Answer Sheet

Index No: 210293K

1. What is the geometrical structure of the Puma 560 robot?

   6 axis, RRRRRR (6 revolute joints)

2. Fill the DH parameter table for Puma 560 robot.

j	θ	d	a	α
1	0	0	0	1.5708
2	0	0.4318	0	0
3	0.15005	0.0203	-1.5708	0
4	0.4318	0	1.5708	0
5	0	0	-1.5708	0
6	0	0	0	0

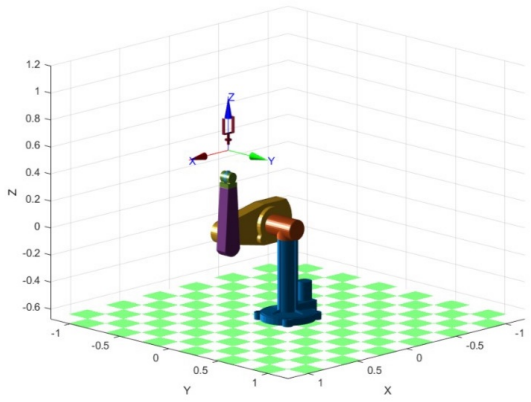
3. Joint coordinate vectors of Puma 560 robot for the following canonical configurations:
   a) zero angle: 0 0 0 0 0 0
   b) ready : 0 1.5708 -1.5708 0 0 0
   c) stretch : 0 1.5708 -1.5708 0 0 0
   d) nominal : 0 0 -1.5708 0 0 0

4. Forward kinematics for tool center point (TCP) in Procedure 3.5 for the canonical configurations.

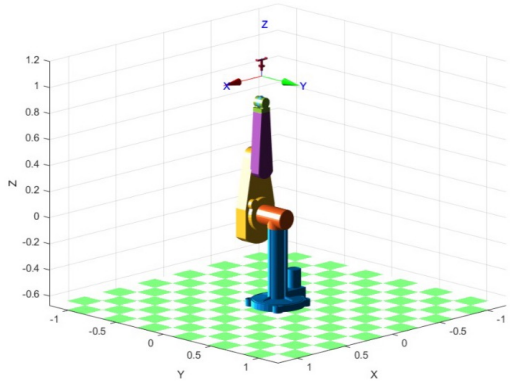
Configuration	**Position**	**Orientation (Rotation Matrix)**
Zero angle	0.4521 -0.15 0.6318	1 0 0 0 1 0 0 0 1 0 0 0
Ready	0.0203 -0.15 1.064	1 0 0 0 1 0 0 0 1 0 0 0
Stretch	1.064 -0.1501 -0.0203	0 0 1 0 1 0 -1 0 0 0 0 0
Nominal	1.064 -0.1501 -0.0203	0 0 1 0 1 0 -1 0 0 0 0 0

5. Visualization of Puma 560 robot for Procedure 3.6.

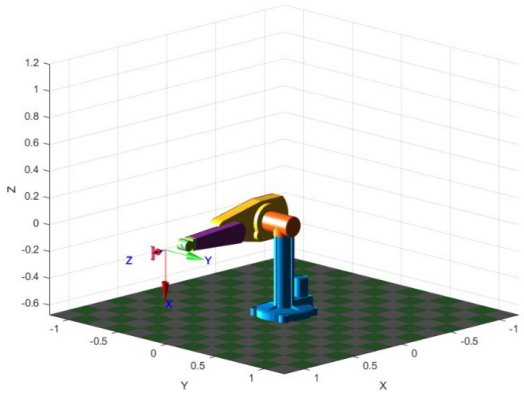
a)



