

$$M(q) = m_1 J_{v_1}^T J_{v_1} + J_{\omega_1}^T I_{c_1} J_{\omega_1} + m_2 J_{v_2}^T J_{v_2} + J_{\omega_2}^T I_{c_2} J_{\omega_2} + m_3 J_{v_3}^T J_{v_3} + J_{\omega_3}^T I_{c_3} J_{\omega_3} + m_4 J_{v_4}^T J_{v_4} + J_{\omega_4}^T I_{c_4} J_{\omega_4} + m_5 J_{v_5}^T J_{v_5} + J_{\omega_5}^T I_{c_5} J_{\omega_5} \quad (75)$$

The values of the moment of inertia for the center of mass were taken from Table 2, and put in the form of a matrix as shown in Equation (76).

$$I_{c_1} = \begin{bmatrix} 0.0031 & 0.0043 & 0.0019 \\ 0.0043 & -0.0005 & 0.0017 \\ 0.0019 & 0.0017 & 0.003 \end{bmatrix} I_{c_2} = \begin{bmatrix} 0.0021 & 0.00660 & 0.0048 \\ 0.0066 & -0 & -0.0028 \\ 0.0048 & -0.0028 & -0 \end{bmatrix} \\ I_{c_3} = e^{-3} \begin{bmatrix} 0.4028 & 0.6201 & 0.7881 \\ 0.6201 & -0.0276 & -0.0616 \\ 0.7881 & -0.0616 & -0.2498 \end{bmatrix} I_{c_4} = \begin{bmatrix} 0.0034 & 0.0034 & 0.0002 \\ 0.0034 & 0 & -0 \\ 0.0002 & -0 & 0 \end{bmatrix} \quad (76) \\ I_{c_5} = e^{-3} \begin{bmatrix} 0.5892 & 0.0067 & 0.5842 \\ 0.0067 & -0.0001 & 0 \\ 0.5842 & 0 & -0.0076 \end{bmatrix}$$

To calculate the mass matrix of the robot, the value of  $J_{v_1}^T, J_{v_2}^T, J_{v_3}^T, J_{v_4}^T, J_{v_5}^T$  and  $J_{\omega_1}^T, J_{\omega_2}^T, J_{\omega_3}^T, J_{\omega_4}^T, J_{\omega_5}^T$  computed above was substituted into Equation (75) using the Jacobian in the center of mass, and substituting for the inertia values from Equation (76), and the mass values from Table 1, by solving this equation using the MATLAB, the Equations (77) to (101) are got.  $M(q)$  is a  $5 \times 5$  matrix representing the mass affecting each link according to the configuration of the robotic arm.

$$m_{11} = 0.004c(\theta_2 + 5.6192e^{-4}) - 0.0072s(2\theta_1) + 593(2.0329e^{-29}c_1 + 8.6736e^{-29}c_{12} + 4.7592e^{-33}c_4s_1 - 7.5027e^{-29}c_1s_{23} + 3.7355e^{-29}s_{14}c(\theta_5 - 1.5843) + 7.5027e^{-29}c_{123} - 8.1315e^{-30}c_{12}s_3 - 8.1315e^{-30}c_{13}s_2 + 3.7355e^{-29}s(\theta_5 - 1.5843)c_1s_{23} + 4.7592e^{-23}c_{12}s_{34} + 4.7592e^{-33}c_{13}s_{24} - 3.7355e^{-29}s(\theta_5 - 1.5843)c_{123} - 3.7355e^{-29}c_{124}s_3c(\theta_5 - 1.5843) - 3.7355e^{-29}c_{134}s_2c(\theta_5 - 1.5843))^2 + 67471(6.5052e^{-27}c_1 - 6.0346e^{-28}s_1 + 2.7756e^{-26}c_{12} + 4.8721e^{-27}c(\theta_3 - 2.5577)c_{12} - 4.8721e^{-27}s(\theta_3 - 2.5577)c_1s_2)^2 + 4.8499e^{-6}c(\theta_2 + \theta_3)^2 + 58369(1.9594e^{-30}c_1s(\theta_4 + 1.5843) - 3.4694e^{-27}c_2s_1 - 8.1315e^{-28}s_1 + 3.2526e^{-28}c_2s_{13} + 3.2526e^{-28}c_3s_{12} - 1.6169e^{-27}s_{123} + 1.6169e^{-27}c_{23}s_1 + 1.9594e^{-30}c_2c(\theta_4 + 1.5843)s_{13} + 1.9594e^{-30}c_3c(\theta_4 + 1.5843)s_{12})^2 - 0.0026c_1^2 + 6747(6.0346e^{-28}c_1 + 6.5052e^{-27}s_1 + 2.775e^{-26}c_2s_1 + 4.8721e^{-27}c(\theta_3 - 2.5577)c_2s_1 - 4.8721e^{-27}s(\theta_3 - 2.5577)s_{12})^2 + (c_4s_1 + c_{12}s_{34} + c_{13}s_{24})(5.8916e^{-4}c_4s_1 - 6.7417e^{-5}c_{14} - 5.8418e^{-4}c(\theta_2 + \theta_3)s_4 + 5.8916e^{-4}c_{12}s_{34} + 5.8916e^{-4}c_{13}s_{24} + 6.7417e^{-6}c_2s_{134} + 6.7417e^{-6}c_3s_{124}) + (c_2s_{134} - c_{14} + c_3s_{124})(8.7259e^8c_{14} + 6.7417e^{-6}c_4s_1 - 9.7093e^{-11}c(\theta_2 + \theta_3)s_4 + 6.7417e^{-6}c_{12}s_{34} + 6.7417e^{-6}c_{13}s_{24} - 8.7259e^{-8}c_2s_{134} - 8.7259e^{-8}c_3s_{124} + 58369(1.6169e^{-27}c_{123} - 3.4694e^{-27}c_{12} - 1.9594e^{-30}s_1s(\theta_4 + 1.5843) - 1.6169e^{-27}c_1s_{23} - 8.1315e^{-28}c_1 + 3.256e^{-28}c_{12}s_3 + 3.256e^{-28}c_{13}s_2 + 1.9594e^{-30}c_{12}c(\theta_4 + 1.5843)s_3 + 1.9594e^{-30}c_{13}c(\theta_4 + 1.5843)s_2)^2 + 0.0034c(\theta_2 + \theta_3)^2c_1^2 + 593(4.7592e^{-33}c_{14} - 2.0329e^{-29}s_1 - 8.6736e^{-29}c_2s_1 + 8.1315e^{-30}c_2s_{13} + 8.1315e^{-30}c_3s_{12} + 3.7355e^{-29}c_1s_4c(\theta_5 + 1.5843) + 7.5027e^{-29}s_{123} - 7.5027e^{-29}c_{23}s_1 - 3.7355e^{-29}s(\theta_5 + 1.5843)s_{123} - 4.7592e^{-33}c_2s_{134} - 4.7592e^{-33}c_3s_{124} + 3.7355e^{-29}s(\theta_5 + 1.5843)c_{23}s_1 + 3.7355e^{-29}c_{24}s_{13}c(\theta_5 + 1.5843) + 3.7355e^{-29}c_{34}s_{12}c(\theta_5 + 1.5843))^2 + 0.3830c(\theta_2 + 5.6192e^{-4})^2 + 0.0068c(\theta_2 + \theta_3)^2c_1s_1 - c(\theta_2 + \theta_3)s_4(5.8418e^{-4}c_4s_1 - 9.7093e^{-10}c_{14} + 7.6194e^{-6}c(\theta_2 + \theta_3)s_4 + 5.8418e^{-4}c_{12}s_{34} + 5.8418e^{-4}c_{13}s_{24} + 9.7093e^{-10}c_2s_{134} + 9.7093e^{-10}c_3s_{124}) \times 3.2361e^{-4}c(\theta_2 + \theta_3)s(\theta_2 + \theta_3)c_1 - 3.2188e^{-7}c(\theta_2 + \theta_3)s(\theta_2 + \theta_3)s_1 + 0.0071 \quad (77)$$

$$m_{12} = 6.5921e^{-5}s(\theta_2 + \theta_3 - 2.5577) - 0.0072s(2\theta_1) - 0.0027s(\theta_2 + 5.6192e^{-4}) + 3.7554e^{-4}s_2 + 4.8499e^{-6}c(\theta_2 + \theta_3)^2 + 1.1437e^{-26}s(\theta_4 + \quad (78)$$

