$$A_{01} = \begin{pmatrix} \cos(q_1) & 0 & \sin(q_1) & 33\cos(q_1) \\ \sin(q_1) & 0 & -\cos(q_1) & 33\sin(q_1) \\ 0 & 1 & 0 & 147 \\ 0 & 0 & 0 & 1 \end{pmatrix} \tag{1}$$

$$A_{12} = \begin{pmatrix} \cos(q_2) & -\sin(q_2) & 0 & 155\cos(q_2) \\ \sin(q_2) & \cos(q_2) & 0 & 155\sin(q_2) \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \tag{2}$$

$$A_{23} = \begin{pmatrix} \cos(q_3) & -\sin(q_3) & 0 & 135\cos(q_3) \\ \sin(q_3) & \cos(q_3) & 0 & 135\sin(q_3) \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \tag{3}$$

$$A_{34} = \begin{pmatrix} \cos(q_4) & 0 & \sin(q_4) & 0 \\ \sin(q_4) & 0 & -\cos(q_4) & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \tag{4}$$

$$A_{45} = \begin{pmatrix} \cos(q_5) & -\sin(q_5) & 0 & 0 \\ \sin(q_5) & \cos(q_5) & 0 & 0 \\ 0 & 0 & 1 & \frac{435}{2} \\ 0 & 0 & 0 & 1 \end{pmatrix} \tag{5}$$

$$A_{01} = \begin{pmatrix} \cos(q_1) & -\sin(q_1) & 0 & 0 \\ \sin(q_1) & \cos(q_1) & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \tag{6}$$

$$A_{02} = \begin{pmatrix} \cos(q_1)\cos(q_2) & -\cos(q_1)\sin(q_2) & \sin(q_1) & 33\cos(q_1) \\ \cos(q_2)\sin(q_1) & -\sin(q_1)\sin(q_2) & -\cos(q_1) & 33\sin(q_1) \\ \sin(q_2) & \cos(q_2) & 0 & 147 \\ 0 & 0 & 0 & 1 \end{pmatrix} \tag{7}$$

$$A_{03} = \begin{pmatrix} \cos(q_2+q_3)\cos(q_1) & -\sin(q_2+q_3)\cos(q_1) & \sin(q_1) & \cos(q_1)\,(155\cos(q_2)+33) \\ \cos(q_2+q_3)\sin(q_1) & -\sin(q_2+q_3)\sin(q_1) & -\cos(q_1) & \sin(q_1)\,(155\cos(q_2)+33) \\ \sin(q_2+q_3) & \cos(q_2+q_3) & 0 & 155\sin(q_2)+147 \\ 0 & 0 & 0 & 1 \end{pmatrix} \tag{8}$$

$$A_{04} = \begin{pmatrix} \cos(q_2+q_3+q_4)\cos(q_1) & -\sin(q_2+q_3+q_4)\cos(q_1) & \sin(q_1) & \cos(q_1)\,(135\cos(q_2+q_3)+155\cos(q_2)+33) \\ \cos(q_2+q_3+q_4)\sin(q_1) & -\sin(q_2+q_3+q_4)\sin(q_1) & -\cos(q_1) & \sin(q_1)\,(135\cos(q_2+q_3)+155\cos(q_2)+33) \\ \sin(q_2+q_3+q_4) & \cos(q_2+q_3+q_4) & 0 & 135\sin(q_2+q_3)+155\sin(q_2)+147 \\ 0 & 0 & 0 & 1 \end{pmatrix} \tag{9}$$

$$A_{05} = \begin{pmatrix} \sin(q_1)\sin(q_5)+\cos(q_2+q_3+q_4)\cos(q_1)\cos(q_5) & \cos(q_5)\sin(q_1)-\cos(q_2+q_3+q_4)\cos(q_1)\sin(q_5) & \sin(q_2+q_3+q_4)\cos(q_1) & \cos(q_1)\,(135\cos(q_2+q_3)+155\,c \\ \cos(q_2+q_3+q_4)\cos(q_5)\sin(q_1)-\cos(q_1)\sin(q_5) & -\cos(q_1)\cos(q_5)-\cos(q_2+q_3+q_4)\sin(q_1)\sin(q_5) & \sin(q_2+q_3+q_4)\sin(q_1) & \sin(q_1)\,(135\cos(q_2+q_3)+155\,c \\ \sin(q_2+q_3+q_4)\cos(q_5) & -\sin(q_2+q_3+q_4)\sin(q_5) & -\cos(q_2+q_3+q_4) & 135\sin(q_2+q_3)+155\sin(q \\ 0 & 0 & 0 & 1 \end{pmatrix} \tag{10}$$

