5ELEN018W Robotic Principles - Other Sample In-Class Test Questions

Only one correct answer per question. No negative marking. **Formatting of this document is not important as the actual test will take place in Blackboard.**.

Question 1

The position and orientation of one coordinate frame with respect to another reference coordinate frame is called:

A: Configuration

B: Kinematics

C: Pose

D: Inverse Kinematics

(5 marks)

Correct answer: C

Question 2

What is true about the following homogeneous transformation matrix in the 3D space?

$$\begin{pmatrix} cos\frac{\pi}{2} & -sin\frac{\pi}{2} & 0 & v_1 \\ sin\frac{\pi}{2} & cos\frac{\pi}{2} & 0 & v_2 \\ 0 & 0 & 1 & v_3 \\ 0 & 0 & 0 & 1 \end{pmatrix} \tag{1}$$

A: This is a transformation of a rotation of 90^o about the x-axis with translation afterwards

B: This is a transformation of a rotation of 180^o about the y-axis with translation afterwards

C: This is a transformation of a rotation of 90^o about the z-axis with translation afterwards

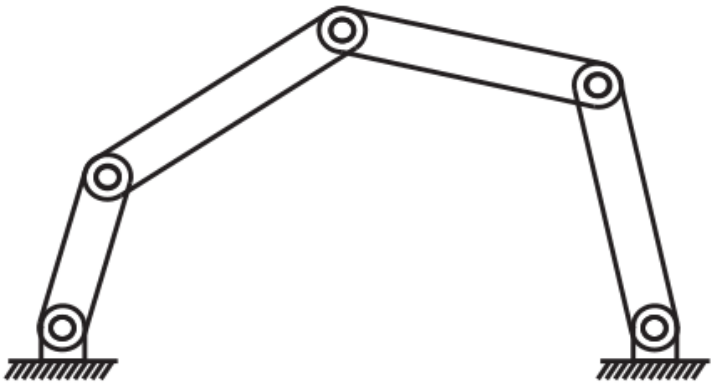
D: This is a transformation of a translation followed by a rotation about some axis afterwards

(8 marks)

Correct answer: C

Question 3

Consider the following robot manipulator. How many degrees of freedom has?



A: 1

B: 2

C: 3

D: 4

E: 5

(8 marks)

Correct answer: B

Question 4

A solid body which cannot change shape whatever we do to it, is called:

A: A Rigid Body

B: A Robot

C: A Stationary Body

D: A Stochastic Dynamic System

(5 marks)

Correct answer: A

Question 5

The Denavit-Hartenberg convention reduces the number of independent parameters necessary to specify a coordinate frame attached to a rigid body:

A: from 4 to 3

B: from 5 to 3

C: from 6 to 3

D: from 6 to 4

(5 marks)

Correct answer: D

Question 6

Consider the following homogeneous transformation matrix:

$$\begin{pmatrix} 0.0000 & -1.0000 & 0 & 1.0000 \\ -1.0000 & 0.0000 & 0 & 3.0000 \\ 0 & 0 & 1.0000 & 2.0000 \\ 0 & 0 & 0 & 1.0000 \end{pmatrix}$$

Calculate the inverse transformation:

A:

$$\begin{pmatrix} -0.0000 & -1.0000 & 0 & 3.0000 \\ -1.0000 & -0.0000 & 0 & 1.0000 \\ 0 & 0 & 1.0000 & -2.0000 \\ 0 & 0 & 0 & 1.0000 \end{pmatrix}$$

B:

$$\begin{pmatrix} 0.0000 & -1.0000 & 0 & 1.0000 \\ -1.0000 & 0.0000 & 0 & 3.0000 \\ 0 & 0 & 1.0000 & 2.0000 \\ 0 & 0 & 0 & 1.0000 \end{pmatrix}$$

C:

$$\begin{pmatrix} -1.6331 & -0.0000 & 0 & 0.0000 \\ 0.0000 & -1.6331 & 0 & 0.0000 \\ 0 & 0 & 1.0000 & 1.0000 \\ 0 & 0 & 0 & 0.5 \end{pmatrix}$$

D:

$$\begin{pmatrix} -0.0000 & -1.0000 & 0 & 1.5 \\ -1.0000 & -0.0000 & 0 & 0.5 \\ 0 & 0 & 1.0000 & -1.0 \\ 0 & 0 & 0 & 0.5 \end{pmatrix}$$

(8 marks)

Correct answer: A

Question 7

Which joint provides a linear freedom to a rigid body?