$$\begin{aligned}
& 1.6029) \left( 4.0422e^{-27}c_2s_3 - 8.1315e^{-28}c_{23} - 8.6736e^{-27}s_2 + 4.0422e^{-27}c_3s_2 + \right. \\
& \quad 8.1315e^{-28}c_2s_3 + 4.8984e^{-30}c(\theta_4 + 1.5843)s_{23} - 4.8984e^{-30}c_{23}c(\theta_4 + \\
& \quad \left. 1.5843) \right) - 0.0026c_1^2 - 593(4.7592e^{-33}c_4 + 3.755e^{-29}s_4c(\theta_5 - \\
& \quad 1.5843)(5.4210e^{-26}s_2 + 5.0822e^{-27}c_{23} + 4.6892e^{-26}c_{23} + 4.6892e^{-26}c_3s_2 - \\
& \quad 5.0822e^{-27}s_{23} + 2.9745e^{-30}s_{234} - 2.3347e^{-26}s(\theta_5 - 1.5843)c_2s_3 - \\
& \quad 2.3347e^{-26}s(\theta_5 - 1.5843)c_3s_2 - 2.9745e^{-30}c_{23}s_4 + 2.3347e^{-26}c_{234}c(\theta_5 - \\
& \quad 1.5843) - 2.3347e^{-26}c_4s_{23}c(\theta_5 - 1.5843) + (c_4s_1 + c_{12}s_{34} + \\
& \quad c_{13}s_{24})(5.8916e^{-4}c_4s_1 - 6.7417e^{-6}c_{14} - 5.8418e^{-4}c(\theta_2 + \theta_3)s_4 + \\
& \quad 5.8916e^{-4}c_{12}s_{34} + 5.8916e^{-4}c_{13}s_{24} + 6.7417e^{-6}c_2s_{134} + 6.7417e^{-6}c_3s_{124}) + \\
& \quad (c_2s_{134} - c_{14} + c_3s_{124})(8.7259e^{-8}c_{14} + 6.7417e^{-6}c_4s_1 - 9.7093e^{-10}c(\theta_2 + \\
& \quad \theta_3)s_4 + 6.7417e^{-6}c_{12}s_{34} + 6.7417e^{-6}c_{13}s_{24} - 8.7259e^{-8}c_2s_{134} - \\
& \quad 8.7259e^{-8}c_3s_{124}) + 3.4167c(\theta_2 + \theta_3)^2c_1^2 + 0.0068c(\theta_2 + \theta_3)^2c_1s_1 - \\
& \quad c(\theta_2 + \theta_3)s_4(5.8418e^{-4}c_4s_1 - 9.7093e^{-10}c_{14} + 7.6194e^{-5}c(\theta_2 + \theta_3)s_4 + \\
& \quad 5.8418e^{-4}c_{12}s_{34} + 5.8418e^{-4}c_{13}s_{24} + 9.7093e^{-10}c_2s_{134} + 9.7093e^{-10}c_3s_{124}) + \\
& \quad 0.0032c(\theta_2 + \theta_3)s(\theta_2 + \theta_3)c_1 - 3.2188e^{-7}c(\theta_2 + \theta_3)s(\theta_2 + \theta_3)s_1 + 0.0029 \\
& m_{13} = 6.5921e^{-5}s(\theta_2 + \theta_3 - 2.5577) - 0.0072s(2\theta_1) + 4.8499e^{-6}c(\theta_2 + \theta_3)^2 - \\
& \quad 593(4.7592e^{-33}c_4 + 3.7355e^{-29}s_4c(\theta_5 + 1.5843))(5.0822e^{-27}c_{23} + \\
& \quad 4.6892e^{-26}c_2s_3 + 4.6892e^{-26}c_3s_2 - 5.0822e^{-27}s_{23} + 2.9745e^{-30}s_{234} - \\
& \quad 2.3347e^{-26}s(\theta_5 + 1.5843)c_2s_3 - 2.3347e^{-26}s(\theta_5 + 1.5843)c_3s_2 - \\
& \quad 2.9745e^{-30}c_{23}s_4 + 2.3347e^{-26}c_{234}c(\theta_5 + 1.5843) - 2.3347e^{-26}c_4s_{23}c(\theta_5 + \\
& \quad 1.5843)) - 0.0026c_1^2 + (c_4s_1 + c_{12}s_{34} + c_{13}s_{24})(5.8916e^{-4}c_4s_1 - \\
& \quad 6.7417e^{-6}c_{14} - 5.8418e^{-4}c(\theta_2 + \theta_3)s_4 + 5.8916e^{-4}c_{12}s_{34} + 5.8916e^{-4}c_{13}s_{24} + \\
& \quad 6.7417e^{-6}c_2s_{134} + 6.7417e^{-6}c_3s_{124}) + (c_2s_{134} - c_{14} + c_3s_{124})(8.7259e^{-8}c_{14} + \\
& \quad 6.7417e^{-6}c_4s_1 - 9.7093e^{-10}c(\theta_2 + \theta_3)s_4 + 6.7417e^{-6}c_{12}s_{34} + \\
& \quad 6.7417e^{-6}c_{13}s_{24}) - 8.7259e^{-8}c_2s_{134} - 8.7259e^{-8}c_3s_{124}) + 3.4167c(\theta_2 + \\
& \quad \theta_3)^2c_1^2 + 3.4310e^{-25}s(\theta_4 + 1.6029)(1.3474e^{-26}c_2s_3 - 2.7105e^{-27}c_{23} + \\
& \quad 1.3474e^{-26}c_3s_2 + 2.7105e^{-27}s_{23} + 1.6328e^{-29}c(\theta_4 + 1.5843)s_{23} - \\
& \quad 1.6328e^{-29}c_{23}c(\theta_4 + 1.5843)) + 0.0068c(\theta_2 + \theta_3)^2c_1s_1 - c(\theta_2 + \\
& \quad \theta_3)s_4(5.8916e^{-4}c_4s_1 - 9.7093e^{-10}c_{14} + 7.6194e^{-5}c(\theta_2 + \theta_3)s_4 + \\
& \quad 5.8418e^{-4}c_{12}s_{34} + 5.8418e^{-4}c_{13}s_{24} + 9.7093e^{-10}c_2s_{134} + 9.7093e^{-10}c_3s_{124}) + \\
& \quad 0.0032c(\theta_2 + \theta_3)s(\theta_2 + \theta_3)c_1 - 3.2188e^{-7}c(\theta_2 + \theta_3)s(\theta_2 + \theta_3)s_1 + 0.0029
\end{aligned} \tag{79}$$

$$\begin{aligned}
& m_{14} = 3.9045e^{-8}s_4 - 1.9778e^{-6}c(\theta_4 + 1.5843) - 0.0072s(2\theta_1) + \\
& \quad 4.8499e^{-6}c(\theta_2 + \theta_3)^2 - 8.4387e^{-6}c_2c(\theta_4 + 1.5843) + 4.7749e^{-9}c_2s_3 + \\
& \quad 4.7749e^{-9}c_3s_2 + 1.6659e^{-7}c_2s_4 - 3.0647e^{-4}c_4c(\theta_5 - 1.5843) - 0.0026c_1^2 + \\
& \quad 3.4167c(\theta_2 + \theta_3)^2c_1^2 - 7.6194e^{-5}c(\theta_2 + \theta_3)^2c_4^2 - 8.7259e^{-8}c_1^2c_4^2 + \\
& \quad 5.8916e^{-4}c_4^2s_1^2 - 0.0013c_{24}c(\theta_5 - 1.5843) - 1.5618e^{-8}c_2s_{34} - \\
& \quad 1.5618e^{-8}c_3s_{24} - 3.9327e^{-6}c(\theta_4 + 1.5843)s_{23} - 1.4410e^{-7}s_{234} + 0.0068c(\theta_2 + \\
& \quad \theta_3)^2c_1s_1 - 1.3483e^{-5}c_1c_4^2s_1 + 5.6315e^{-4}c_2s_3c(\theta_5 - 1.5843)^2 + \\
& \quad 5.6315e^{-4}c_3s_2c(\theta_5 - 1.5843)^2 + 0.0032c(\theta_2 + \theta_3)s(\theta_2 + \theta_3)c_1 - \\
& \quad 3.2188e^{-7}c(\theta_2 + \theta_3)s(\theta_2 + \theta_3)s_1 + 3.9327e^{-6}c_{23}c(\theta_4 + 1.5843) + \\
& \quad 1.4410e^{-7}c_{23}s_4 + 7.9113e^{-7} + 7.9113e^{-7}c_3c(\theta_4 + 1.5843)s_2 + \\
& \quad 7.1747e^{-7}s(\theta_5 - 1.5843)s_{234} + 5.8916e^{-4}c_1^2c_2^2s_3^2s_4^2 + \\
& \quad 5.8916e^{-4}c_1^2c_3^2s_2^2s_4^2 - 8.7259e^{-8}c_2^2s_2^2s_3^2s_4^2 - 8.7259e^{-8}c_3^2s_1^2s_2^2s_4^2 + \\
& \quad 1.9419e^{-9}c(\theta_2 + \theta_3)c_{14}s_4 - 0.0012c(\theta_2 + \theta_3)c_4s_{14} - 1.1311e^{-5}c_{234}c(\theta_5 - \\
& \quad 1.5843) + 1.2259e^{-4}c_{24}s_3c(\theta_5 - 1.5843) + 1.2259e^{-4}c_{34}s_2c(\theta_5 - 1.5843) - \\
& \quad 7.1747e^{-7}s(\theta_5 - 1.5843)c_{23}s_4 + 1.1311e^{-5}c_4s_{23}c(\theta_5 - 1.5843) - \\
& \quad 5.6315e^{-4}s(\theta_5 - 1.5843)c_4s_{23}c(\theta_5 - 1.5843) - 1.3483e^{-5}c_1^2c_2c_4s_{34} -
\end{aligned} \tag{80}$$

$$\begin{aligned}
& 1.3483e^{-5}c_1^2c_{34}s_{24} + 1.3483e^{-5}c_{24}s_1^2s_{34} + 1.3483e^{-5}c_{34}s_1^2s_{24} + \\
& 5.6315e^{-4}s(\theta_5 - 1.5843)c_{234}c(\theta_5 - 1.5843) + 1.3483e^{-5}c_1c_2^2s_1s_3^2s_4^2 + \\
& 1.3483e^{-5}c_1c_3^2s_1s_4^2 - 0.0012c(\theta_2 + \theta_3)c_1c_2s_3s_4^2 - 0.0012c(\theta_2 + \theta_3)c_{13}s_2s_4^2 - \\
& 1.9419e^{-9}c(\theta_2 + \theta_3)c_2s_{13}s_4^2 - 1.9419e^{-9}c(\theta_2 + \theta_3)c_3s_{12}s_4^2 + 0.0012 + \\
& 2.6967e^{-5}c_{123}s_{123}s_4^2 + 0.0029 \\
m_{15} = & 4.8499e^{-6}c(\theta_2 + \theta_3)^2 - 0.0072s(2\theta_1) - 0.0026c_1^2 + 3.0647e^{-4}s(\theta_5 - \\
& 1.5843)s_4 + 3.4167c(\theta_2 + \theta_3)^2c_1^2 - 7.6194e^{-5}c(\theta_2 + \theta_3)^2s_4^2 - \\
& 8.7259e^{-8}c_1^2c_4^2 + 5.8916e^{-4}c_4^2s_1^2 + 5.6315e^{-4}s_{234} + 7.1747e^{-7}s(\theta_5 - \\
& 1.5843)c_2s_3 + 7.1747e^{-7}s(\theta_5 - 1.5843)c_3s_2 + 0.0013s(\theta_5 - 1.5843)c_2s_4 + \\
& 0.0068c(\theta_2 + \theta_3)^2c_1s_1 - 1.3483e^{-5}c_1c_4^2s_1 + 0.0032c(\theta_2 + \theta_3)s(\theta_2 + \theta_3)c_1 - \\
& 3.2188e^{-7}c(\theta_2 + \theta_3)s(\theta_2 + \theta_3)s_1 - 5.6315e^{-4}c_{23}s_4 - 1.2259e^{-4}s(\theta_5 - \\
& 1.5843)c_2s_{34} - 1.2259e^{-4}s(\theta_5 - 1.5843)c_3s_{24} - 1.1311e^{-5}s(\theta_5 - \\
& 1.5843)s_{234} + 5.8916e^{-4}c_1^2c_2^2s_3^2s_4^2 + 5.8916e^{-4}c_1^2c_3^2s_2^2s_4^2 - \\
& 8.7259e^{-8}c_2^2s_1^2s_3^2s_4^2 - 8.7259e^{-8}c_3^2s_1^2s_2^2s_4^2 + 1.9419e^{-9}c(\theta_2 + \theta_3)c_{14}s_4 - \\
& 0.0012c(\theta_2 + \theta_3)c_4s_{14} - 7.1747e^{-7}c_{234}c(\theta_5 - 1.5843) + 1.1311e^{-5}s(\theta_5 - \\
& 1.5843)c_{23}s_4 + 7.1747e^{-7}c_4s_{23}c(\theta_5 - 1.5843) - 1.3483e^{-5}c_1^2c_{24}s_{34} - \\
& 1.3483e^{-5}c_1^2c_{34}s_{24} + 1.3483e^{-5}c_{24}s_1^2s_{34} + 1.3483e^{-5}c_{34}s_1^2s_{24} + \\
& 1.3483e^{-5}c_1c_2^2s_1s_3^2s_4^2 + 1.3483e^{-5}c_1c_3^2s_1s_2^2s_4^2 - 0.0012c(\theta_2 + \\
& \theta_3)c_{12}s_3s_4^2 - 0.0012c(\theta_2 + \theta_3)c_{13}s_2s_4^2 - 1.9419e^{-9}c(\theta_2 + \theta_3)c_2s_{13}s_4^2 - \\
& 1.9419e^{-9}c(\theta_2 + \theta_3)c_3s_{12}s_4^2 + 0.0012c_1^2c_{23}s_{23}s_4^2 - 1.7452e^{-7}c_{23}s_1^2s_{23}s_4^2 + \\
& 0.0012c_{124}s_{134} + 0.0012c_{134}s_{124} + 2.6967e^{-5}c_{123}s_{123}s_4^2 + 0.0029
\end{aligned} \tag{81}$$