$$w_1 = \begin{pmatrix} 0 & 0 & 1 & 0 \end{pmatrix} \tag{11}$$

$$w_2 = \begin{pmatrix} \sin(q_2) & \cos(q_2) & 0 & 147 \end{pmatrix} \tag{12}$$

$$w_3 = \begin{pmatrix} \sin(q_2+q_3) & \cos(q_2+q_3) & 0 & 155\sin(q_2)+147 \end{pmatrix} \tag{13}$$

$$w_4 = \begin{pmatrix} \sin(q_2+q_3+q_4) & \cos(q_2+q_3+q_4) & 0 & 135\sin(q_2+q_3)+155\sin(q_2)+147 \end{pmatrix} \tag{14}$$

$$w_5 = \begin{pmatrix} \sin(q_2+q_3+q_4)\cos(q_5) & -\sin(q_2+q_3+q_4)\sin(q_5) & -\cos(q_2+q_3+q_4) & 135\sin(q_2+q_3)+155\sin(q_2)+147 \end{pmatrix} \tag{15}$$

$$p_1 = g\,m_1\,\mathrm{rz}_1 \tag{16}$$

$$p_2 = g\,m_2\,(\mathrm{ry}_2\,\cos(q_2) + \mathrm{rx}_2\,\sin(q_2) + 147) \tag{17}$$

$$p_3 = g\,m_3\,(155\,\sin(q_2) + \mathrm{ry}_3\,\cos(q_2+q_3) + \mathrm{rx}_3\,\sin(q_2+q_3) + 147) \tag{18}$$

$$p_4 = g\,m_4\,(135\,\sin(q_2+q_3) + 155\,\sin(q_2) + \mathrm{ry}_4\,\cos(q_2+q_3+q_4) + \mathrm{rx}_4\,\sin(q_2+q_3+q_4) + 147) \tag{19}$$

$$p_5 = g\,m_5\,(135\,\sin(q_2+q_3) + 155\,\sin(q_2) + 147) - g\,m_5\,\mathrm{rz}_5\,\cos(q_2+q_3+q_4) + g\,m_5\,\mathrm{rx}_5\,\sin(q_2+q_3+q_4)\,\cos(q_5) - g\,m_5\,\mathrm{ry}_5\,\sin(q_2+q_3+q_4)\,\sin(q_5) \tag{20}$$

$P_1 = 147\,g\,m_2 + g\,m_1\,\mathrm{rz}_1 + g\,m_3\,(155\,\sin(q_2) + 147) + g\,m_4\,(135\,\sin(q_2+q_3) + 155\,\sin(q_2) + 147) + g\,m_5\,(135\,\sin(q_2+q_3) + 155\,\sin(q_2) + 147) + g\,m_3\,\mathrm{ry}_3\,\cos(q_2+q_3) + g\,m_3\,\mathrm{rx}_3\,\sin(q_2+q_3) + g\,m_2\,\mathrm{ry}_2\,\cos(q_2) + g\,m_2\,\mathrm{rx}_2\,\sin(q_2) + g\,m_4\,\mathrm{ry}_4\,\cos(q_2+q_3+q_4) - g\,m_5\,\mathrm{rz}_5\,\cos(q_2+q_3+q_4) + g\,m_4\,\mathrm{rx}_4\,\sin(q_2+q_3+q_4) + g\,m_5\,\mathrm{rx}_5\,\sin(q_2+q_3+q_4)\,\cos(q_5) - g\,m_5\,\mathrm{ry}_5\,\sin(q_2+q_3+q_4)\,\sin(q_5)$

$P_2 = 147\,g\,m_2 + g\,m_3\,(155\,\sin(q_2) + 147) + g\,m_4\,(135\,\sin(q_2+q_3) + 155\,\sin(q_2) + 147) + g\,m_5\,(135\,\sin(q_2+q_3) + 155\,\sin(q_2) + 147) + g\,m_3\,\mathrm{ry}_3\,\cos(q_2+q_3) + g\,m_3\,\mathrm{rx}_3\,\sin(q_2+q_3) + g\,m_2\,\mathrm{ry}_2\,\cos(q_2) + g\,m_2\,\mathrm{rx}_2\,\sin(q_2) + g\,m_4\,\mathrm{ry}_4\,\cos(q_2+q_3+q_4) - g\,m_5\,\mathrm{rz}_5\,\cos(q_2+q_3+q_4) + g\,m_4\,\mathrm{rx}_4\,\sin(q_2+q_3+q_4) + g\,m_5\,\mathrm{rx}_5\,\sin(q_2+q_3+q_4)\,\cos(q_5) - g\,m_5\,\mathrm{ry}_5\,\sin(q_2+q_3+q_4)\,\sin(q_5)$

