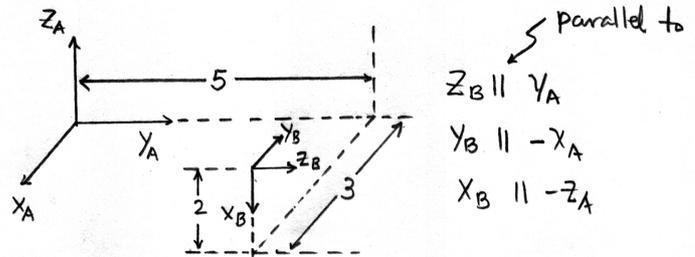
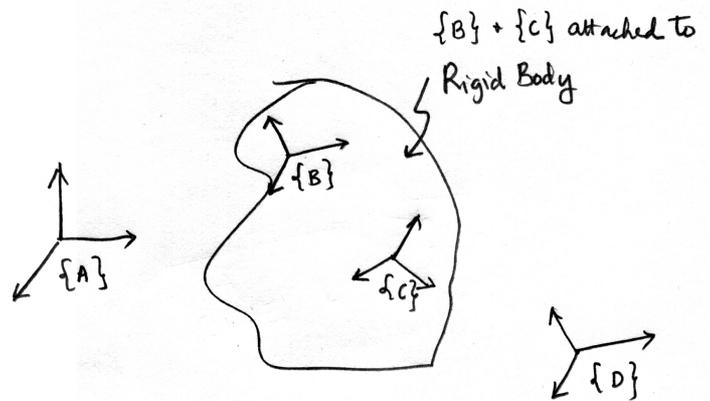


Please print clearly your name (as it appears in your student ID card) and Matric Number in your answer sheets. For all questions below, you need not evaluate or simplify your expressions. But just make sure that your solutions are complete.

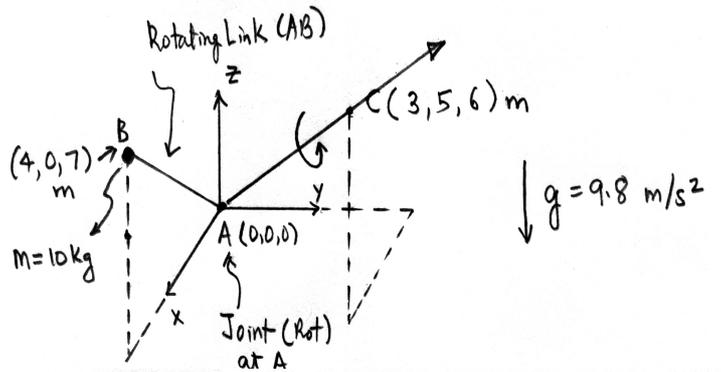
1. (25 marks) Figure 1 shows the positions and orientations of Frames A and B. Determine  ${}^A T_B$ . Determine also the roll pitch and yaw angles that describe the orientation of B in A.



2. (25 marks) Figure 2 shows four frames. Frames B and C are attached to the same rigid body with  ${}^B T_C$  known. Frames A and D are fixed with  ${}^D T_A$  known. The rigid body is initially at  ${}^A T_B$ . The rigid body then undergoes the following sequence of motions:  
 1> Rotation about  $X_D$  by 10 degrees  
 2> Rotation about  $Y_C$  by 20 degrees  
 3> Translation along Frame A by (1,2,3)  
 Determine the new position and orientation of Frame C in A,  ${}^A T_C$ .



3. (25 marks) Figure 3 shows a 1-joint robot carrying a payload of 10 kg at B. The joint is at A and is rotational. The rotating link is AB and rotates about a fixed axis AC. The coordinates of A, B and C are shown in the figure. Determine the joint torque required to carry the payload at the indicated position. (This joint torque is the torque exerted by the joint actuator on the link).



4. (25 marks) Figure 4 shows a 2-joint robot with the first joint rotating about  $Z_0$  and the 2<sup>nd</sup> joint (B) translating along BC. The 2<sup>nd</sup> joint axis is parallel to the XY plane of Frame 0. The first link is OAB and the 2<sup>nd</sup> link is an extendable link BC. Assign frames to the 1<sup>st</sup> link according to the D-H convention given in class. What are the four parameters that relates Frames 0 and 1. Indicate which of the parameters is the joint variable.