$$\begin{aligned}
m_{21} = & 6.5921e^{-5}s(\theta_2 + \theta_3 - 2.5577) - 0.0072s(2\theta_1) - 0.0072s(\theta_2 + \\
& 5.6192e^{-4}) + 3.7554e^{-4}s_2 + 4.8499e^{-6}c(\theta_2 + \theta_3)^2 + 1.1437e^{-26}s(\theta_4 + \\
& 1.6029)(4.0422e^{-4}c_2s_3 - 8.1315e^{-28}c_{23} - 8.6736e^{-27}s_2 + 4.0422e^{-27}c_3s_2 + \\
& 8.1315e^{-28}s_{23} + 4.8984e^{-30}c(\theta_4 + 1.5843)s_{23} - 4.8984e^{-3}c_{23}c(\theta_4 + \\
& 1.5843)) - 0.0026c_1^2 - 593(4.7592e^{-23}c_4 + 3.7355e^{-29}s_4c(\theta_5 - \\
& 1.5843))(5.4210e^{-26}s_2 + 5.0822e^{-27}c_{23} + 4.6892e^{-26}c_2s_3 + 4.6892e^{-26}c_3s_2 - \\
& 5.0822e^{-27}s_{23} + 2.9745e^{-30}s_{234} - 2.3347e^{-26}s(\theta_5 - 1.5843)c_2s_3 - \\
& 2.3347e^{-26}s(\theta_5 - 1.5843)c_3s_2 - 2.9745e^{-30}c_{23}s_4 + 2.3347e^{-26}c_{234}c(\theta_5 - \\
& 1.5843) - 2.3347e^{-26}c_4s_{23}c(\theta_5 - 1.5843)) + (c_4s_1 + c_{12}s_{34} + \\
& c_{13}s_{24})(5.8916e^{-4}c_4s_1 - 6.7417e^{-6}c_{14} - 5.8418e^{-4}c(\theta_2 + \theta_3)s_4 + \\
& 5.8916e^{-4}c_{12}s_{34} + 5.8916e^{-4}c_{13}s_{24} + 6.7417e^{-6}c_2s_{134} + 6.7417e^{-6}c_3s_{124} + \\
& c_2s_{134} - c_{14} + c_3s_{124})(8.7259e^{-8}c_{14} + 6.7417e^{-6}c_4s_1 - 9.7093e^{-10}c(\theta_2 + \\
& \theta_3)s_4 + 6.7417e^{-6}c_{12}s_{34} + 6.7417e^{-6}c_{13}s_{24} + 8.7259e^{-8}c_2s_{134} - \\
& 8.7259e^{-8}c_2s_{134} - 8.7259e^{-8}c_2s_{124}) + 3.4167c(\theta_2 + \theta_3)^2c_1^2 + 0.0068c(\theta_2 + \\
& \theta_3)^2c_1s_1 - c(\theta_2 + \theta_3)s_4)(5.8418e^{-4}c_4s_1 - 9.7093e^{-10}c_{14} + 7.6194e^{-4}c(\theta_2 + \\
& \theta_3)s_4 + 5.8418e^{-4}c_{12}s_{34} + 5.8418e^{-4}c_{13}s_{24} + 9.7093e^{-10}c_2s_{134} + \\
& 9.7093e^{-10}c_3s_{124}) + 0.0032c(\theta_2 + \theta_3)s(\theta_2 + \theta_3)c_1 - 3.288e^{-7}c(\theta_2 + \theta_3)s(\theta_2 + \\
& \theta_3)s_1 + 0.0029
\end{aligned} \tag{82}$$

$$\begin{aligned}
m_{22} = & 1.4079e^{-4}c(2\theta_4) - 0.0072s(2\theta_1) + 0.0061c(\theta_3 - 2.5577) - 0.0087c_3 - \\
& 0.0034s_3 - 3.1236e^{-8}s_4 + 4.899e^{-6}c(\theta_2 + \theta_3)^2 + 3.3318e^{-7}s_{34} - 0.0026c_1^2 + \\
& 1.5823e^{-6}c(1.6029)c_4 - 1.5823e^{-6}s(1.6029)s_4 - 2.2622e^{-5}c(1.5843)s_5 + \\
& 2.2622e^{-5}s(1.5843)c_5 + 2.3829e^{-9}c(3.2058)c(2\theta_4) + 3.4167c(\theta_2 + \theta_3)^2c_1^2 - \\
& 7.6194e^{-5}c(\theta_2 + \theta_3)^2s_4^2 - 1.4079e^{-4}c(3.1687)c(2\theta_5) - \\
& 2.3829e^{-9}s(3.2058)s(2\theta_4) - 8.7259e^{-8}c_1^2c_4^2 - 1.4079e^{-4}s(3.1687)s(2\theta_5) + \\
& 5.8916e^{-4}c_4^2s_1^2 + 1.4079e^{-4}s(3.1687)c(2\theta_4)s(2\theta_5) - \\
& 1.6877e^{-5}c(1.6029)c_4s_3 + 0.0068c(\theta_2 + \theta_3)^2c_1s_1 + 2.4518e^{-4}c(1.5843)c_{45} -
\end{aligned} \tag{83}$$

$$\begin{aligned}
& 0.0026c(1.5843)c_3s_5 + 0.0026c(1.5843)c_{35} + 1.6877e^{-5}s(1.5843)s_{34} + \\
& 2.4518e^{-4}s(1.5843)c_4s_5 - 1.3483e^{-5}c_1c_1^2s_1 + 0.0032c(\theta_2 + \theta_3)(\theta_2 + \theta_3)c_1 - \\
& 7.1747e^{-7}c(1.5843)s(2\theta_4)c_5 - 3.2188e^{-7}c(\theta_2 + \theta_3)(\theta_2 + \theta_3)s_1 - \\
& 7.1747e^{-7}s(1.5843)s(2\theta_4)s_5 + 1.4079e^{-4}c(3.1687)c(2\theta_4)c(2\theta_5) - \\
& 0.0026c(1.5843)c_{45}s_3 - 0.0026(1.5843)c_4s_{35} + 5.8916e^{-4}c_1^2c_2^2s_3^2s_4^2 + \\
& 5.8916e^{-4}c_1^2c_3^2s_2^2s_4^2 - 8.7259e^{-8}c_2^2s_1^2s_3^2s_4^2 - 8.7259e^{-8}c_3^2s_1^2s_2^2s_4^2 + \\
& 1.9419e^{-9}c(\theta_2 + \theta_3)c_{14}s_4 - 0.0012c(\theta_2 + \theta_3)c_4s_{14} - 1.3483e^{-5}c_1^2c_{24}s_{34} - \\
& 1.3483e^{-5}c_1^2c_{34}s_{24} + 1.3483e^{-5}c_{24}s_1^2s_{34} + 1.3483e^{-5}c_{34}s_1^2s_{24} + \\
& 1.3483e^{-5}c_1c_2^2s_1s_3^2s_4^2 + 1.3483e^{-5}c_1c_3^2s_1s_2^2s_4^2 - 0.0012c(\theta_2 + \\
& \theta_3)c_{12}s_3s_4^2 - 0.0012c(\theta_2 + \theta_3)c_{13}s_2s_4^2 - 1.9419e^{-9}c(\theta_2 + \theta_3)c_2s_{13}s_4^2 - \\
& 1.9419e^{-9}c(\theta_2 + \theta_3)c_3s_{12}s_4^2 + 0.0012c_1^2c_{23}s_3s_4^2 - 1.7452e^{-7}c_{23}s_1^2s_{23}s_4^2 + \\
& 0.0012c_{124}s_{134} + 0.0012c_{134}s_{124} + 2.6967e^{-5}c_{123}s_{123}s_4^2 + 0.0486
\end{aligned}$$

$$\begin{aligned}
m_{23} = & 1.4079e^{-4}c(2\theta_4) - 0.0072s(2\theta_1) + 0.0030c(\theta_3 - 2.5577) - 0.0043c_3 - \\
& 0.0017s_3 - 3.1236e^{-8}s_4 + 4.8499e^{-6}c(\theta_2 + \theta_3)^2 + 1.6659e^{-7}s_{34} - 0.0026c_1^2 + \\
& 1.5823e^{-6}c(1.6029)c_4 - 1.5823e^{-6}s(1.6029)s_4 - 2.2622e^{-5}c(1.6029)s_5 + \\
& 2.2622e^{-5}s(1.6029)c_5 + 2.3829e^{-9}c(3.2058)c(2\theta_4) + 3.4167c(\theta_2 + \theta_3)^2c_{12} - \\
& 7.6194e^{-5}c(\theta_2 + \theta_3)^2s_4^2 - 1.4079e^{-4}c(3.1687)c(2\theta_5) - \\
& 2.3829e^{-9}s(3.2058)s(2\theta_4) - 8.7259e^{-8}c_1^2c_4^2 - 1.4079e^{-4}s(3.1687)s(2\theta_5) + \\
& 5.8916e^{-4}c_4^2s_1^2 + 1.4079e^{-4}s(3.1687)c(2\theta_4)s(2\theta_5) - \\
& 8.4387e^{-6}c(1.6029)c_4s_3 + 0.0068c(\theta_2 + \theta_3)^2c_1s_1 + 2.4518e^{-4}c(1.5843)c_{45} - \\
& 0.0013c(1.5843)c_3s_5 + 0.0013s(1.5843)c_{35} + 8.4387e^{-6}s(1.6029)s_{34} + \\
& 2.4518e^{-4}s(1.5843)c_4s_5 - 1.3483e^{-5}c_1c_4^2s_1 + 0.0032c(\theta_2 + \theta_3)s(\theta_2 + \theta_3)c_1 - \\
& 7.1747e^{-7}c(1.5843)c(2\theta_5)s(2\theta_4) - 3.2188e^{-7}c(\theta_2 + \theta_3)s(\theta_2 + \theta_3)s_1 - \\
& 1.1747e^{-7}s(1.5843)s(2\theta_4)s_5 + 1.4079e^{-4}c(3.1687)c(2\theta_4)c(2\theta_5) - \\
& 0.0013c(1.5843)c_{45}s_3 - 0.0013c(1.5843)c_4s_{35} + 5.8916e^{-4}c_1^2c_2^2s_3^2s_4^2 + \\
& 5.8916e^{-4}c_1^2c_3^2s_2^2s_4^2 - 8.7259e^{-8}c_2^2s_1^2s_3^2s_4^2 - 8.7259e^{-8}c_3^2s_1^2s_2^2s_4^2 + \\
& 1.9419e^{-9}c(\theta_2 + \theta_3)c_{14}s_4 - 0.0012c(\theta_2 + \theta_3)c_4s_{14} - 1.3483e^{-5}c_1^2c_{24}s_{34} - \\
& 1.3483e^{-5}c_1^2c_{34}s_{24} + 1.3483e^{-5}c_{24}s_1^2s_{34} + 1.3483e^{-5}c_{34}s_1^2s_{24} + \\
& 1.3483e^{-5}c_1c_2^2s_1s_3^2s_4^2 + 1.3483e^{-5}c_1c_3^2s_1s_2^2s_4^2 - 0.0012c(\theta_2 + \\
& \theta_3)c_{12}s_3s_4^2 - 0.0012c(\theta_2 + \theta_3)c_{13}s_2s_4^2 - 1.9419e^{-9}c(\theta_2 + \theta_3)c_2s_{13}s_4^2 - \\
& 1.9419e^{-9}c(\theta_2 + \theta_3)c_3s_{12}s_4^2 + 0.0012c_1^2c_{23}s_{23}s_4^2 - 1.7352e^{-7}c_{23}s_1^2s_{23}s_4^2 + \\
& 0.0012c_{124}s_{134} + 0.0012c_{134}s_{124} + 2.6967e^{-5}c_{123}s_{123}s_4^2 + 0.0095
\end{aligned} \tag{84}$$