$P_3 = g\,m_3\,(155\,\sin(q_2) + 147) + g\,m_4\,(135\,\sin(q_2+q_3) + 155\,\sin(q_2) + 147) + g\,m_5\,(135\,\sin(q_2+q_3) + 155\,\sin(q_2) + 147) + g\,m_3\,\mathrm{ry}_3\,\cos(q_2+q_3) + g\,m_3\,\mathrm{rx}_3\,\sin(q_2+q_3) + g\,m_4\,\mathrm{ry}_4\,\cos(q_2+q_3+q_4) - g\,m_5\,\mathrm{rz}_5\,\cos(q_2+q_3+q_4) + g\,m_4\,\mathrm{rx}_4\,\sin(q_2+q_3+q_4) + g\,m_5\,\mathrm{rx}_5\,\sin(q_2+q_3+q_4)\,\cos(q_5) - g\,m_5\,\mathrm{ry}_5\,\sin(q_2+q_3+q_4)\,\sin(q_5)$

$P_4 = g\,m_4\,(135\,\sin(q_2+q_3) + 155\,\sin(q_2) + 147) + g\,m_5\,(135\,\sin(q_2+q_3) + 155\,\sin(q_2) + 147) + g\,m_4\,\mathrm{ry}_4\,\cos(q_2+q_3+q_4) - g\,m_5\,\mathrm{rz}_5\,\cos(q_2+q_3+q_4) + g\,m_4\,\mathrm{rx}_4\,\sin(q_2+q_3+q_4) + g\,m_5\,\mathrm{rx}_5\,\sin(q_2+q_3+q_4)\,\cos(q_5) - g\,m_5\,\mathrm{ry}_5\,\sin(q_2+q_3+q_4)\,\sin(q_5)$

$P_5 = g\,m_5\,(135\,\sin(q_2+q_3) + 155\,\sin(q_2) + 147) - g\,m_5\,\mathrm{rz}_5\,\cos(q_2+q_3+q_4) + g\,m_5\,\mathrm{rx}_5\,\sin(q_2+q_3+q_4)\,\cos(q_5) - g\,m_5\,\mathrm{ry}_5\,\sin(q_2+q_3+q_4)\,\sin(q_5)$

$$W_1 = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix} \tag{21}$$

$$W_2 = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix} \tag{22}$$

$$W_3 = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix} \tag{23}$$

$$W_4 = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix} \tag{24}$$

$$W_5 = \begin{pmatrix} 0 \\ \cos(q_2) \\ 0 \\ 0 \\ 0 \end{pmatrix} \tag{25}$$

$$W_6 = \begin{pmatrix} 0 \\ -\sin(q_2) \\ 0 \\ 0 \\ 0 \end{pmatrix} \tag{26}$$

$$W_7 = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix} \tag{27}$$

$$W_8 = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix} \tag{28}$$

$$W_9 = \begin{pmatrix} 0 \\ \cos(q_2 + q_3) \\ \cos(q_2 + q_3) \\ 0 \\ 0 \end{pmatrix} \tag{29}$$

$$W_{10} = \begin{pmatrix} 0 \\ -\sin(q_2 + q_3) \\ -\sin(q_2 + q_3) \\ 0 \\ 0 \end{pmatrix} \tag{30}$$

$$W_{11} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix} \tag{31}$$

$$W_{12} = \begin{pmatrix} 0 \\ 155\,\cos(q_2) \\ 0 \\ 0 \\ 0 \end{pmatrix} \tag{32}$$

$$W_{13} = \begin{pmatrix} 0 \\ \cos(q_2 + q_3 + q_4) \\ \cos(q_2 + q_3 + q_4) \\ \cos(q_2 + q_3 + q_4) \\ 0 \end{pmatrix} \tag{33}$$

