Roll No.											

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

PRESIDENCY UNIVERSITY
BENGALURU

SCHOOL OF ENGINEERING

TEST - 1

Even Semester: 2018-19 | **Date**: 06 March 2019

Course Code: MEC 313 | **Time**: 1 Hour

Course Name: Robotics | **Max Marks**: 40

Programme & Sem: B.Tech (DE) & VI Sem | **Weightage**: 20%

Instructions:

(i) Read the question carefully and answer accordingly.
(ii) Your answers must be brief and to the point
(iii) Question paper consists of 3 parts
(iv) Scientific and Non-programmable calculators are permitted

Part A

Answer **all** the Questions. **Each** question carries **four** marks. (3Qx4M=12)

1. What are the different components in a robot? Explain each in a sentence or two. (4 Marks)

2. Answer the following –

a. Explain the Degree of Freedom (DOF) in a robot (2 Marks)

b. Express the vector $\vec{P} = 3\hat{\imath} + 4\hat{\jmath} + 5\hat{k}$ in matrix form with scale factor w=2. Express the unit vector in the direction of $\vec{P}$ in matrix form. (2 Marks)

3. Find the missing orientation elements and complete the matrix representation of the frame F

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

(4 Marks)

Part B

Answer **all** the Questions. **Each** question carries **eight** marks. (2Qx8M=16)

4. a. Write any 4 advantages and 4 disadvantages of using robots in industries. (4 Marks)

   b. A point p $(3, 4, -2)^T$ is attached to a rotating frame. The frame rotates 45^0 about the x-axis of the reference frame. Find the coordinates of the point relative to the reference frame after the rotation. (4 Marks)

5. a. Write about any 4 applications of robots in industries with 1-2 sentences for each application. (4 Marks)

   b. Calculate the inverse of the following transformation matrix (4 Marks)

$$T = \begin{bmatrix} 1 & 0 & 0 & 3 \\ 0 & 0.843 & 0.538 & 1 \\ 0 & -0.538 & 0.843 & 4 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Part C

Answer **any one** Question. Question carries **twelve** marks. (1Qx12M=12)

6. a. A frame F has been moved 5 units along the y-axis and 3 units along the z-axis of the reference frame. Find the new location. (4 Marks)

$$F = \begin{bmatrix} 0.527 & -0.574 & -0.628 & 4 \\ 0..369 & 0.819 & 0.439 & 3 \\ -0.766 & 0 & 0.643 & 2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

   b. A point [3, 5, 7] is attached to a rotating frame. The frame is subjected to the following transformations –
   i. A rotation of 45^0 about the z-axis
   ii. Followed by a rotation of 90^0 about the y-axis
   iii. Followed by a translation of [4, 5, 6]

   Find the coordinates of the point relative to the reference frame at the conclusion of the transformations. (8 marks)

OR

7. a. A frame F has been moved 2 units along the x-axis and 4 units along the y-axis of the reference frame. Find the new location. (4 Marks)

$$F = \begin{bmatrix} 0.527 & -0.574 & -0.628 & 3 \\ 0..369 & 0.819 & 0.439 & 2 \\ -0.766 & 0 & 0.643 & 1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

b. In a robotic setup a camera is attached to the 5th link of a 6 DOF robot. It observes the point of interest (object) on a car body that needs to be welded and determines its frame relative to the camera's frame. Using the following information determine the necessary motion of the end effector E (connected to H on the last link) must make to get to the point of interest ($^{E}T_{obj}$). (8 marks)

$$^{5}T_{cam} = \begin{bmatrix} 0 & 1 & 0 & 3 \\ -1 & 0 & 0 & 2 \\ 0 & 0 & -1 & 3 \\ 0 & 0 & 0 & 1 \end{bmatrix}; \quad ^{5}T_{H} = \begin{bmatrix} 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & 1 \\ 0 & 0 & -1 & 2 \\ 0 & 0 & 0 & 1 \end{bmatrix}; \quad ^{cam}T_{obj} = \begin{bmatrix} 0 & 1 & 0 & 2 \\ 1 & 0 & 0 & 1 \\ 0 & 0 & 1 & 2 \\ 0 & 0 & 0 & 1 \end{bmatrix};$$

$$^{H}T_{E} = \begin{bmatrix} 0 & 0 & -1 & 1 \\ -1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

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SCHOOL OF ENGINEERING

TEST - 2

Even Semester: 2018-19
Course Code: MEC 313
Course Name: Robotics
Program & Sem: B.Tech & VI Sem (DE)

Date: 16 April 2019
Time: 1 Hour
Max Marks: 40
Weightage: 20%

Instructions:

(i) Read the question carefully and answer accordingly.
(ii) Your answers must be brief and to the point
(iii) Question paper consists of 3 parts
(iv) Scientific and Non-programmable calculators are permitted

Part A

Answer **all** the Questions. **Each** question carries **four** marks. (3Qx4M=12)

1. What is Degeneracy and Dexterity in a robot? Explain in 3-4 sentences each.
2. Explain any four sensor characteristics that you would consider when using them in a robot
3. Explain the two types of trajectory planning descriptions in 3-4 sentences each.