$$\begin{aligned}
m_{24} = & 4.8499e^{-6}c(\theta_2 + \theta_3)^2 - 0.0072s(2\theta_1) - 0.0026c_1^2 - 593 \left( 3.897e^{-29}c_4 + \right. \\
& 3.0601e^{-25}s_4s(\theta_5 - 1.5843) \left. \right) (5.4210e^{-26}c_3 - 2.3347e^{-26}s(\theta_5 - 1.5843) + \\
& 4.6892e^{-26}) + (c_4s_1 + c_{12}s_{34} + c_{13}s_{24}) (5.8916e^{-4}c_4s_1 - 6.7417e^{-6}c_{14} - \\
& 5.8916e^{-4}c(\theta_2 + \theta_3)s_4 + 5.8916e^{-4}c_{12}s_{34} + 5.8916e^{-4}c_{13}s_{24} + \\
& 6.7417e^{-6}c_2s_{134} + 6.7417e^{-6}c_3s_{124}) + (c_2s_{134} - c_{14} + c_3s_{124})(8.7259e^{-8}c_{14} + \\
& 6.7417e^{-6}c_4s_1 - 9.7093e^{-10}c(\theta_2 + \theta_3)s_4 + 6.7417e^{-6}c_{12}s_{34} + \\
& 6.7417e^{-6}c_{13}s_{24} - 8.7259e^{-8}c_2s_{134} - 8.7259e^{-8}c_3s_{124}) + 3.4167c(\theta_2 + \\
& \theta_3)^2c_1^2 - 2.9278e^{-23}(\theta_4 - 1.6029)(8.6736e^{-26}c_3 - 4.0422e^{-26}) + \\
& 0.0068c(\theta_2 + \theta_3)^2c_1s_1 - c(\theta_2 + \theta_3)s_4(5.8916e^{-4}c_4s_1 - 9.7093e^{-10}c_{14} + \\
& 7.6194e^{-5}(\theta_2 + \theta_3)s_4 + 5.8418e^{-4}c_{12}s_{34} + 5.8418e^{-4}c_{13}s_{24} + \\
& 9.7093e^{-10}c_2s_{134} + 9.7093e^{-10}c_3s_{124}) + 0.0032c(\theta_2 + \theta_3)s(\theta_2 + \theta_3)c_1 - \\
& 3.2188e^{-7}c(\theta_2 + \theta_3)s(\theta_2 + \theta_3)s_1 + 0.0029
\end{aligned} \tag{85}$$

$$\begin{aligned}
m_{25} = & 5.6315e^{-4}c_4 - 0.0072s(2\theta_1) + 1.2259e^{-4}c(\theta_5 - 1.5843) + \\
& 4.8499e^{-6}c(\theta_2 + \theta_3)^2 - 0.0026c_{12} - 0.0013s_3c(\theta_5 - 1.5843) - 1.311e^{-5}s(\theta_5 - \\
& 1.5843)c_4 - 7.1747e^{-7}s_4c(\theta_5 - 1.5843) + 3.4167c(\theta_2 + \theta_3)^2c_1^2 - \\
& 7.6194e^{-5}c(\theta_2 + \theta_3)^2s_4^2 - 8.7259e^{-8}c_1^2c_4^2 + 5.8916e^{-4}c_4^2s_1^2 -
\end{aligned} \tag{86}$$

$$\begin{aligned}
& 0.0013s(\theta_5 - 1.5843)c_{34} + 0.0068c(\theta_2 + \theta_3)^2c_1s_1 - 1.3483e^{-5}c_1c_4^2s_1 + \\
& 0.0032c(\theta_2 + \theta_3)s(\theta_2 + \theta_3)c_1 - 3.2188e^{-7}c(\theta_2 + \theta_3)s(\theta_2 + \theta_3)s_1 + \\
& 5.8916e^{-4}c_1^2c_2^2s_3^2s_4^2 + 5.8916e^{-4}c_1^2c_3^2s_2^2s_4^2 - 8.7259e^{-8}c_2^2s_1^2s_3^2s_4^2 - \\
& 8.7259e^{-8}c_3^2s_1^2s_2^2s_4^2 + 1.9419e^{-9}c(\theta_2 + \theta_3)c_{14}s_3 - 0.0012c(\theta_2 + \theta_3)c_4s_{14} - \\
& 1.3483e^{-5}c_1^2c_{24}s_{34} - 1.3483e^{-5}c_1^2c_{34}s_{24} + 1.3483e^{-5}c_{24}s_1^2s_{34} + \\
& 1.3483e^{-5}c_{34}s_1^2s_{24} + 1.3483e^{-5}c_1c_2^2s_1s_3^2s_4^2 + 1.3483e^{-5}c_1c_3^2s_1s_2^2s_4^2 - \\
& 0.0012c(\theta_2 + \theta_3)c_{12}s_3s_4^2 - 0.0012c(\theta_2 + \theta_3)c_{13}s_2s_4^2 - 1.9419e^{-9}c(\theta_2 + \\
& \theta_3)c_2s_1s_3s_4^2 - 1.9419e^{-9}c(\theta_2 + \theta_3)c_3s_{12}s_4^2 + 0.0012c_1^2c_{23}s_3s_4^2 - \\
& 1.7452e^{-7}c_{23}s_1^2s_{23}s_4^2 + 0.0012c_{124}s_{134} + 0.0012c_{134}s_{124} + \\
& 2.6967e^{-5}c_{123}s_{123}s_4^2 + 0.0029
\end{aligned}$$

$$\begin{aligned}
m_{31} = & 6.5921e^{-5}s(\theta_2 + \theta_3 - 2.5577) - 0.0072s(2\theta_1) + 4.8499e^{-6}c(\theta_2 + \theta_3)^2 - \\
& 593(4.7592e^{-33}c_4 + 3.7355e^{-29}s_4c(\theta_5 - 1.5843))(5.0822e^{-27}c_{23} + \\
& 4.6892e^{-26}c_2s_3 + 4.6892e^{-26}c_3s_2 - 5.0822e^{-27}s_{23} + 2.9745e^{-30}s_{234} - \\
& 2.3347e^{-26}s(\theta_5 - 1.5843)c_2s_3 - 2.3347e^{-26}s(\theta_5 - 1.5843)c_3s_2 - \\
& 2.9745e^{-30}c_{23}s_4 + 2.3347e^{-26}c_{234}c(\theta_5 - 1.5843) - 2.3347e^{-26}c_4s_{23}c(\theta_5 - \\
& 1.5843)) - 0.0026c_1^2 + (c_4s_1 + c_{12}s_{34} + c_{13}s_{24})(5.8916e^{-4}c_4s_1 - \\
& 6.7417e^{-6}c_{14} - 5.8916e^{-4}e^{-7}c(\theta_2 + \theta_3)s_4 + 5.8916e^{-4}c_{12}s_{34} + \\
& 5.8916e^{-4}c_{13}s_{24} + 6.7417e^{-6}c_2s_{134} + 6.7417e^{-6}c_3s_{124}) + (c_2s_{134} - c_{14} + \\
& c_3s_{124})(8.7259e^{-8}c_{14} + 6.7417e^{-6}c_4s_1 - 9.7093e^{-10}c(\theta_2 + \theta_3)s_4 + \\
& 6.7417e^{-6}c_{12}s_{34} + 6.7417e^{-6}c_{13}s_{24} - 8.7259e^{-8}c_2s_{134} - 8.7259e^{-8}c_3s_{124}) + \\
& 3.4167c(\theta_2 + \theta_3)^2c_1^2 + 3.4310e^{-25}s(\theta_4 + 1.6029)(1.3474e^{-26}c_2s_3 - \\
& 2.7105e^{-27}c_{23} + 1.3474e^{-26}c_3s_2 + 2.7105e^{-27}s_{23} + 1.6328e^{-29}c(\theta_4 - \\
& 1.6029)s_{23} - 1.6328e^{-29}c_{23}c(\theta_4 - 1.6029) + 0.0068c(\theta_2 + \theta_3)^2c_1s_1 - \\
& c(\theta_2 + \theta_3)s_4(5.8418e^{-4}c_4s_1 - 9.7093e^{-10}c_{14} + 7.6194e^{-5}c(\theta_2 + \theta_3)s_4 + \\
& 5.8418e^{-4}c_{12}s_{34} + 5.8418e^{-4}c_{13}s_{24} + 9.7093e^{-10}c_2s_{134} + 9.7093e^{-10}c_3s_{124} + \\
& 0.0032c(\theta_2 + \theta_3)s(\theta_2 + \theta_3)c_1 - 3.2188e^{-7}c(\theta_2 + \theta_3)s(\theta_2 + \theta_3)s_1 + 0.0029
\end{aligned} \tag{87}$$

$$\begin{aligned}
m_{32} = & 1.4079e^{-4}c(2\theta_4) - 0.0072s(2\theta_1) + 0.0030c(\theta_3 - 2.5577) - 0.0043c_3 - \\
& 0.0017s_3 - 3.1236e^{-8}s_4 + 4.8499e^{-6}c(\theta_2 + \theta_3)^2 + 1.6659e^{-7}s_{34} - 0.0026c_1^2 + \\
& 1.5823e^{-6}c(1.6029)c_4 - 1.5823e^{-6}s(1.6029)s_4 - 2.2622e^{-5}c(1.6029)s_5 + \\
& 2.2622e^{-5}s(1.5843)c_5 + 2.3829e^{-9}c(1.6029)c(2\theta_4) + 3.4167c(\theta_2 + \theta_3)^2c_1^2 - \\
& 7.6194e^{-5}c(\theta_2 + \theta_3)^2s_4^2 - 1.4079e^{-4}c(3.1687)c(2\theta_5) - \\
& 2.3829e^{-9}s(3.2058)s(2\theta_4) - 8.7259e^{-8}c_1^2c_4^2 - 1.4079e^{-4}s(3.1687)s(2\theta_5) + \\
& 5.8916e^{-4}c_4^2s_1^2 + 1.4079e^{-4}s(3.1687)c(2\theta_4)s(2\theta_5) - \\
& 8.4387e^{-6}c(1.6029)c_4s_3 + 0.0068c(\theta_2 + \theta_3)^2c_1s_1 + 2.4518e^{-4}c(1.5843)c_{45} - \\
& 0.0013c(1.5843)c_3s_5 + 0.0013s(1.5843)c_{35} + 8.4387e^{-6}s(1.6029)s_{34} + \\
& 2.4518e^{-4}s(1.5843)c_4s_5 - 1.3483e^{-5}c_1c_4^2s_1 + 0.0032c(\theta_2 + \theta_3)s(\theta_2 + \theta_3)c_1 - \\
& 7.1747e^{-7}c(1.5843)s(2\theta_1)c_5 - 3.2188e^{-7}c(\theta_2 + \theta_3)s(\theta_2 + \theta_3)s_1 - \\
& 7.1747e^{-7}s(1.5843)s(2\theta_4)s_5 + 1.4079e^{-4}c(3.1687)c(2\theta_4)c(2\theta_5) - \\
& 0.0013c(1.5843)c_{45}s_3 - 0.0013s(1.5843)c_4s_{35} + 5.8916e^{-4}c_1^2c_2^2s_3^2s_4^2 + \\
& 5.8916e^{-4}c_1^2c_3^2s_2^2s_4^2 - 8.7259e^{-8}c_2^2s_1^2s_3^2s_4^2 - 8.7259e^{-8}c_3^2s_1^2s_2^2s_4^2 + \\
& 1.9419e^{-9}c(\theta_2 + \theta_3)c_{14}s_4 - 0.0012c(\theta_2 + \theta_3)c_4s_{14} - 1.3483e^{-5}c_1^2c_{24}s_{34} - \\
& 1.3483e^{-5}c_1^2c_{34}s_{24} + 1.3483e^{-5}c_{24}s_1^2s_{34} + 1.3483e^{-5}c_{34}s_1^2s_{24} + \\
& 1.3483e^{-5}c_1c_2^2s_1s_4^2 + 1.3483e^{-5}c_1c_3^2s_1s_2^2s_4^2 - 1.9419e^{-9}c(\theta_2 + \\
& \theta_3)c_3s_{12}s_4^2 + 0.0012c_1^2c_{23}s_{23}s_4^2 - 1.7452e^{-7}c_{23}s_1^2s_{23}s_4^2 + 0.0012c_{124}s_{134} + \\
& 0.0012c_{134}s_{124} + 2.6967e^{-5}c_{123}s_{123}s_4^2 + 0.0095
\end{aligned} \tag{88}$$