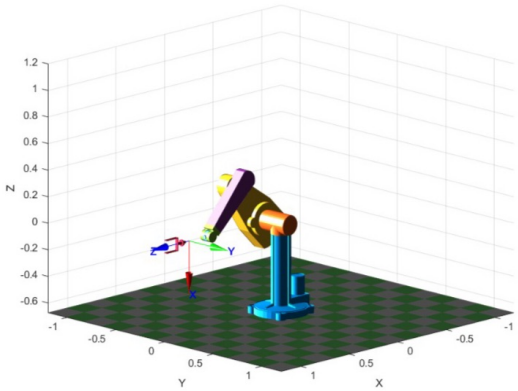
b)



c)



d)



6. Inverse kinematics joint vector for Procedure 3.8. What is your observation?

2.6486 -3.9270 0.0940 2.5326 0.9743 0.3734

These are the joint angle vector we got after performing inverse kinematics

7. Correct arm configuration for Procedure 3.9.

Right elbow up

We calculated inverse kinematics for each 4 configurations and the only matching joint angle was Right hand elbow up.

Joint vector for each,
Right hand elbow up = [0, 0.7854, 3.1416, 0,0.7854,0]
Right hand elbow down = [0,-.8355, 0.094, -3.1416, 0.8312]
Left hand elbow up = [2.6486, -3.9270, 0.0940, 2.5326, 0.9743, 0.3734]
Left hand elbow down = [2.6486, -2.3081, 3.1416, 0.6743, 0.8604, 2.6611]

and the Joint vector required is
[0, 0.7854, 3.1416, 0, 0.7854, 0]

8. What can be observed for Procedure 3.10?

Joint angle vector we got is

NaN NaN NaN NaN NaN NaN

And in the command window it displayed "Warning: point not reachable"

The EE position we used to calculate the inverse kinematics was [0,0,2]

9. MATLAB code for the entire procedure.

```
mdl_puma560;
p560;

qz = p560.qz ; % Zero angle configuration
qr = p560.qr ;  % Ready pose
qs = p560.qs ;  % Stretch pose
qn = p560.qn ;  % Nominal pose

p560.tool = SE3(0,0,0.2);

Tz = p560.fkine(qz);
Tr = p560.fkine(qr);
Ts = p560.fkine(qs);
Tn = p560.fkine(qn);

%p560.plot3d(qz);
%p560.plot3d(qr);
%p560.plot3d(qs);
%p560.plot3d(qn);

p560.tool = SE3();
qn = p560.qn ;
T_nominal = p560.fkine(qn);
q_ikine = p560.ikine6s(T_nominal);

q_left_elbow_up = p560.ikine6s(T_nominal, 'lu');    % Left hand, elbow up
T_nominal_left_elbow_up = p560.fkine(q_left_elbow_up);
q_left_elbow_down = p560.ikine6s(T_nominal, 'ld');  % Left hand, elbow down
T_nominal_left_elbow_down = p560.fkine(q_left_elbow_down);
q_right_elbow_up = p560.ikine6s(T_nominal, 'ru');   % Right hand, elbow up
T_nominal_right_elbow_up = p560.fkine(q_right_elbow_up);
q_right_elbow_down = p560.ikine6s(T_nominal, 'rd'); % Right hand, elbow down
T_nominal_right_elbow_down = p560.fkine(q_right_elbow_down);

%p560.plot3d(q_left_elbow_up);
%p560.plot3d(q_left_elbow_down);
p560.plot3d(q_right_elbow_up);
%p560.plot3d(q_right_elbow_down);

T_unreachable = [0; 0; 2];
q_ikine_unreachable = p560.ikine6s(T_unreachable);
```

10. Explain in point form what the MATLAB code in 3.11 does.

First it closes all open figures and remove all the variables.

Then as previous loading the puma 560 robot model.

Defining transformation matrices.
T1-moving 0.8 units along x-axis and rotates 90 deg around y axis.
T2-moves -0.8 along x axis and rotates 180 deg around x axis.

calculating inverse kinematics for both T1 and T2 transformations.

Creates a time vector from 0 to 2 seconds with increments of 0.05 seconds.

Generating a joint trajectory that moves the robot from position q1 to q2 over specified time.

finally, it animates the robot motion.