$$W_{14} = \begin{pmatrix} 0 \\ -\sin(q_2+q_3+q_4) \\ -\sin(q_2+q_3+q_4) \\ -\sin(q_2+q_3+q_4) \\ 0 \end{pmatrix} \tag{34}$$

$$W_{15} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix} \tag{35}$$

$$W_{16} = \begin{pmatrix} 0 \\ 135\cos(q_2+q_3)+155\cos(q_2) \\ 135\cos(q_2+q_3) \\ 0 \\ 0 \end{pmatrix} \tag{36}$$

$$W_{17} = \begin{pmatrix} 0 \\ \cos(q_2+q_3+q_4)\cos(q_5) \\ \cos(q_2+q_3+q_4)\cos(q_5) \\ \cos(q_2+q_3+q_4)\cos(q_5) \\ -\sin(q_2+q_3+q_4)\sin(q_5) \end{pmatrix} \tag{37}$$

$$W_{18} = \begin{pmatrix} 0 \\ -\cos(q_2+q_3+q_4)\sin(q_5) \\ -\cos(q_2+q_3+q_4)\sin(q_5) \\ -\cos(q_2+q_3+q_4)\sin(q_5) \\ -\sin(q_2+q_3+q_4)\cos(q_5) \end{pmatrix} \tag{38}$$

$$W_{19} = \begin{pmatrix} 0 \\ \sin(q_2+q_3+q_4) \\ \sin(q_2+q_3+q_4) \\ \sin(q_2+q_3+q_4) \\ 0 \end{pmatrix} \tag{39}$$

$$W_{20} = \begin{pmatrix} 0 \\ 135\,\cos\left(q_2 + q_3\right) + 155\,\cos\left(q_2\right) \\ 135\,\cos\left(q_2 + q_3\right) \\ 0 \\ 0 \end{pmatrix} \tag{40}$$

$$W_{1_R} = \begin{pmatrix} -\sin(\mathrm{q2}) \\ 0 \\ 0 \\ 0 \end{pmatrix} \tag{41}$$

$$W_{2_R} = \begin{pmatrix} \cos(\mathrm{q2} + \mathrm{q3}) \\ \cos(\mathrm{q2} + \mathrm{q3}) \\ 0 \\ 0 \end{pmatrix} \tag{42}$$

$$W_{3_R} = \begin{pmatrix} -\sin(\mathrm{q2} + \mathrm{q3}) \\ -\sin(\mathrm{q2} + \mathrm{q3}) \\ 0 \\ 0 \end{pmatrix} \tag{43}$$

$$W_{4_R} = \begin{pmatrix} 155\,\cos(\mathrm{q2}) \\ 0 \\ 0 \\ 0 \end{pmatrix} \tag{44}$$

$$W_{5_R} = \begin{pmatrix} \cos(\mathrm{q2} + \mathrm{q3} + \mathrm{q4}) \\ \cos(\mathrm{q2} + \mathrm{q3} + \mathrm{q4}) \\ \cos(\mathrm{q2} + \mathrm{q3} + \mathrm{q4}) \\ 0 \end{pmatrix} \tag{45}$$

$$W_{6_R} = \begin{pmatrix} -\sin(\mathrm{q2}+\mathrm{q3}+\mathrm{q4}) \\ -\sin(\mathrm{q2}+\mathrm{q3}+\mathrm{q4}) \\ -\sin(\mathrm{q2}+\mathrm{q3}+\mathrm{q4}) \\ 0 \end{pmatrix} \tag{46}$$

$$W_{7_R} = \begin{pmatrix} 135\,\cos(\mathrm{q2}+\mathrm{q3}) + 155\,\cos(\mathrm{q2}) \\ 135\,\cos(\mathrm{q2}+\mathrm{q3}) \\ 0 \\ 0 \end{pmatrix} \tag{47}$$

$$W_{8_R} = \begin{pmatrix} \cos(\mathrm{q2}+\mathrm{q3}+\mathrm{q4})\,\cos(\mathrm{q5}) \\ \cos(\mathrm{q2}+\mathrm{q3}+\mathrm{q4})\,\cos(\mathrm{q5}) \\ \cos(\mathrm{q2}+\mathrm{q3}+\mathrm{q4})\,\cos(\mathrm{q5}) \\ -\sin(\mathrm{q2}+\mathrm{q3}+\mathrm{q4})\,\sin(\mathrm{q5}) \end{pmatrix} \tag{48}$$

$$W_{9_R} = \begin{pmatrix} -\cos(\mathrm{q2}+\mathrm{q3}+\mathrm{q4})\,\sin(\mathrm{q5}) \\ -\cos(\mathrm{q2}+\mathrm{q3}+\mathrm{q4})\,\sin(\mathrm{q5}) \\ -\cos(\mathrm{q2}+\mathrm{q3}+\mathrm{q4})\,\sin(\mathrm{q5}) \\ -\sin(\mathrm{q2}+\mathrm{q3}+\mathrm{q4})\,\cos(\mathrm{q5}) \end{pmatrix} \tag{49}$$