$$\begin{aligned}
m_{33} = & 1.407e^{-4}c(2\theta_4) + 2.3829e^{-9}c(2\theta_4 + 3.258) - 0.0072s(2\theta_1) + \\
& 1.5823e^{-6}c(\theta_4 + 1.6029) - 3.1236e^{-8}s_4 + 4.8499e^{-6}c(\theta_2 + \theta_3)^2 - 0.0026c_1^2 - \\
& 2.2622e^{-5}c(1.5843)s_5 + 2.2622e^{-5}s(1.5843)c_5 + 3.4167c(\theta_2 + \theta_3)^2c_1^2 -
\end{aligned} \tag{89}$$

$$\begin{aligned}
& 7.6194e^{-5}c(\theta_2 + \theta_3)^2s_4^2 - 1.4079e^{-4}c(3.1687)c(2\theta_5) - 8.7259e^{-8}c_1^2c_4^2 - \\
& \quad 1.4079e^{-4}s(3.1687)s(2\theta_5) + 5.8916e^{-4}c_4^2s_1^2 + \\
& \quad 1.4079e^{-4}s(3.1687)c(2\theta_4)s(2\theta_5) + 0.0068c(\theta_2 + \theta_3)^2c_1s_1 + \\
& \quad 2.4518e^{-4}c(1.5843)c_{45} + 2.4518e^{-4}s(1.5843)c_4s_5 - 1.3483e^{-5}c_1c_4^2s_1 + \\
& 0.0032c(\theta_2 + \theta_3)s(\theta_2 + \theta_3)c_1 - 7.174e^{-7}c(1.5843)s(2\theta_4)c_5 - 3.2188e^{-7}c(\theta_2 + \\
& \quad \theta_3)s(\theta_2 + \theta_3)s_1 - 7.174e^{-7}s(1.5843)s(2\theta_4)s_5 + \\
& \quad 1.4079e^{-4}c(3.1687)c(2\theta_4)c(2\theta_5) + 5.8916e^{-4}c_1^2c_2^2s_3^2s_4^2 + \\
& 5.8916e^{-4}c_1^2c_3^2s_2^2s_4^2 - 8.7259e^{-8}c_2^2s_1^2s_3^2s_4^2 - 8.7259e^{-8}c_3^2s_1^2s_2^2s_4^2 + \\
& 1.9419e^{-9}c(\theta_2 + \theta_3)c_{14}s_4 - 0.0012c(\theta_2 + \theta_3)c_4s_{14} - 1.3483e^{-5}c_1^2c_{24}s_{34} - \\
& \quad 1.3483e^{-5}c_1^2c_{34}s_{24} + 1.3483e^{-5}c_{24}s_1^2s_{34} + 1.3483e^{-5}c_{34}s_1^2s_{24} + \\
& \quad 1.3483e^{-5}c_1c_2^2s_1s_3^2s_4^2 + 1.3483e^{-5}c_1c_3^2s_1s_2^2s_4^2 - 0.0012c(\theta_2 + \\
& \quad \theta_3)c_{12}s_3s_4^2 - 0.0012c(\theta_2 + \theta_3)c_{13}s_2s_4^2 - 1.9419e^{-9}c(\theta_2 + \theta_3)c_2s_{13}s_4^2 - \\
& 1.9419e^{-9}c(\theta_2 + \theta_3)c_3s_{12}s_4^2 + 0.0012c_1^2c_{23}s_{23}s_4^2 - 1.7452e^{-7}c_{23}s_1^2s_{23}s_4^2 + \\
& \quad 0.0012c_{124}s_{134} + 0.0012c_{134}s_{124} + 2.6967e^{-5}c_{123}s_{123}s_4^2 + 0.0095 \\
\\
& m_{34} = 3.9327e^{-6}s(1.6029 + \theta_4) - 1.4410e^{-7}c_4 - 0.0072s(2\theta_1) + \\
& 4.8499e^{-6}c(\theta_2 + \theta_3)^2 - 0.0026c_1^2 + 7.1747e^{-7}s(\theta_5 - 1.5843)c_4 - \\
& 1.1311e^{-5}s_4c(\theta_5 - 1.5843) + 3.4167c(\theta_2 + \theta_3)^2c_1^2 - 7.6194e^{-5}c(\theta_2 + \\
& \quad \theta_3)^2s_4^2 - 8.7259e^{-8}c_1^2c_4^2 + 5.8916e^{-4}c_4^2s_1^2 + 0.0068c(\theta_2 + \theta_3)^2c_1s_1 + \\
& 5.6315e^{-4}s(\theta_5 - 1.5843)s_4c(\theta_5 - 1.5843) - 1.348e^{-5}c_1c_4^2s_1 + 0.0032c(\theta_2 + \\
& \quad \theta_3)s(\theta_2 + \theta_3)c_1 - 3.2188e^{-7}c(\theta_2 + \theta_3)s(\theta_2 + \theta_3)s_1 + 5.8916e^{-4}c_1^2c_2^2s_3^2s_4^2 + \\
& 5.8916e^{-4}c_1^2c_3^2s_2^2s_4^2 - 8.7259e^{-8}c_2^2s_1^2s_3^2s_4^2 - 8.7259e^{-8}c_3^2s_1^2s_2^2s_4^2 + \\
& 1.9419e^{-9}c(\theta_2 + \theta_3)c_{14}s_4 - 0.0012c(\theta_2 + \theta_3)c_4s_{14} - 1.3483e^{-5}c_1^2c_{24}s_{34} - \\
& \quad 1.3483e^{-5}c_1^2c_{34}s_{24} + 1.3483e^{-5}c_{24}s_1^2s_{34} + 1.3483e^{-5}c_{34}s_1^2s_{24} + \\
& 1.3483e^{-5}c_1c_2^2s_3^2s_4^2 + 1.3483e^{-5}c_1c_3^2s_1s_2^2s_4^2 - 0.0012c(\theta_2 + \theta_3)c_{12}s_3s_4^2 - \\
& \quad 0.0012c(\theta_2 + \theta_3)c_{13}s_2s_4^2 - 1.9419e^{-9}c(\theta_2 + \theta_3)c_2s_{13}s_4^2 - 1.9419e^{-9}c(\theta_2 + \\
& \quad \theta_3)c_3s_{12}s_4^2 + 0.0012c_1^2c_{23}s_{23}s_4^2 - 1.7452e^{-7}c_{23}s_1^2s_{23}s_4^2 + 0.0012c_{124}s_{134} + \\
& \quad 0.0012c_{134}s_{124} + 2.6967e^{-5}c_{123}s_{123}s_4^2 + 0.0029 \\
\\
& m_{35} = 5.6315e^{-4}c_4 - 0.0072s(2\theta_1) + 1.2259e^{-4}c(\theta_5 - 1.5843) + \\
& 4.8499e^{-6}c(\theta_2 + \theta_3)^2 - 0.0026c_1^2 - 1.1311e^{-5}s(\theta_5 - 1.5843)c_4 - \\
& 7.1747e^{-7}s_4c(\theta_5 - 1.5843) + 3.4167c(\theta_2 + \theta_3)^2c_1^2 - 7.6194e^{-5}c(\theta_2 + \\
& \quad \theta_3)^2s_4^2 - 8.7259e^{-8}c_1^2c_4^2 + 5.8916e^{-4}c_4^2s_1^2 + 0.0068c(\theta_2 + \theta_3)^2c_1s_1 - \\
& 1.3483e^{-5}c_1c_4^2s_1 + 0.0032c(\theta_2 + \theta_3)s(\theta_2 + \theta_3)c_1 - 3.2188e^{-7}c(\theta_2 + \theta_3)s(\theta_2 + \\
& \quad \theta_3)s_1 + 5.8916e^{-4}c_1^2c_2^2s_4^2 + 5.8916e^{-4}c_1^2c_3^2s_2^2s_4^2 - \\
& 8.7259e^{-8}c_2^2s_1^2s_3^2s_4^2 - 8.7259e^{-8}c_3^2s_1^2s_2^2s_4^2 + 1.9419e^{-9}c(\theta_2 + \theta_3)c_{14}s_4 - \\
& \quad 0.0012c(\theta_2 + \theta_3)c_4s_{14} - 1.3483e^{-5}c_1^2c_{24}s_{34} + 1.3483e^{-5}c_1^2c_{34}s_{24} + \\
& \quad 1.3483e^{-5}c_{24}s_1^2s_{34} + 1.3483e^{-5}c_{34}s_1^2s_{24} + 1.3483e^{-5}c_1c_2^2s_1s_4^2 + \\
& 1.3483e^{-5}c_1c_3^2s_1s_2^2s_4^2 - 0.0012c(\theta_2 + \theta_3)c_{12}s_3s_4^2 - 0.0012c(\theta_2 + \theta_3)c_{12}s_4^2 - \\
& \quad 1.9419e^{-9}c(\theta_2 + \theta_3)c_2s_{13}s_4^2 - 1.9419e^{-9}c(\theta_2 + \theta_3)c_3s_{12}s_4^2 + \\
& \quad 0.0012c_1^2c_{23}s_{23}s_4^2 - 1.7452e^{-7}c_{23}s_1^2s_{23}s_4^2 + 0.0012c_{124}s_{134} + \\
& \quad 0.0012c_{134}s_{124} + 2.6967e^{-5}c_{123}s_{123}s_4^2 + 0.0029
\end{aligned}
\tag{90}$$