A: Revolute

B: Prismatic

C: Universal

D: Spherical

(5 marks)

Correct answer: B

Question 8

What is true regarding the properties of a rotation matrix?

A: Its inverse matrix is equal to its transpose

B: Its inverse matrix is equal to its determinant

C: Its inverse matrix is 1

D: Its inverse matrix is equal to itself

(5 marks)

Correct answer: A

Question 9

A rigid body in 3D-space can be specified with:

A: 2 coordinates

B: 3 coordinates

C: 4 coordinates

D: 6 coordinates

(5 marks)

Correct answer: D

Question 10

The following DH matrices correspond to the joints of a robot, from robot base to end-effector. Find the pose of the end-effector relative to the robot base.

$$A_1 = \begin{bmatrix} -1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 1 & 2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$A_2 = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 1 \\ 0 & 0 & -1 & 3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$A_3 = \begin{bmatrix} -1 & 0 & 0 & -2 \\ 0 & -0 & 1 & 0 \\ 0 & 1 & 0 & 4 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Choose the answer from one of the following:

A:

$$\begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 24 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

B:

$$\begin{bmatrix} 0 & 0 & 1 & 0 \\ -1 & 0 & 0 & 1 \\ 0 & -1 & 0 & 1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

C:

$$\begin{bmatrix} 0 & -1 & 0 & 0 \\ -1 & 0 & 0 & -1 \\ 0 & 0 & -1 & 5 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

D:

$$\begin{bmatrix} 0 & 0 & -1 & 0 \\ 1 & 0 & 0 & 1 \\ 0 & -1 & 0 & 1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

(8 marks)

Correct answer: D

Question 11

Consider the following DH table:

Joint	$\boldsymbol{\theta}$	$\boldsymbol{r}$	$\boldsymbol{d}$	$\boldsymbol{\alpha}$
1	0	3	4	$\frac{\pi}{2}$

What is the DH matrix which corresponds to the above table?

A:

$$\begin{bmatrix} 0 & 0 & 0 & 3 \\ 0 & 0 & -1 & 0 \\ 0 & 1 & 0 & 4 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

B:

$$\begin{bmatrix} 1 & 0 & 0 & 3 \\ 0 & 0 & -1 & 0 \\ 0 & 1 & 0 & 3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

C:

$$\begin{bmatrix} 1 & 0 & 0 & 3 \\ 0 & 0 & -1 & 0 \\ 0 & 1 & 0 & 4 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

D:

$$\begin{bmatrix} 1 & 0 & 0 & 3 \\ 0 & 0 & -1 & 0 \\ 0 & 1 & 0 & 4 \\ 1 & 0 & 0 & 1 \end{bmatrix}$$

(8 marks)

Correct answer: C

Question 12

Grübler's formula refers to the:

A: Transformation of a reference frame fixed to a robot to the world reference frame

B: Calculation of the inverse of a rotational transformation matrix

C: Calculation of the position of the end-effector of a robot manipulator, given the joints angles.

D: Calculation of degrees of freedom

(5 marks)

Correct answer: D

Question 13

Consider a reference frame A fixed to the robot's body and a reference frame B which is the world frame. Given that we know the matrix for the pose of B relative to A, how can we determine the pose of A relative to B ?

A: Calculate the transpose of the matrix

B: Calculate the inverse of the matrix

C: Calculate a transformation of the matrix

D: Calculate the homogeneous form of the matrix

(5 marks)

Correct answer: B

Question 14

Which of the following situations poses an ethical issue relevant to robotics?

A: Unemployment

B: Financial gains due to robot traders

C: Robots performing a surgical operation successfully.

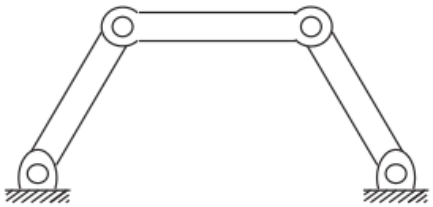
D: Robots creating works of art.

