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Problem 1:
(See PDF)

Problem 2:
angular velocities for each of the joints in order that the end effector moves as desired at this instant are (1-6):
[-8.7322, 6.6690, 71.3122, -188.1239, 10.9410, -64.2889] (rad/s^2 rad/s^2 in/s^2 in/s^2 rad/s^2 in/s^2)
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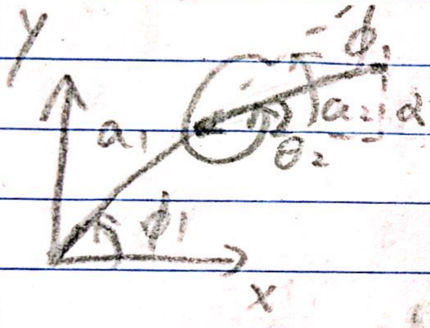
Exam 4

1) ${}^0\underline{S}^1 = {}^1\underline{S}^2 = {}^2\underline{S}^3 = \begin{bmatrix}0\\0\\1\end{bmatrix}$ ${}^2\underline{S}_0^3 = \begin{bmatrix}a_1\sin\phi_1 + a_2\sin(\phi_1+\theta_2)\\ -a_1\cos\phi_1 - a_2\cos(\phi_1+\theta_2)\\ 0\end{bmatrix}$

${}^0\underline{S}_0^1 = \begin{bmatrix}0\\0\\0\end{bmatrix}$ ${}^1\underline{S}_0^2 = \begin{bmatrix}a_1\sin\phi_1\\ -a_1\cos\phi_1\\ 0\end{bmatrix}$

(goes through origin) $\begin{bmatrix}a_1\cos\phi_1\\ a_1\sin\phi_1\\ 0\end{bmatrix} \times \begin{bmatrix}0\\0\\1\end{bmatrix}$ $\begin{bmatrix}a_1\cos\phi_1 + a_2\cos(\phi_1+\theta_2)\\ a_1\sin\phi_1 + a_2\sin(\phi_1+\theta_2)\\ 0\end{bmatrix} \times \begin{bmatrix}0\\0\\1\end{bmatrix}$



$\alpha = \phi_1 - (360 - \theta_2)$

$\alpha = \phi_1 + \theta_2 - 360$

$$J = \begin{bmatrix} 0 & 0 & 0\\ 0 & 0 & 0\\ 1 & 1 & 1\\ 0 & a_1\sin\phi_1 & a_1\sin\phi_1 + a_2\sin(\phi_1+\theta_2)\\ 0 & -a_1\cos\phi_1 & -a_1\cos\phi_1 - a_2\cos(\phi_1+\theta_2)\\ 0 & 0 & 0 \end{bmatrix}$$

$$\begin{bmatrix}{}^0\omega^3\\ {}^0V_0^3\end{bmatrix} = J\,\omega$$

$$\det\begin{bmatrix} 1 & 1 & 1\\ 0 & a\sin\phi_1 & a\sin\phi_1 + a_2\sin(\phi_1+\theta_2)\\ 0 & -a_1\cos\phi_1 & -a_1\cos\phi_1 - a_2\cos(\phi_1+\theta_2)\end{bmatrix}$$

$= -a_1\sin\phi_1(a_1\cos\phi_1 + a_2\cos(\phi_1+\theta_2)) + a_1\cos\phi_1(a_1\sin\phi_1 + a_2\sin(\phi_1+\theta_2))$

$\det = 0$

$$a_1 \sin\phi_1 \left(a_1 \cos\phi_1 + a_2 \cos(\phi_1 + \theta_2)\right) = a_1 \cos\phi_1 \left(a_1 \sin\phi_1 + a_2 \sin(\phi_1 + \theta_2)\right)$$

$$a_1 \sin\phi_1 \cos\phi_1 + a_2 \sin\phi_1 \cos(\phi_1 + \theta_2) = a_1 \sin\phi_1 \cos\phi_1 + a_2 \cos\phi_1 \sin(\phi_1 + \theta_2)$$

$$\sin\phi_1 \cos(\phi_1 + \theta_2) = \cos\phi_1 \sin(\phi_1 + \theta_2)$$

$$\tan\phi_1 = \tan(\phi_1 + \theta_2)$$

$\theta_2 = 0, \pi$

a_2 is collinear with a_1, or overlaps with a_1.