$$\begin{aligned}
& m_{35} = 5.6315e^{-4}c_4 - 0.0072s(2\theta_1) + 1.2259e^{-4}c(\theta_5 - 1.5843) + \\
& 4.8499e^{-6}c(\theta_2 + \theta_3)^2 - 0.0026c_1^2 - 1.1311e^{-5}s(\theta_5 - 1.5843)c_4 - \\
& 7.1747e^{-7}s_4c(\theta_5 - 1.5843) + 3.4167c(\theta_2 + \theta_3)^2c_1^2 - 7.6194e^{-5}c(\theta_2 + \\
& \quad \theta_3)^2s_4^2 - 8.7259e^{-8}c_1^2c_4^2 + 5.8916e^{-4}c_4^2s_1^2 + 0.0068c(\theta_2 + \theta_3)^2c_1s_1 - \\
& 1.3483e^{-5}c_1c_4^2s_1 + 0.0032c(\theta_2 + \theta_3)s(\theta_2 + \theta_3)c_1 - 3.2188e^{-7}c(\theta_2 + \theta_3)s(\theta_2 + \\
& \quad \theta_3)s_1 + 5.8916e^{-4}c_1^2c_2^2s_4^2 + 5.8916e^{-4}c_1^2c_3^2s_2^2s_4^2 - \\
& 8.7259e^{-8}c_2^2s_1^2s_3^2s_4^2 - 8.7259e^{-8}c_3^2s_1^2s_2^2s_4^2 + 1.9419e^{-9}c(\theta_2 + \theta_3)c_{14}s_4 - \\
& \quad 0.0012c(\theta_2 + \theta_3)c_4s_{14} - 1.3483e^{-5}c_1^2c_{24}s_{34} + 1.3483e^{-5}c_1^2c_{34}s_{24} + \\
& \quad 1.3483e^{-5}c_{24}s_1^2s_{34} + 1.3483e^{-5}c_{34}s_1^2s_{24} + 1.3483e^{-5}c_1c_2^2s_1s_4^2 + \\
& 1.3483e^{-5}c_1c_3^2s_1s_2^2s_4^2 - 0.0012c(\theta_2 + \theta_3)c_{12}s_3s_4^2 - 0.0012c(\theta_2 + \theta_3)c_{12}s_4^2 - \\
& \quad 1.9419e^{-9}c(\theta_2 + \theta_3)c_2s_{13}s_4^2 - 1.9419e^{-9}c(\theta_2 + \theta_3)c_3s_{12}s_4^2 + \\
& \quad 0.0012c_1^2c_{23}s_{23}s_4^2 - 1.7452e^{-7}c_{23}s_1^2s_{23}s_4^2 + 0.0012c_{124}s_{134} + \\
& \quad 0.0012c_{134}s_{124} + 2.6967e^{-5}c_{123}s_{123}s_4^2 + 0.0029
\end{aligned}
\tag{91}$$

$$\begin{aligned}
m_{41} = & 3.9045e^{-8}s_1 - 1.9778e^{-6}c(\theta_4 + 1.6029) - 0.0072s(2\theta_1) \\
& + 4.8499e^{-6}c(\theta_2 + \theta_3)^2 - 8.4387e^{-6}c_2c(\theta_4 + 1.6029) \\
& + 4.7749e^{-9}c_2s_3 + 4.7749e^{-9}c_3s_2 + 1.6659e^{-7}c_2s_4 \\
& - 3.0647e^{-4}c_4c(\theta_5 - 1.5843) - 0.0026c_1^2 + 3.4167c(\theta_2 \\
& + \theta_3)^2c_1^2 - 7.6194e^{-5}c(\theta_2 + \theta_3)^2s_4^2 - 8.7259e^{-8}c_1^2c_4^2 \\
& + 5.8916e^{-4}c_4^2s_1^2 - 0.0013c_{24}c(\theta_5 - 1.5843) - 1.5618e^{-8}c_2s_{34} \\
& - 1.5618e^{-8}c_3s_{24} - 3.9327e^{-6}c(\theta_4 + 1.6029)s_{23} \\
& - 1.4410e^{-7}s_{234} + 0.0068c(\theta_2 + \theta_3)^2c_1s_1 - 1.3483e^{-5}c_1c_4^2s_1 \\
& + 5.6315e^{-4}c_2s_3c(\theta_5 - 1.5843)^2 \\
& + 5.6315e^{-4}c_3s_2c(\theta_5 - 1.5843)^2 \\
& + 0.0032c(\theta_2 + \theta_3)s(\theta_2 + \theta_3)c_1 \\
& - 3.2188e^{-7}c(\theta_2 + \theta_3)s(\theta_2 + \theta_3)s_1 \\
& + 3.9327e^{-6}c_{23}c(\theta_4 + 1.6029) + 1.4410e^{-7}c_{23}s_4 \\
& + 7.911e^{-7}c_2c(\theta_4 + 1.6029)s_3 + 7.911e^{-7}c_3c(\theta_4 + 1.6029)s_2 \\
& + 7.911e^{-7}s(\theta_5 - 1.5843)s_{234} + 5.8916e^{-4}c_1^2c_2^2s_3^2s_4^2 \\
& + 5.8916e^{-4}c_1^2c_3^2s_2^2s_4^2 - 8.7259e^{-8}c_2^2s_1^2s_3^2s_4^2 \\
& - 8.7259e^{-8}c_3^2s_1^2s_4^2s_4^2 + 1.9419e^{-9}c(\theta_2 + \theta_3)c_{14}s_4 \\
& - 0.0012c(\theta_2 + \theta_3)c_4s_{14} - 1.1311e^{-5}c_{234}c(\theta_5 - 1.5843) \\
& + 1.2259e^{-4}c_{24}s_3c(\theta_5 - 1.5843) \\
& + 1.2259e^{-4}c_{34}s_2c(\theta_5 - 1.5843) \\
& - 7.1747e^{-7}s(\theta_5 - 1.5843)c_{23}s_4 \\
& + 1.1311e^{-5}c_4s_{23}c(\theta_5 - 1.5843) \\
& - 5.6315e^{-4}s(\theta_5 - 1.5843)c_4s_{23}c(\theta_5 - 1.5843) \\
& - 1.3483e^{-5}c_1^2c_{24}s_{34} - 1.3483e^{-5}c_1^2c_{34}s_{24} \\
& + 1.3483e^{-5}c_{24}s_1^2s_{34} + 1.3483e^{-5}c_{34}s_1^2s_{24} \\
& + 5.6315e^{-4}s(\theta_5 - 1.5843)c_{234}c(\theta_5 - 1.5843) \\
& + 1.3483e^{-5}c_{34}s_1^2s_{24} + 1.3483e^{-5}c_1c_3^2s_1s_2^2s_4^2 \\
& - 0.0012c(\theta_2 + \theta_3)c_{12}s_3s_4^2 - 0.0012c(\theta_2 + \theta_3)c_{13}s_2s_4^2 \\
& - 1.9419e^{-9}c(\theta_2 + \theta_3)c_2s_{13}s_4^2 - 1.9419e^{-9}c(\theta_2 + \theta_3)c_3s_{12}s_4^2 \\
& + 0.0012c_1^2c_{23}s_{23}s_4^2 - 1.7452e^{-7}c_{23}s_1^2s_{23}s_4^2 + 0.0012c_{124}s_{134} \\
& + 0.0012c_{134}s_{124} + 2.6967e^{-5}c_{123}s_{123}s_4^2 + 0.0029
\end{aligned} \tag{92}$$

$$\begin{aligned}
m_{42} = & 4.8499e^{-6}c(\theta_2 + \theta_3)^2 - 0.0072s(2\theta_1) - 0.0026c_1^2 - \\
& 593 \left( 3.8987e^{-29}c_4 + 3.6601e^{-25}s_4c(\theta_5 - 1.5843) \right) (5.4210e^{-2}c_3 - \\
& 2.3347e^{-26}s(\theta_5 - 1.5843) + 4.6892e^{-26}) + (c_4s_1 + c_{12}s_{34} + \\
& c_{13}s_{24})(5.8916e^{-4}c_4s_1 - 6.7417e^{-6}c_{14} - 5.8418e^{-4}c(\theta_2 + \theta_3)s_4 + \\
& 5.8418e^{-4}c_{12}s_{34} + 5.8418e^{-4}c_{13}s_{24} + 6.7417e^{-6}c_2s_{134} + 6.7417e^{-6}c_3s_{124}) + \\
& (c_2s_{134} - c_{14} + c_3s_{124})(8.7259e^{-8}c_{14} + 6.7417e^{-6}c_4s_1 - 9.7093e^{-10}c(\theta_2 + \\
& \theta_3)s_4 + 6.7417e^{-6}c_{12}s_{34} + 6.7417e^{-6}c_{13}s_{24} - 8.7259e^{-8}c_2s_{134} - \\
& 8.7259e^{-8}c_3s_{124}) + 3.4167c(\theta_2 + \theta_3)^2c_1^2 - 2.9278e^{-23}s(\theta_4 + \\
& 1.6029)(8.6736e^{-26}c_3 - 4.0422e^{-26}) + 0.0068c(\theta_2 + \theta_3)^2c_1s_1 - c(\theta_2 + \\
& \theta_3)s_4(5.8418e^{-4}c_4s_1 - 9.7093e^{-10}c_{14} + 7.6194e^{-5}c(\theta_2 + \theta_3)s_4 + \\
& 5.8418e^{-4}c_{12}s_{34} + 5.8418e^{-4}c_{13}s_{24} + 9.7093e^{-10}c_2s_{134} + 9.7093e^{-10}c_3s_{124}) + \\
& 0.0032c(\theta_2 + \theta_3)s(\theta_2 + \theta_3)c_1 - 3.2188e^{-7}c(\theta_2 + \theta_3)s(\theta_2 + \theta_3)s_1 + 0.0029
\end{aligned} \tag{93}$$

$$\begin{aligned}
m_{43} = & 3.9327e^{-6}s(\theta_4 + 1.6029) - 1.4410e^{-7}c_4 - 0.0072s(2\theta_1) + \\
& 4.8499e^{-6}c(\theta_2 + \theta_3)^2 - 0.0026c_1^2 + 7.1747e^{-7}s(\theta_5 - 1.5843)c_4 - \\
& 1.1311e^{-5}s_4c(\theta_5 - 1.5843) + 3.4167c(\theta_2 + \theta_3)^2c_1^2 - 7.6194e^{-5}c(\theta_2 + \\
& \theta_3)^2s_4^2 - 8.7259e^{-8}c_1^2c_4^2 + 5.8916e^{-4}c_4^2s_1^2 + 0.0068c(\theta_2 + \theta_3)^2c_1s_1 + \\
& 5.6315e^{-4}s(\theta_5 - 1.5843)s_4c(\theta_5 - 1.5843) - 1.3483e^{-5}c_1c_4^2s_1 + 0.0032c(\theta_2 + \\
& \theta_3)s(\theta_2 + \theta_3)c_1 - 3.2188e^{-7}c(\theta_2 + \theta_3)s(\theta_2 + \theta_3)s_1 + 5.8916e^{-4}c_1^2c_2^2s_3^2s_4^2 + \\
& 5.8916e^{-4}c_1^2c_3^2s_2^2s_4^2 - 8.7259e^{-8}c_2^2s_1^2s_3^2s_4^2 - 8.7259e^{-8}c_3^2s_1^2s_2^2s_4^2 +
\end{aligned} \tag{94}$$