1 W

$$W = \begin{bmatrix} -0.831 & -0.994 & 0.110 & 86.145 & 0.227 & 0.974 & -48.043 & -0.097 & -0.205 \\ 0.000 & -0.994 & 0.110 & 0.000 & 0.227 & 0.974 & -134.188 & -0.097 & -0.205 \\ 0.000 & 0.000 & 0.000 & 0.000 & 0.227 & 0.974 & 0.000 & -0.097 & -0.205 \\ 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.880 & -0.418 \\ -0.669 & -0.687 & 0.727 & -115.274 & 0.979 & -0.202 & -208.032 & -0.056 & -0.978 \\ 0.000 & -0.687 & 0.727 & 0.000 & 0.979 & -0.202 & -92.758 & -0.056 & -0.978 \\ 0.000 & 0.000 & 0.000 & 0.000 & 0.979 & -0.202 & 0.000 & -0.056 & -0.978 \\ 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & -0.201 & 0.011 \\ -0.991 & 0.423 & -0.906 & 20.408 & -0.846 & -0.533 & 77.569 & -0.628 & -0.568 \\ 0.000 & 0.423 & -0.906 & 0.000 & -0.846 & -0.533 & 57.161 & -0.628 & -0.568 \\ 0.000 & 0.000 & 0.000 & 0.000 & -0.846 & -0.533 & 0.000 & -0.628 & -0.568 \\ 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.357 & -0.395 \end{bmatrix} \tag{50}$$

$$\begin{bmatrix} W^T W = 2.121 & 0.866 & 0.321 & -14.783 & -0.005 & -0.147 & 102.118 & 0.740 & 1.387 \\ 0.866 & 3.279 & -1.983 & 2.218 & -2.514 & -2.110 & 444.854 & -0.261 & 1.271 \\ 0.321 & -1.983 & 2.721 & -92.809 & 3.006 & 0.886 & -360.555 & 1.035 & -0.437 \\ -14.783 & 2.218 & -92.809 & 21125.485 & -110.623 & 96.271 & 21424.890 & -14.771 & 83.476 \\ -0.005 & -2.514 & 3.006 & -110.623 & 5.181 & 1.423 & -449.989 & 1.363 & -1.572 \\ -0.147 & -2.110 & 0.886 & 96.271 & 1.423 & 3.819 & -188.596 & 0.752 & 0.900 \\ 102.118 & 444.854 & -360.555 & 21424.890 & -449.989 & -188.596 & 81480.247 & -50.055 & 255.016 \\ 0.740 & -0.261 & 1.035 & -14.771 & 1.363 & 0.752 & -50.055 & 2.162 & 0.781 \\ 1.387 & 1.271 & -0.437 & 83.476 & -1.572 & 0.900 & 255.016 & 0.781 & 4.292 \end{bmatrix} \tag{51}$$

$$R = \begin{bmatrix} -103.220 & -439.843 & 343.413 & -18170.737 & 429.365 & 200.375 & -77549.497 & 47.363 & -240.436 \\ 0.000 & 66.834 & -143.258 & 23729.152 & -173.636 & 66.284 & 32751.713 & -22.058 & 118.046 \\ 0.000 & 0.000 & 13.430 & -3467.557 & 16.413 & -17.639 & -3467.557 & 0.251 & -16.582 \\ 0.000 & 0.000 & 0.000 & 278.045 & 0.808 & 0.981 & 278.045 & 1.087 & 0.877 \\ 0.000 & 0.000 & 0.000 & 0.000 & -1.634 & -0.313 & 0.000 & -0.282 & 1.452 \\ 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & -1.938 & -0.000 & -0.761 & -2.000 \\ 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.059 & 0.148 \\ 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & -1.138 & 0.098 \\ 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.973 \end{bmatrix} \tag{52}$$