Second Midterm Examination

1. Given a coordinate frame

\[
T = \begin{bmatrix}
0 & -1 & 0 & 2 \\
0 & 0 & 1 & 5 \\
-1 & 0 & 0 & 10 \\
0 & 0 & 0 & 1
\end{bmatrix}
\]

a) What is the differential transformation dA corresponding to a differential translation \( d = 0i + 1j + 2k \) and rotation \( \delta = 0.1i + 0j + 0k \) made with respect to \( T \). (20 pts.)

b) What is the equivalent translation and rotation with respect to base coordinate frame? (15 pts.)

2. Consider the R-P-R manipulator shown in Fig. 1 (R-P-R specifies the type and order of the joints. R: Revolute, P: Prismatic joint). Find the Jacobian of the manipulator

a) using Paul’s method (20 pts.)

b) using vector-cross product method. (20 pts.)

3. The three-link manipulator shown in Fig. 1 is applying a force \( ^3F = [100 \ 0 \ 0]^T \) and moment \( ^3M = [0 \ 0 \ 0]^T \) with its end-effector (consider this force to be acting at the origin of the end-effector frame). If \( \theta_i = 60^\circ \), \( d_2 = 0.9 \text{ m} \), and \( \theta_1 = 30^\circ \) then find the required joint torques (forces). (25 pts.)