$$\begin{aligned}
& 1.9419e^{-9}c(\theta_2 + \theta_3)c_{14}s_4 - 0.0012c(\theta_2 + \theta_3)c_4s_{14} - 1.3483e^{-5}c_1^2c_{24}s_{34} - \\
& 1.3483e^{-5}c_1^2c_{34}s_{24} + 1.3483e^{-5}c_{24}s_1^2s_{34} + 1.3483e^{-5}c_{34}s_1^2s_{24} + \\
& 1.3483e^{-5}c_1c_2^2s_3^2s_4^2 + 1.3483e^{-5}c_1c_3^2s_1s_2^2s_4^2 - 0.0012c(\theta_2 + \theta_3)c_{12}s_3s_4^2 - \\
& 0.0012c(\theta_2 + \theta_3)c_{13}s_2s_4^2 - 1.9419e^{-9}c(\theta_2 + \theta_3)c_2s_{13}s_4^2 - 1.9419e^{-9}c(\theta_2 + \\
& \theta_3)c_3s_{12}s_4^2 + 0.0012c_1^2c_{23}s_{23}s_4^2 - 1.7452e^{-7}c_{23}s_1^2s_{23}s_4^2 + \\
& 0.0012c_{124}s_{134}s_4^2 + 0.0012c_{134}s_{124} + 2.6967e^{-5}c_{123}s_{123}s_4^2 + 0.0029 \\
& m_{44} = -5.6315e^{-4}s(\theta_5 - 1.5843)^2 + 3.4167c(\theta_2 + \theta_3)^2c_1^2 + 0.0068c(\theta_2 + \\
& \theta_3)^2c_1s_1 - 7.6194e^{-5}c(\theta_2 + \theta_3)^2s_4^2 + 4.8499e^{-6}c(\theta_2 + \theta_3)^2 - 0.0012c(\theta_2 + \\
& \theta_3)c_{12}s_3s_4^2 - 0.0012c(\theta_2 + \theta_3)c_{13}s_2s_4^2 + 1.9419e^{-9}c(\theta_2 + \theta_3)c_{14}s_4 + \\
& 0.0032c(\theta_2 + \theta_3)s(\theta_2 + \theta_3)c_1 - 1.9419e^{-9}c(\theta_2 + \theta_3)c_2s_{13}s_4^2 - \\
& 1.9419e^{-9}c(\theta_2 + \theta_3)c_3s_{12}s_4^2 - 0.0012c(\theta_2 + \theta_3)c_4s_{14} - 3.2188e^{-7}s(\theta_2 + \\
& \theta_3)c(\theta_2 + \theta_3)s_1 + 5.8916e^{-4}c_1^2c_2^2s_3^2s_4^2 + 0.0012c_1^2c_{23}s_{23}s_4^2 - \\
& 1.3483e^{-5}c_1^2c_{24}s_{34} + 5.8916e^{-4}c_1^2c_3^2s_2^2s_4^2 - 1.3483e^{-5}c_1^2c_{34}s_{24} - \\
& 8.7259e^{-8}c_1^2c_4^2 - 0.0026c_1^2 + 1.3483e^{-5}c_1c_2^2s_1s_3^2s_4^2 + \\
& 2.6967e^{-5}c_{123}s_{12}s_4^2 + 0.0012c_{124}s_{134} + 1.383e^{-5}c_1c_3^2s_1s_2^2s_4^2 + \\
& 0.0012c_{134}s_{124} - 1.3483e^{-5}c_1c_4^2s_1 - 8.7259e^{-8}c_2^2s_1^2s_3^2s_4^2 - \\
& 1.7452e^{-7}c_{23}s_1^2s_{23}s_4^2 + 1.3483e^{-5}c_{24}s_1^2s_{24} - 8.7259e^{-8}c_3^2s_1^2s_2^2s_4^2 + \\
& 1.3483e^{-5}c_{34}s_1^2s_{24} + 5.8916e^{-4}c_4^2s_1^2 - 0.0072 + 0.0034
\end{aligned} \tag{95}$$

$$\begin{aligned}
& m_{45} = 3.4167c(\theta_2 + \theta_3)^2c_1^2 + 0.0068c(\theta_2 + \theta_3)^2c_1s_1 - 7.6194e^{-5}c(\theta_2 + \\
& \theta_3)^2s_4^2 + 4.8499e^{-6}c(\theta_2 + \theta_3)^2 - 0.0012c(\theta_2 + \theta_3)c_{12}s_3s_4^2 - 0.0012c(\theta_2 + \\
& \theta_3)c_{13}s_2s_4^2 + 1.9419e^{-9}c(\theta_2 + \theta_3)c_{14}s_4 + 0.0032s(\theta_2 + \theta_3)c(\theta_2 + \theta_3)c_1 - \\
& 1.9419e^{-9}c(\theta_2 + \theta_3)c_3s_{13}s_4^2 - 1.9419e^{-9}c(\theta_2 + \theta_3)c_3s_{12}s_4^2 - 0.0012c(\theta_2 + \\
& \theta_3)c_4s_{14} - 3.2188e^{-7}s(\theta_2 + \theta_3)c(\theta_2 + \theta_3)s_1 + 5.8916e^{-4}c_1^2c_2^2s_3^2s_4^2 + \\
& 0.0012c_1^2c_{23}s_{23}s_4^2 - 1.3483e^{-5}c_1^2c_{24}s_{34} + 5.8916e^{-4}c_1^2c_3^2s_2^2s_4^2 - \\
& 1.3483e^{-5}c_1^2c_{34}s_{24} - 8.7259e^{-8}c_1^2c_4^2 - 0.0026c_1^2 + \\
& 1.3483e^{-5}c_1c_2^2c_2^2s_1s_3^2s_4^2 + 2.6967e^{-5}c_{123}s_{123}s_4^2 + 0.0012c_{124}s_{124} + \\
& 1.3483e^{-5}c_1c_3^2s_1s_2^2s_4^2 + 0.0012c_{134}s_{124} - 1.3483e^{-5}c_1c_4^2s_1 - \\
& 8.7259e^{-8}c_2^2s_1^2s_3^2s_4^2 - 1.7452e^{-7}c_{23}s_1^2s_{23}s_4^2 + 1.3483e^{-5}c_{24}s_1^2s_{24} - \\
& 8.7259e^{-8}c_3^2s_1^2s_2^2s_4^2 + 1.3483e^{-5}c_{34}s_1^2s_{24} + 5.8916e^{-4}c_4^2s_1^2 + \\
& 7.1747e^{-7}s(\theta_5 - 1.5843) - 0.0072s(2\theta_1) + 0.0029
\end{aligned} \tag{96}$$

$$\begin{aligned}
& m_{51} = 4.8499e^{-6}c(\theta_2 + \theta_3)^2 - 0.0072s(2\theta_1) - 0.0026c(2\theta_1)^2 + \\
& 3.0647e^{-4}s(\theta_5 - 1.5843)s_4 + 3.4167c(\theta_2 + \theta_3)^2c_1^2 - 7.6194e^{-5}c(\theta_2 + \\
& \theta_3)^2s_4^2 - 8.7259e^{-8}c_1^2c_4^2 + 5.8916e^{-4}c_4^2s_1^2 + 5.6315e^{-4}s_{234} + \\
& 7.1747e^{-7}s(\theta_5 - 1.5843)c_2s_3 + 7.1747e^{-7}s(\theta_5 - 1.5843)c_3s_2 + 0.0013s(\theta_5 - \\
& 1.5843)c_2s_4 + 0.0068c(\theta_2 + \theta_3)^2c_1s_1 - 1.3483e^{-5}c_1c_4^2s_1 + 0.0032c(\theta_2 + \\
& \theta_3)s(\theta_2 + \theta_3)c_1 - 3.2188e^{-7}c(\theta_2 + \theta_3)s(\theta_2 + \theta_3)s_1 - 5.6315e^{-4}c_{23}s_4 - \\
& 1.2259e^{-4}s(\theta_5 - 1.5843)c_2s_{34} - 1.2259e^{-4}s(\theta_5 - 1.5843)c_3s_{24} - \\
& 1.311e^{-5}s(\theta_5 - 1.5843)s_{234} + 5.8916e^{-4}c_1^2c_2^2s_3^2s_4^2 + \\
& 5.8916e^{-4}c_1^2c_3^2s_2^2s_4^2 - 8.7259e^{-8}c_2^2s_1^2s_3^2s_4^2 - 8.7259e^{-8}c_3^2s_1^2s_2^2s_4^2 + \\
& 1.9419e^{-9}c(\theta_2 + \theta_3)c_{14}s_4 - 0.0012(\theta_2 + \theta_3)c_4s_{14} - 7.1747e^{-7}c_{234}c(\theta_5 - \\
& 1.5843) + 1.1311e^{-5}s(\theta_5 - 1.5843)c_{23}s_4 + 7.1747e^{-7}c_4s_{23}c(\theta_5 - 1.5843) - \\
& 1.3483e^{-5}c_1^2c_{24}s_{34} - 1.3483e^{-5}c_1^2c_{34}s_{24} + 1.3483e^{-5}c_{24}s_1^2s_{34} + \\
& 1.3483e^{-5}c_{34}s_1^2s_{24} + 1.3483e^{-5}c_1c_2^2s_1s_3^2s_4^2 + 1.3483e^{-5}c_1c_3^2s_1s_2^2s_4^2 - \\
& 0.0012c(\theta_2 + \theta_3)c_{12}s_3s_4^2 - 0.0012c(\theta_2 + \theta_3)c_{13}s_2s_4^2 - 1.9419e^{-9}c(\theta_2 + \\
& \theta_3)c_2s_{13}s_4^2 - 1.9419e^{-9}c(\theta_2 + \theta_3)c_3s_{12}s_4^2 + 0.0012c_1^2c_{23}s_{23}s_4^2 - \\
& 1.7452e^{-7}c_{23}s_1^2s_{23}s_4^2 + 0.0012c_{124}s_{134} + 0.0012c_{134}s_{124} + \\
& 2.6967e^{-5}c_{123}s_{123}s_4^2 + 0.0029
\end{aligned} \tag{97}$$



$$\begin{aligned}
m_{52} = & 5.6315e^{-4}c_4 - 0.0072s(2\theta_1) + 1.2259e^{-4}c(\theta_5 - 1.5843) + \\
& 4.8499e^{-6}c(\theta_2 + \theta_3)^2 - 0.0026c_1^2 - 0.0013s_3c(\theta_5 - 1.5843) - \\
& 1.1311e^{-5}s(\theta_5 - 1.5843)c_4 - 7.1747e^{-7}s_4c(\theta_5 - 1.5843) + 3.4167c(\theta_2 + \\
& \theta_3)^2c_1^2 - 7.6194e^{-5}c(\theta_2 + \theta_3)^2s_4^2 - 8.7259e^{-8}c_1^2c_4^2 + 5.8916e^{-4}c_4^2s_1^2 - \\
& 0.0013s(\theta_5 - 1.5843)c_{34} + 0.0068c(\theta_2 + \theta_3)^2c_1s_1 - 1.3483e^{-5}c_1c_4^2s_1 + \\
& 0.0032c(\theta_2 + \theta_3)s(\theta_2 + \theta_3)c_1 - 3.2188e^{-7}c(\theta_2 + \theta_3)s(\theta_2 + \theta_3)s_1 + \\
& 5.8916e^{-4}c_1^2c_2^2s_3^2s_4^2 + 5.8916e^{-4}c_1^2c_3^2s_2^2s_4^2 - 8.7259e^{-8}c_2^2s_1^2s_3^2s_4^2 - \\
& 8.7259e^{-8}c_3^2s_1^2s_2^2s_4^2 + 1.9419e^{-9}c(\theta_2 + \theta_3)c_{14}s_4 - 0.0012c(\theta_2 + \theta_3)c_4s_{14} - \\
& 1.3483e^{-5}c_1^2c_{24}s_{34} - 1.3483e^{-5}c_1^2c_{34}s_{24} + 1.3483e^{-5}c_{24}s_1^2s_{34} + \\
& 1.3483e^{-5}c_{34}s_1^2s_{24} + 1.3483e^{-5}c_1c_2^2s_1s_3^2s_4^2 + 1.3483e^{-5}c_1c_3^2s_1s_2^2s_4^2 - \\
& 0.0012c(\theta_2 + \theta_3)c_{12}s_3s_4^2 - 0.0012c(\theta_2 + \theta_3)c_{13}s_2s_4^2 - 1.9419e^{-9}c(\theta_2 + \\
& \theta_3)c_2s_{13}s_4^2 - 1.9419e^{-9}c(\theta_2 + \theta_3)c_3s_{12}s_4^2 + 0.0012c_1^2c_{23}s_{23}s_4^2 - \\
& 1.7452e^{-7}c_{23}s_1^2s_{23}s_4^2 + 0.0012c_{124}s_{134} + 0.0012c_{134}s_{124} + \\
& 2.6967e^{-5}c_{123}s_{123}s_4^2 + 0.0029
\end{aligned} \tag{98}$$

