جامعة بيرزيت
BIRZEIT UNIVERSITY

Faculty of Engineering and Technology
Department of Mechanical and Mechatronics Engineering
Second Examination – Spring 2017

ENMC 532: Robotics
Date of Examination: 7/5/2017
Instructor: Eng. Sima Rishmawi

Student ID: _____
Time duration: 90 minutes
Total Marks: 100

This exam contains 8 pages (including this cover page) and 3 problems. Check to see if any pages are missing. Enter your Student ID number on the top of this page, and at the bottom of each page.

You may *not* use your books, notes, or any other reference on this exam, except for a two-sided A4 cheat sheet (to be handed in with your exam). You can use your own calculator only. Borrowing calculators is not allowed.

You are required to show your work on each problem on this exam.
Do not write in the table to the right.

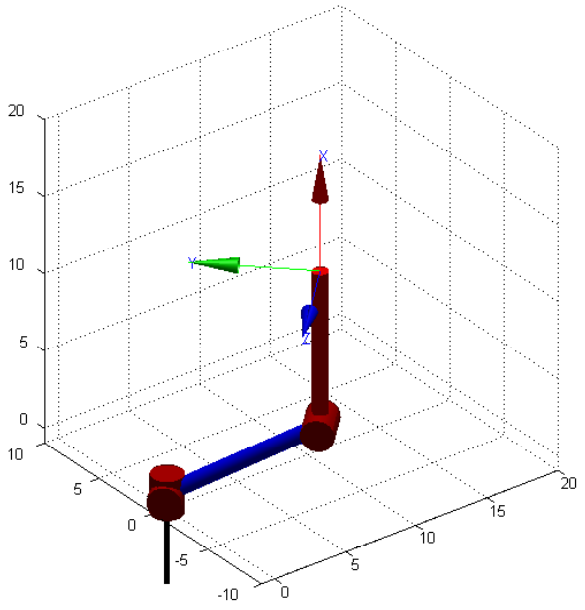
Problem	Points	Score
1	35	
2	40	
3	25	
Total:	100	

1) The robot arm shown in the Figure has the following DH-parameters:

Link	α_{i-1}	a_{i-1}	θ_i	d_i
1	0	0	θ_1	0
2	90	0	θ_2	0
3	0	10	θ_3	0
4	0	10	0	0

The desired position and orientation of the end-effector are described in the following transformation matrix:

$$ {}^0_4T = \begin{bmatrix} 0 & -0.7071 & -0.7071 & 6.1237 \\ 0 & 0.7071 & -0.7071 & 6.1237 \\ 1 & 0 & 0 & 15 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$



Determine the values of the joint angles θ_1, θ_2, and θ_3 that give the desired position and orientation of the end-effector.

35 marks

2) The Figure shows a 3R robot which allows the en-effector to move in three-dimensional space. Given are the rotation matrices relating the joint axes to each other for the configuration: $\theta_1 = \frac{\pi}{2}$, $\theta_2 = \frac{\pi}{6}$, $\theta_3 = \frac{-2\pi}{3}$,

$$ {}^{0}_{1}R = \begin{bmatrix} 0 & -1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} $$

$$ {}^{1}_{2}R = \begin{bmatrix} 0.866 & -0.500 & 0 \\ 0 & 0 & -1 \\ 0.500 & 0.866 & 0 \end{bmatrix} $$

$$ {}^{2}_{3}R = \begin{bmatrix} -0.500 & 0.866 & 0 \\ -0.866 & -0.500 & 0 \\ 0 & 0 & 1 \end{bmatrix} $$

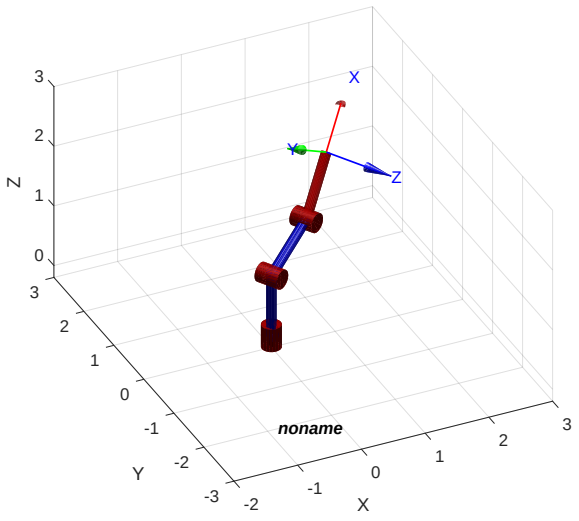
$$ {}^{3}_{e}R = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} $$

$$ {}^{0}_{e}R = \begin{bmatrix} 0 & 0 & 1 \\ 0 & 1 & 0 \\ -1 & 0 & 0 \end{bmatrix} $$

(a) Calculate the Jacobian for this configuration with respect to the base frame.

(b) If the end effector is supposed to move linearly with velocities $v_x = 1\ m/s$, $v_y = 2\ m/s$, $v_z = 0\ m/s$, what are the joint velocities at the configuration mentioned above?

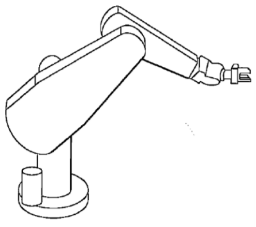
(c) If the end effector applies the load ${}^{e}F = [0\ 0\ 10]^T$ and moment ${}^{e}N = [6\ 5\ 4]^T$, what are the required joint torques?



40 marks

3) Circle the correct answer.

1. The volume of space that the end-effector can reach with all orientations:
   A. Subspace B. Reachable Workspace C. Dextrous Workspace D. Workspace
2. In the Puma560, θ_3 has two values representing the configurations:
   A. Left-hand, Right-hand B. Elbow-up, Elbow-down C. Flipped wrist, Non-flipped wrist D. None of the above
3. In the Puma560, θ_3 has two values representing the configurations:
   A. Left-hand, Right-hand B. Elbow-up, Elbow-down C. Flipped wrist, Non-flipped wrist D. None of the above
4. Which solution of the Puma560 is represented by the figure shown?



   A. LUF B. RDF C. RUN D. RUF
5. What is the size of the Jacobian matrix for a 2P1R robot whose end effector is limited to move in the xy-plane?
   A. 3×3 B. 2×3 C. 3×2 D. None of the above
6. A 6DOF robot arm has a Jacobian matrix with a 3×3 zero submatrix in its upper right corner, this means that the robot arm:
   A. is singular B. has a spherical wrist C. is fully extended D. has a redundant degree of freedom
7. A robot at a singular position has joint velocities that are:
   A. Zero B. Infinite C. Negative D. None of the above
8. The singularity of the system whose Jacobian is $\begin{bmatrix} -c_1 d_3 & 0 & -s_1 \\ -s_1 d_3 & 0 & c_1 \\ 0 & 1 & 0 \end{bmatrix}$ happen when:
   A. $\theta_1 = 0$ B. $d_3 = 1$ C. $d_3 = 0$ D. $\theta_1 = 90$
9. Describe the workspace of the 2R planar robot where $L_1 = 1\ m$ and $L_2 = 2\ m/s$.
   A. A disk with a radius of 3 m
   B. A disk with an outer radius of 3 m and an inner radius of 1 m
   C. A disk with an outer radius of 3 m and an inner radius of 2 m
   D. A sphere with a radius of 3 m
10. Workspace boundary singularities happen when:
    A. The robot arm is fully stretched out B. Two or more angles are equal
    C. The robot is folded on itself D. A and C

25 marks