(5 marks)

Correct answer: A

Question 15

Consider the following robot manipulator. Using Grübler's formula calculate how many degrees of freedom the manipulator has. Show all the steps of the calculation.



Sample answer

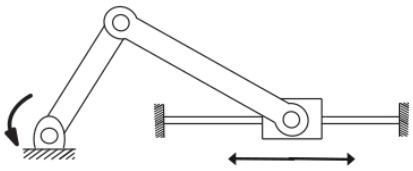
- $m = 3$ (planar)

- $J = 4$
- $N = 4$ (including the ground)
- $f_i = 1$

$$\text{dof} = 3(4 - 1 - 4) + 4 = 1 \tag{2}$$

Question 16

Consider the following robot manipulator. Using Grübler's formula calculate how many degrees of freedom the manipulator has. Show all the steps of the calculation.



Sample answer

3 revolute joints and 1 prismatic joint.

- $m = 3$ (planar)
- $J = 4$
- $N = 4$ (including the ground)
- $f_i = 1$

$$\text{dof} = 3(4 - 1 - 4) + 4 = 1 \tag{3}$$

Question 17

Write a Matlab function which accepts 4 arguments corresponding to the DH parameters and returns the DH matrix.

(10 marks)

Sample answer

You have to do this on your own in Matlab.

Question 18

Describe briefy what is the DH notation.

(5 marks)

Sample answer

A notation which reduced from 6 to 4 the parameters required to describe the relationship between 2 coordinate frames.

Question 19

Describe briefly what is homogeneous transformation matrix.

(5 marks)

Sample answer

A matrix which combines a rotation followed by a translation. It is a 3x3 for the 2D space and a 4x4 in the 3D space.

Question 20

Write a Matlab function which accepts 2 matrices as arguments corresponding to two consecutive rotations in the 2D space. The function returns matrix corresponding to the overall transformation, i.e. the combination of both rotations together.

(10 marks)

Sample answer

Implement this on your own and in Matlab as a function. You just need to multiply the 2 arguments passed to the function and return it as the result of the function.

1) The following DH matrices correspond to the joints of a robot, from robot base to end-effector. Find the pose of the end-effector relative to the robot base.

$$A_1 = \begin{bmatrix} -1 & 0 & 0 & -1 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 1 & 2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$A_2 = \begin{bmatrix} 0 & 0.99 & 0.1411 & 0 \\ 1 & 0 & 0 & 3 \\ 0 & 1 & 0 & 4 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$A_3 = \begin{bmatrix} 0.5000 & -0.2457 & -0.8305 & 2.5000 \\ 0.8660 & 0.3536 & -0.3536 & 4.3301 \\ 0 & 0.7071 & 0.7071 & 3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Choose the correct answer from the below:

A. $$\begin{bmatrix} -0.8574 & -0.4498 & 0.2502 & -5.7102 \\ -0.5 & 0.2457 & 0.8305 & -5.5000 \\ 0.866 & 0.3536 & -0.3536 & 9 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

B. $$\begin{bmatrix} -0.8574 & -0.4498 & 0.2502 & -5.7102 \\ -0.5 & 0.2457 & 0.8305 & -5.5000 \\ 0.866 & 0.3536 & -0.3536 & 10.3301 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

C. $$\begin{bmatrix} -0.8574 & -0.4498 & 0.2502 & -5.7102 \\ -0.5 & 0.2457 & 0.8305 & -5.5000 \\ 0.866 & 0.3536 & -0.3536 & 10.3301 \\ 0 & 0 & 1 & 1 \end{bmatrix}$$

D. $$\begin{bmatrix} -0.8574 & -0.5 & 0.8660 & 0 \\ -0.4498 & 0.2457 & 0.3536 & 0 \\ 0.2502 & 0.8305 & -0.3536 & 0 \\ -5.7102 & -5.5000 & 10.3301 & 1 \end{bmatrix}$$

2) Consider the following DH table:

Joint	θ	**r**	**d**	α
1	$\frac{\pi}{4}$	2	4	$\frac{\pi}{2}$

What is the DH matrix which corresponds to the above table?