Part B

Answer **both** the Questions. **Each** question carries **four** marks. (2Qx8M=16)

4. The first joint of a 6 DOF robot moves from an initial angle of 15^0 to a final angle of 60^0 in 5 seconds. Using a 3rd order polynomial equation calculate the joint angles at 1, 2, 3 and 4 seconds and the joint velocity and joint accelerations at these times. (8 marks)

5. a. Explain PID controller and the effect of P, I and D controls. (4 Marks)

   b. Derive the expression for Closed Loop Transfer Function in terms of system dynamics G(s) and feedback multiplier H(s) for the following control system shown in figure 1. (4 Marks)

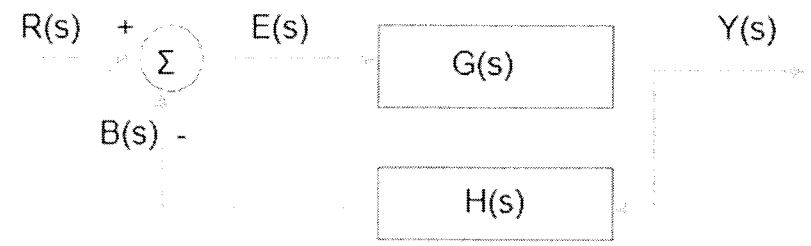

Figure.1

Part C

Answer **the** Question. The Question carries **twelve** marks. (1Qx12M=12)

6. A 2 DOF planar robot is to follow a straight line from (3,5) to end point (7,13) of the motion segment as shown in Figure 2. Find the joint angles of the robot for each of the coordinate points if the path is divided into 4 segments. Each link is of 12 cm long.

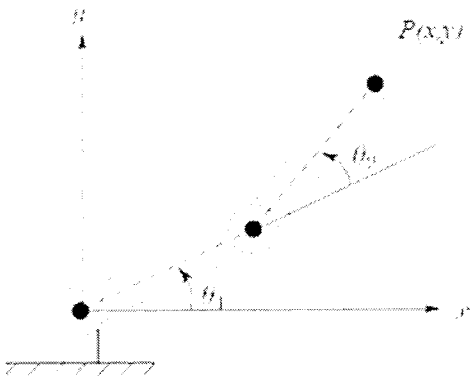

Figure 2.

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END TERM FINAL EXAMINATION

Even Semester: 2018-2019 | **Date**: 23 May 2019

Course Code: MEC 313 | **Time**: 3 Hours

Course Name: Robotics (DE) | **Max Marks**: 80

Program & Sem: B. Tech. & VI Sem | **Weightage**: 40%

Instructions:

(i) Answer all the questions!

Part A

Answer **all** the Questions. (3Q=20M)

1. State whether the statements that follow are true or false. Justify your claim when you feel a statement is true. Correct the statement if you feel it is false.
   (a) Robot actuators can be stiff and compliant at the same time. (2 Marks)
   (b) Hydraulic actuators are accurate because they make use of heavy liquids which are incompressible fluids. (2 Marks)
   (c) Pneumatic actuators are preferred in surgical robots. (2 Marks)
   (d) Reduction gearing is used in robot joints to speed up a robot's response. (2 Marks)
   (e) Closed loop systems do not need sensors. (2 Marks)
   (f) A robot may injure a human being to save a tree. (2 Marks)
2. Fill in words or phrases to correctly complete the following sentences.
   (a) _____ is the ease with which a robot can reach and orient itself at a location. (1 Mark)
   (b) The letter D in PID stands for _____. (1 Mark)
   (c) The torque output of an AC motor is directly proportional to _____. (1 Mark)
   (d) The objective of a closed loop system is to drive the _____ between the desired and measured values of a quantity to zero. (1 Mark)
3. Select the right option for each of the following questions and justify your choice.
   (a) Suppose the location and orientation of the end effector of a robot are known. What is the process of determination of the joint variables called? (2 Marks)
   i. Forward Kinematics ii. Inverse Kinematics iii. Error Analysis iv. Joint Matching
   (b) Which of the following best describes a revolute joint? (2 Marks)
   i. 1 DOF, Linear ii. 1 DOF, Rotary iii. 2 DOF, Linear iv. 2 DOF, Rotary

