$$
$$\alpha_D = 31.14[\mathrm{rad/s^2}]$$

6.141

- y軸方向の速度の釣り合いより求める

$$v_H + 0.08\omega_M = 0.12$$
$$v_H = 0.04\omega_S$$
$$v_H - 0.08\omega_M = -0.04\omega_S \quad \Rightarrow \quad v_H = 0.04[\mathrm{m/s}]$$
$$\omega_S = 1[\mathrm{rad/s}]$$

6.142

- ピストンの速度

$$v_c\,j = -382.16 \text{ [in/s]}$$

6.143

- 角速度は以下のようになる

$$\omega_{AB} = -10.92 \quad \text{[rad/s]}$$

$$\omega_{BC} = 3.22 \quad \text{[rad/s]}$$

6.144

- 角加速度は以下のようになる

$$\alpha_{AB} = -94.45 \quad \text{[rad/s^2]}$$

$$\alpha_{BC} = 59.96 \quad \text{[rad/s^2]}$$

6.147

$$v_C = \omega_{AB} \times \vec{r}_{B/A} + \omega_{BC} \times \vec{r}_{C/B} = [20 \quad 0 \quad 0]^T$$

$$\Rightarrow \quad \omega_{AB} = -2.94[\text{rad/s}]$$

$$\omega_{BC} = 1.18[\text{rad/s}]$$

$$v_G = \omega_{AB} \times \vec{r}_{B/A} + \omega_{BC} \times \vec{r}_{G/B}$$

$$\Rightarrow v_G = \begin{bmatrix} 15.89 \\ -5.86 \\ 0 \end{bmatrix} [\text{in/s}]$$

6.148

$$
\begin{aligned}
a_C &= \alpha_{AB} \times \vec{r}_{B/A} - \omega_{AB}^2 \vec{r}_{B/A} + \alpha_{BC} \times \vec{r}_{C/B} - \omega_{BC}^2 \vec{r}_{C/B} \\
&= [0 \quad 0 \quad 0]^T
\end{aligned}
$$

$$
\Rightarrow \quad \begin{aligned} \alpha_{AB} &= -4.57[\mathrm{rad/s^2}] \\ \alpha_{BC} &= 4.31[\mathrm{rad/s^2}] \end{aligned}
$$

$$
a_G = \alpha_{AB} \times \vec{r}_{B/A} - \omega_{AB}^2 \vec{r}_{B/A} + \alpha_{BC} \times \vec{r}_{G/B} - \omega_{BC}^2 \vec{r}_{G/B}
$$

$$
\Rightarrow a_G = \begin{bmatrix} -8.14 \\ -26.42 \\ 0 \end{bmatrix} [\mathrm{in/s^2}]
$$

6.149

$$v_C = \omega_{AB} \times \vec{r}_{B/A} + \omega_{BC} \times \vec{r}_{C/B} = [1.0 \quad 0 \quad 0]^T$$

$$\Rightarrow \quad \omega_{AB} = -0.15[\mathrm{rad/s}]$$

$$\omega_{BC} = 0.06[\mathrm{rad/s}]$$

6.150

$$v_C = \omega_{AB} \times \vec{r}_{B/A} + \omega_{BC} \times \vec{r}_{C/B}$$

$$\Rightarrow v_C = \begin{bmatrix} -1.48 \\ 0.79 \\ 0 \end{bmatrix} [\mathsf{m/s}]$$

6.151

$$v_C = \omega_{AB} \times \vec{r}_{B/A} + \omega_{BC} \times \vec{r}_{C/B} = [1.0 \quad 0 \quad 0]^T$$

$$\Rightarrow \quad \omega_{AB} = 0.93[\text{rad/s}]$$

$$\omega_{BC} = -1.18[\text{rad/s}]$$

6.152

$$a_C = \alpha_{AB} \times \vec{r}_{B/A} - \omega_{AB}^2 \vec{r}_{B/A} + \alpha_{BC} \times \vec{r}_{C/B} - \omega_{BC}^2 \vec{r}_{C/B}$$

$$\Rightarrow a_C = \begin{bmatrix} -2.99 \\ -1.40 \\ 0 \end{bmatrix} [\mathrm{m/s^2}]$$

6.153

$$
\begin{aligned}
a_C &= \alpha_{AB} \times \vec{r}_{B/A} - \omega_{AB}^2 \vec{r}_{B/A} + \alpha_{BC} \times \vec{r}_{C/B} - \omega_{BC}^2 \vec{r}_{C/B} \\
&= [0 \quad 0 \quad 0]^T
\end{aligned}
$$

$$
\Rightarrow \quad \begin{aligned} \alpha_{AB} &= 2.22[\mathrm{rad/s^2}] \\ \alpha_{BC} &= -1.44[\mathrm{rad/s^2}] \end{aligned}
$$

6.156

$$
\begin{aligned}
v_C &= \omega_{AB} \times \vec{r}_{B/A} + \omega_{BC} \times \vec{r}_{C/B} + \omega_{CD} \times \vec{r}_{D/C} \\
&= = [0.2 \quad 0.8 \quad 0]^T
\end{aligned}
$$

$$
\Rightarrow \quad \begin{aligned} \omega_{AB} &= 0.26[\text{rad/s}] \\ \omega_{BC} &= 2.80[\text{rad/s}] \end{aligned}
$$

6.157

$$\begin{aligned} a_D &= \alpha_{AB} \times \vec{r}_{B/A} - \omega_{AB}^2 \vec{r}_{B/A} + \alpha_{BC} \times \vec{r}_{C/B} - \omega_{BC}^2 \vec{r}_{C/B} \\ &\quad + \alpha_{CD} \times \vec{r}_{D/C} - \omega_{CD}^2 \vec{r}_{D/C} \\ &= [0 \quad 0 \quad 0]^T \end{aligned}$$

$$\Rightarrow \quad \begin{aligned} \alpha_{AB} &= -8.66[\mathrm{rad/s^2}] \\ \alpha_{BC} &= 6.77[\mathrm{rad/s^2}] \end{aligned}$$

6.158

$$\begin{aligned} v_C &= \omega_{AB} \times \vec{r}_{B/A} + \vec{v}_{BC} + \omega_{BC} \times \vec{r}_{C/B} \\ &= \begin{vmatrix} i & j & k \\ 0 & 0 & \omega_{AB} \\ 1.8\cos 30 & 1.8\sin 30 & 0 \end{vmatrix} + \begin{bmatrix} -v_{BC}\sin\beta \\ v_{BC}\cos\beta \\ 0 \end{bmatrix} \\ &\quad + \begin{vmatrix} i & j & k \\ 0 & 0 & \omega_{AB} \\ 2 - 1.8\cos 30 & -1.8\sin 30 & 0 \end{vmatrix} \\ &= [0 \quad 0 \quad 0]^T \end{aligned}$$

$$\left(\beta = \tan^{-1}\left(\frac{2 - 1.8\cos 30}{1.8\sin 30}\right)\right)$$

$$\Rightarrow \quad \omega_{BC} = -1.22[\text{rad/s}]$$

$$v_{BC} = 17.96[\text{m/s}]$$