$$\begin{aligned}
m_{53} = & 5.6315e^{-4}c_4 - 0.0072s(2\theta_1) + 1.2259e^{-4}c(\theta_5 - 1.5843) + \\
& 4.8499e^{-6}c(\theta_2 + \theta_3)^2 - 0.0026c_1^2 - 1.1311e^{-5}s(\theta_5 - 1.5843)c_4 - \\
& 7.1747e^{-7}s_4c(\theta_5 - 1.5843) + 3.4167c(\theta_2 + \theta_3)^2c_1^2 - 7.6194e^{-5}c(\theta_2 + \\
& \theta_3)^2s_4^2 - 8.7259e^{-8}c_1^2c_4^2 + 5.8916e^{-4}c_4^2s_1^2 + 0.0068c(\theta_2 + \theta_3)^2c_1s_1 - \\
& 1.3483e^{-5}c_1c_4^2s_1 + 0.0032c(\theta_2 + \theta_3)s(\theta_2 + \theta_3)c_1 - 3.2188e^{-7}c(\theta_2 + \theta_3)s(\theta_2 + \\
& \theta_3)s_1 + 5.8916e^{-4}c_1^2c_2^2s_3^2s_1^2 + 5.8916e^{-4}c_1^2c_3^2s_2^2s_4^2 - \\
& 8.7259e^{-8}c_2^2s_1^2s_3^2s_4^2 - 8.7259e^{-8}c_3^2s_1^2s_2^2s_4^2 + 1.9419e^{-9}c(\theta_2 + \theta_3)c_{14}s_4 - \\
& 0.0012c(\theta_2 + \theta_3)c_4s_{14} - 1.3483e^{-5}c_1^2c_{24}s_{34} - 1.3483e^{-5}c_1^2c_{34}s_{24} + \\
& 1.3483e^{-5}c_{24}s_1^2s_{34} + 1.3483e^{-5}c_{34}s_1^2s_{24} + 1.3483e^{-5}c_1c_2^2s_1s_3^2s_4^2 + \\
& 1.3483e^{-5}c_1c_3^2s_1s_2^2s_4^2 - 0.0012c(\theta_2 + \theta_3)c_{12}s_3s_4^2 - 0.0012c(\theta_2 + \\
& \theta_3)c_{13}s_2s_4^2 - 1.9419e^{-9}c(\theta_2 + \theta_3)c_2s_{13}s_4^2 - 1.9419e^{-9}c(\theta_2 + \theta_3)c_3s_{12}s_4^2 + \\
& 0.0012c_1^2c_{23}s_{23}s_4^2 - 1.7452e^{-7}c_{23}s_1^2s_{23}s_4^2 + 0.0012c_{124}s_{134} + \\
& 0.0012c_{134}s_{124} + 2.6967e^{-5}c_{123}s_{123}s_4^2 + 0.0029
\end{aligned} \tag{99}$$

$$\begin{aligned}
m_{54} = & 3.4167c(\theta_2 + \theta_3)^2c_1^2 + 0.0068c(\theta_2 + \theta_3)^2c_1s_1 - 7.6194e^{-5}c(\theta_2 + \\
& \theta_3)^2s_4^2 + 4.8499e^{-6}c(\theta_2 + \theta_3)^2 - 0.0012c(\theta_2 + \theta_3)c_{12}s_3s_4^2 - 0.0012c(\theta_2 + \\
& \theta_3)c_{13}s_2s_4^2 + 1.9419e^{-9}c(\theta_2 + \theta_3)c_{14}s_4 + 0.0032s(\theta_2 + \theta_3)c(\theta_2 + \theta_3)c_1 - \\
& 1.9419e^{-9}c(\theta_2 + \theta_3)c_2s_{13}s_4^2 - 1.9419e^{-9}c(\theta_2 + \theta_3)c_3s_{12}s_4^2 - 0.0012c(\theta_2 + \\
& \theta_3)c_4s_{14} - 3.2188e^{-7}s(\theta_2 + \theta_3)c(\theta_2 + \theta_3)s_1 + 5.8916e^{-4}c_1^2c_2^2s_3^2s_4^2 + \\
& 5.8916e^{-4}c_1^2c_{23}s_{23}s_4^2 - 1.3483e^{-5}c_1^2c_{24}s_{34} + 5.8916e^{-4}c_1^2c_3^2s_2^2s_4^2 - \\
& 1.3483e^{-5}c_1^2c_{34}s_{24} - 8.7259e^{-8}c_1^2c_4^2 - 0.0026c_1^2 + \\
& 1.3483e^{-5}c_1c_2^2s_1s_3^2s_4^2 + 2.6967e^{-5}c_{123}s_{123}s_4^2 + 0.0012c_{124}s_{134} + \\
& 1.3483e^{-5}c_1c_3^2s_1s_2^2s_4^2 + 0.0012c_{134}s_{124} - 1.3483e^{-6}c_1c_4^2s_1 - \\
& 8.7259e^{-8}c_2^2s_1^2s_3^2s_4^2 - 1.7452e^{-7}c_{23}s_1^2s_{23}s_4^2 + 1.3483e^{-5}c_{24}s_1^2s_{34} - \\
& 8.7259e^{-8}c_3^2s_1^2s_2^2s_4^2 + 1.3483e^{-5}c_{34}s_1^2s_{24} + 5.8916e^{-4}c_4^2s_2^2 + \\
& 7.1747e^{-7}s(\theta_5 - 1.5843) - 0.0072 + 0.0029
\end{aligned} \tag{100}$$

$$\begin{aligned}
m_{55} = & 3.4167c(\theta_2 + \theta_3)^2c_1^2 + 0.0068c(\theta_2 + \theta_3)^2c_1s_1 - 7.6194e^{-5}c(\theta_2 + \\
& \theta_3)^2s_4^2 + 4.8499e^{-6}c(\theta_2 + \theta_3)^2 - 0.0012c(\theta_2 + \theta_3)c_{12}s_3s_4^2 - 0.0012c(\theta_2 + \\
& \theta_3)c_{13}s_2s_4^2 + 1.9419e^{-9}c(\theta_2 + \theta_3)c_{14}s_4 + 0.0032s(\theta_2 + \theta_3)c(\theta_2 + \theta_3)c_1 - \\
& 1.9419e^{-9}c(\theta_2 + \theta_3)c_2s_{13}s_4^2 - 1.9419e^{-9}c(\theta_2 + \theta_3)c_3s_{12}s_4^2 - 0.0012c(\theta_2 + \\
& \theta_3)c_4s_{14} - 3.2188e^{-7}s(\theta_2 + \theta_3)c(\theta_2 + \theta_3)s_1 + 5.8916e^{-4}c_1^2c_2^2s_3^2s_4^2 + \\
& 0.0012c_1^2c_{23}s_{23}s_4^2 - 1.3483e^{-5}c_1^2c_{24}s_{23} + 5.8916e^{-4}c_1^2c_3^2s_2^2s_4^2 - \\
& 1.3483e^{-5}c_1^2c_{34}s_{24} - 8.7259e^{-8}c_1^2c_4^2 - 0.0026c_1^2 + \\
& 1.3483e^{-5}c_1c_1^2s_1s_3^2s_4^2 + 2.6967e^{-5}c_{123}s_{123}s_4^2 + 0.0012c_{124}s_{134} + \\
& 1.3483e^{-5}c_1c_3^2s_1s_2^2s_4^2 + 0.0012c_{134}s_{124} - 1.3483e^{-6}c_1c_4^2s_1 - \\
& 8.7259e^{-8}c_2^2s_1s_3^2s_4^2 - 1.7452e^{-7}c_{23}s_1^2s_{23}s_4^2 + 1.3483e^{-5}c_{24}s_1^2s_{34} -
\end{aligned} \tag{101}$$

$$8.7259e^{-8}c_3^2s_1^2s_2^2s_4^2 + 1.3483e^{-5}c_{34}s_1^2s_{24} + 5.8916e^{-4}c_4^2s_2^2 - 0.0072 + 0.0034$$

### 3.4 Friction

Friction is not considered by the Lagrange-Euler dynamics of the robot manipulator joints. Friction is a very complex process and is a nonlinear phenomenon that is unique to each system [39]. Models of friction include dynamic (viscous) friction and static friction. Static and dynamic friction are defined, for a robot manipulator, as the torque necessary to move the fixed joints of the robot. Static friction indicates that a non-zero torque is needed to initiate joint movement, while dynamic friction indicates the amount of frictional torque that increases as joint speed increases.

Modeling friction force is important for control purposes [40], because it can significantly improve the overall performance of the robot manipulator in terms of accuracy and control stability. Torque control algorithms can also be implemented using axial torque data of the motor rotation axis of the robot manipulator [41]. Friction can be affected by several factors such as temperature, speed, force/torque levels, acceleration, position, and lubricant/grease properties. This poses a major challenge to the robot manipulator, which has very complex dynamics [40]. The literature provides numerous identification methods and friction models, more comprehensive models of friction include dependence on factors such as rotational speed, load, and temperature. Through the Equation (102) [39], the friction torque  $\tau$  can be calculated, which depends on the load torque  $L$ , angular velocity  $\dot{\phi}$  and joint temperature  $T$ . In this study, robot friction is not modeled; instead, the rotational friction block is employed to simulate the friction block in contact with spinning components. The friction is calculated as a function of the robotic arm's relative velocity and is supposed to represent the sum of the Stribeck, Coulomb, and viscous friction.

$$\tau(L, \dot{\phi}, T) = \tau_L(L) + \tau_S(\dot{\phi}) + \tau_V(\dot{\phi}, T) + \tau_C \quad (102)$$

Where  $\tau_L$  is friction component dependent on load,  $\tau_S$  is Stribeck friction,  $\tau_V$  is viscous friction,  $\tau_C$  is Coulomb friction.

### 3.5 Simulink Model of DC Motor

DC motor modeling is the process of creating equations that clearly define the connection between input (voltage or current) and output (angular velocity or torque) to achieve the required position, velocity, and acceleration. DC motors play an essential role in control and drive systems, and they are widely employed in mechanical systems such as robotics [42]. DC motors transform electrical energy into mechanical rotational energy, which is paired with mechanical elements to produce the necessary angular motion of the link. DC motors can be controlled by controlling the voltage or current. Equation (103) depicts the connection between motor torque and current.

$$\tau_m(t) = K_m i_a(t) \quad (103)$$

Where  $\tau_m(t)$  is the motor torque,  $K_m$  is the motor torque constant, and  $i_a(t)$  is the motor current. Equation (104) shows the relationship between the back EMF voltage and the motor shaft speed.

$$v_b = k_m \omega_m \quad (104)$$