A. $\begin{bmatrix} 0.7071 & 0.2943 & 0.6430 & 1.4142 \\ 0.7071 & 0.0000 & -0.7071 & 4 \\ 0 & 1 & 0 & 1.4142 \\ 0 & 0 & 0 & 1 \end{bmatrix}$

B. $\begin{bmatrix} 0 & 0.2943 & 0.6430 & 1.4142 \\ 0.7071 & 0.0000 & -0.7071 & 1.4142 \\ 0 & 1 & 0 & 4 \\ 0 & 0 & 0 & 1 \end{bmatrix}$

C. $\begin{bmatrix} 0.7071 & 0.2943 & 0.6430 & 1.4142 \\ 0.7071 & 0.0000 & -0.7071 & 1.4142 \\ 0 & 1 & 0 & 4 \\ 0 & 0 & 0 & 1 \end{bmatrix}$

D. $\begin{bmatrix} 0.7071 & 0.2943 & 0.6430 & 1.4142 \\ 0.7071 & 0.0000 & -0.7071 & 1.4142 \\ 0 & 1 & 0 & 4 \\ 1 & 0 & 0 & 0 \end{bmatrix}$

3) What is the industry which robots have currently the most widely usage?

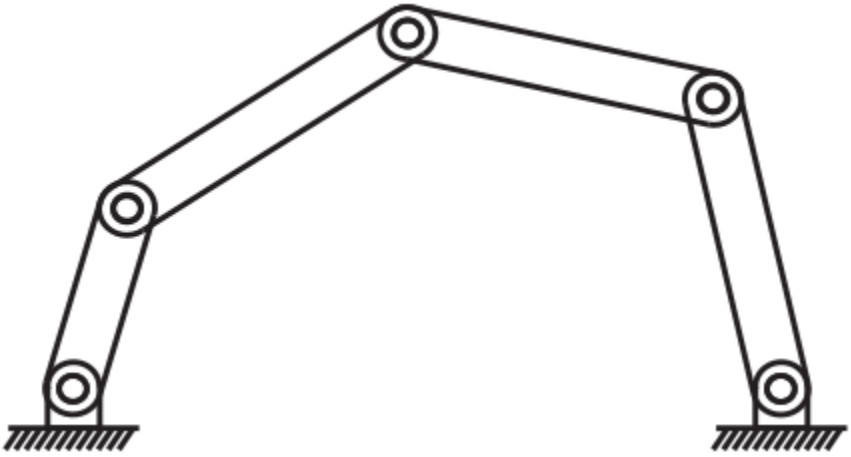
Choose all that apply:

A. Health
B. Manufacturing
C. Army
D. Package delivery

4) How many degrees of freedom revolute and prismatic joints have ?

A. 1
B. 2
C. 3
D. 6
E. It depends on their type.

5) Consider the following robot. How many degrees of freedom has? Use the Grubler's formula.



A. 0
B. 1
C. 2
D. 3
E. 4
F. 5

6) What is the most common form of a modern robot?

Choose all that apply:

A. Dog
B. Humanoid
C. Manipulator
D. Drone

7) A robotic manipulator consists of?

Choose all that apply:

A. Joints and Links
B. Joints and Rigid Bodies
C. Sensors and Joints and Links and Actuators
D. Little robots
E. A human who manipulates the robot remotely

8) A rigid body is:

A. A robot which has a fixed operation that cannot be altered
B. A robot performing its task perfectly
C. A solid body which cannot change shape whatever we do to it
D. A body of a robot

9) What is the configuration space of a robot?

A. The set of all possible ways to assemble a robot
B. The configuration file that we save the software settings of a programmable robot
C. The combination of all possible positions of all of the points of a robot
D. This question is tough out of my reach

10) How many DOF a planar rigid body has?

A. 1
B. 2
C. 3
D. 6
E. What is DOF - what are you talking about?

11) How many DOF a spatial rigid body has?

A. 1
B. 2
C. 3
D. 6
E. What are you talking about?

12) What is a revolute joint in a robot?

