ME4245/EE4304 **Robotics** **1st Semester, 1999/2000**
Quiz 1 30 August 1999, 14:20-15:20

Please print clearly your name (as it appears in your student ID card) and Matric Number in your answer sheets.

1. **(40 marks)** Figure 1 shows a 1-DOF robot with a rotational joint. The link AE is always at an angle of 60° with respect to Z_A. The link rotates about the axis Z_A. Frame A is a fixed frame that serves as the base of the robot. The joint coordinate q_1 is zero when the link is in the YZ plane of Frame A. Frame E is attached to the link as shown. The length of link AE is 2 m.

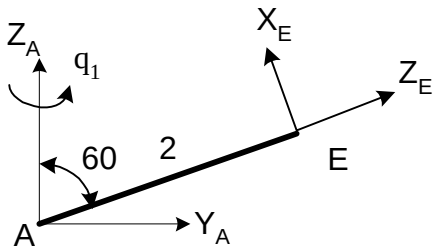

Figure 1

   a) Assign Frames to this robot according to the DH convention given in class
   b) Determine the 4 DH parameters for the link.
   c) Derive an expression for the position and orientation of Frame E in Frame A, ${}^{A}T_{E,}$ as a function of q_1. Express this as a 4×4 homogeneous transformation matrix. You do not need to simplify the expression.
   d) A load of 10 N is attached to Frame E. The direction of the gravitational force is along the negative Z_A axis. Determine the torque needed to carry this load.
   e) Derive the 6×1 Jacobian that relates the joint velocity with the end-effector (Frame E) velocity. You do not need to simplify your expression for the Jacobian.
   f) Does this robot have any singularities? If so, what are the singularities? (Describe the robot configuration(s) that is (are) singular.)

2. **(30 marks)** The robot in Figure 1 is placed on top of another robot that is moving. Frame U is a fixed frame. At a certain instant of time, the following are known:
   - Translational velocity of Frame A with respect to Frame U, ${}^{U}u_A$
   - Angular velocity of Frame A with respect to Frame U, ${}^{U}\omega_A$.
   - Position and Orientation of Frame A in Frame U, ${}^{U}T_A$.
   - Position and Orientation of Frame E in Frame A, ${}^{A}T_E$.
   - Joint velocity, $\dot{q}_1$

   Determine expressions for the following. You do not need to simplify the expressions.

   a) Angular velocity of Frame E with respect to Frame U, ${}^{U}\omega_E$
   b) Translational velocity of Frame E with respect to Frame U, ${}^{U}u_E$

3. **(30 marks)** Frames, A, and B, are fixed with ${}^{A}T_B$ known. Frame C is initially at ${}^{A}T_C$ and moves in the following sequence:
   (1) Rotation about Z_A by q_1.
   (2) Rotation about Y_C by q_2.
   (3) Rotation about X_B by q_3.

   Determine the expression for the final position and orientation of Frame C with respect to Frame A, ${}^{A}T_C$. You do not need to simplify the expression.