A. A joint that can rotate
B. A joint that can move in a linear direction
C. A joint that can both move linearly and rotate
D. A joint that moves like a human shoulder

13) What is a prismatic joint in a robot?

A. A joint that can rotate
B. A joint that can move in a linear direction
C. A joint that can both move linearly and rotate
D. A joint that moves like a human shoulder

14) What is *pose* in Robotics?

A. The position and orientation of a robot
B. The position and orientation of one coordinate frame with respect to another reference coordinate frame
C. The angles of the joints of a robot
D. The "looks" of a robot when demonstrating it in a robot fashion show
E. The performance of a robot in a specific task as measured by the corresponding error

15) The rotation matrix:

Choose all that apply:

A. transforms the coordinates of a vector from a new frame to an old frame
B. transforms the coordinates of a vector from an old frame to a new frame
C. transforms the coordinates of a vector from a frame rotated by an angle with respect to another frame with the same origin.
D. transforms the coordinates of a vector from a frame rotated by an angle with respect to another frame with the a different origin.

16) What is true regarding the properties of a rotation matrix?

A. Its inverse matrix is 1
B. Its inverse matrix is equal to itself
C. Its inverse matrix is equal to its transpose
D. Its inverse matrix is equal to its determinant
E. Its inverse matrix is equal to its eigenvectors

17) What is true about the following matrix?

$$\begin{pmatrix} cos\theta & -sin\theta \\ sin\theta & cos\theta \end{pmatrix}$$

A. This is the rotation matrix of a new coordinate frame with an angle θ rotated counter-clockwise with respect to an original frame
B. This is the rotation matrix of a new coordinate frame with an angle θ rotated clockwise with respect to an original frame
C. This is the translation matrix of a new coordinate frame with respect to an original frame
D. I don't have a clue

18) The homogeneous transform:

$$\begin{pmatrix} cos\theta & -sin\theta & V_x \\ sin\theta & cos\theta & V_y \\ 0 & 0 & 1 \end{pmatrix}$$

represents:

A. Translation only
B. Rotation only
C. Translation followed by rotation
D. Rotation followed by translation
E. Rotation followed by translation and translation followed by rotation. The order of transformations does not matter.

19) What is true about the following homogeneous transformation matrix in the 3D space?

$$\begin{pmatrix} 1 & 0 & 0 & v_x \\ 0 & cos\theta & -sin\theta & v_y \\ 0 & sin\theta & cos\theta & v_z \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

A. This is a transformation of a rotation about the y-axis with translation afterwards
B. This is a transformation of a rotation about the z-axis with translation afterwards
C. This is a transformation of a rotation about the x-axis with translation afterwards
D. This is a transformation of a translation about the x-axis with rotation afterwards

20) A differential equation is an equation which:

Choose all that apply:

A. Involves speed and acceleration and position
B. Involves time-series
C. Involves integrals of a function
D. Involves derivatives of a function

21) Consider the following homogeneous transformation matrix:

$$\begin{pmatrix} -1 & 0 & 0 & 1 \\ 0 & -1 & 0 & 3 \\ 0 & 0 & 1 & 2 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Calculate the inverse transformation:

A. $$\begin{pmatrix} -1 & 0 & 0 & 1 \\ 0 & -1 & 0 & 3 \\ 0 & 0 & 1 & -2 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

B. $$\begin{pmatrix} -1 & 0 & 0 & 1 \\ 0 & -1 & 0 & 3 \\ 0 & 0 & 1 & 2 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

C. $$\begin{pmatrix} -1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 1 & 3 & -2 & 1 \end{pmatrix}$$

D. $$\begin{pmatrix} -1 & 0 & 0 & 1 \\ 0 & -1 & 0 & -3 \\ 0 & 0 & 1 & 2 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

22) Which of the following situations poses an ethical issue relevant to robotics?

A. A human harming another human
B. A human harming an animal
C. A human harming a robot
D. Robots creating works of art

Key:
1. B
2. C
3. B
4. A
5. C
6. C
7. B, A, C
8. C
9. C
10. C
11. D
12. A
13. B
14. B
15. A, C
16. C
17. A
18. D
19. C
20. D
21. A
22. C