Part B

Answer **all** the Questions. (3Qx12M=36M)

4. The following questions pertain to hydraulic actuators used in robots.
   (a) State the characteristics of hydraulic actuators with respect to power to weight ratio, magnitude of forces and torques available with respect to operating speeds, linear or rotary actuation and compatibility with microprocessor and electronic controls. (4 Marks)
   (b) Sketch a linear hydraulic actuator and use it to derive: (Sketch: 2 Marks)
      i. an expression for the linear force output of a hydraulic actuator in terms of the hydraulic fluid pressure and geometry of the actuator, and, (3 Marks)
      ii. an expression for the velocity of the robot arm in terms of the fluid flow rate and geometry of the actuator. (3 Marks)

5. A motor develops a torque of 1.2 N·m at its nominal speed with reference electrical resistance of 8 Ω. The reference torque constant for the motor is 0.5 N·m/A. The thermal resistance of the motor is 1.05 K/W. Assume the ambient temperature to be 20^o C. For the motor used it is known that the material constants for the material of the windings and the material of the permanent magnets are $\alpha = 0.00393$ and $\beta = -0.002$, respectively. You may ignore the heat generated due to friction. Determine the evolution of motor temperature for five iterations. Explain how the passage of time fits into the evolution of motor temperature. (12 Marks)

6. The following questions will test your knowledge of trajectory planning and the control systems used in robots.

   (a) The first joint of a 6-DOF robot rotates from an initial angle of 13^o to a final angle of 46^o in 6 seconds. Use a third order polynomial to determine the angular positions, velocities and accelerations of the robot's joint at the each second between the initial and final times. You may assume the initial and final velocities to be zero. (7 Marks)

   (b) Derive an expression for the closed loop transfer function $\frac{Y(s)}{R(s)}$ in terms of the system dynamics $G(s)$ and the feedback multiplier $H(s)$ for the system shown in Figure 1. (5 Marks)

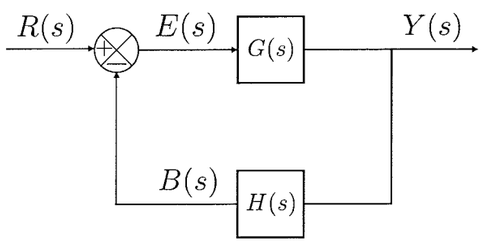

Figure 1: The "Standard" Closed Loop Control System

Part C

Answer **both** the Questions. (2Q=24M)

7. Tesla, Inc. is in talks with ABB to install a 2-DOF planar robot with revolute joints in its battery gigafactory coming up in India. One of the requirements given by Tesla to ABB is that the robot must be able to follow a straight line from an initial position (3,5) to the final position (7,13) in its motion segment. As a robotics engineer in ABB you have been asked to determine the joint angles of the robot for each of the coordinate points if the path is divided into 4 segments. Each link of the robot shown in Figure 2 is 12 m long. NOTE: You must show two sample calculations to receive full credit. (10 Marks)

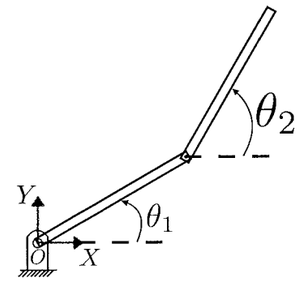

Figure 2: A 2-DOF Planar Robot with Revolute Joints

8. Yaskawa Motoman is an industrial robot manufacturing company credited with coining the word 'mechatronics'. It has installed over 360,000 robots in industries worldwide. Its latest project is to design a robot for Ashok Leyland's CPPS Plant that will be used to manufacture cab panels for the Ashok Leyland Dost+ trucks. The engineers in Yaskawa Motoman have designed a reduction gearing system for the robot. They need to verify their work. Use the data that follows, perform the analysis asked for and report your results.
Figure 3 shows the set-up of the reduction gearing system in the actuator of the robot. The actuator of the motor has motor inertia 0.015 kg·m^2 and maximum torque of 8 N·m. The motor is connected to an arm of uniform mass distribution with a concentrated mass at its end. The engineers at Yaskawa Motoman ignored the inertia of the pair of gears and any frictional effects. Calculate the maximum angular acceleration the system can develop for reduction ratios of 3 and 30. (14 Marks)

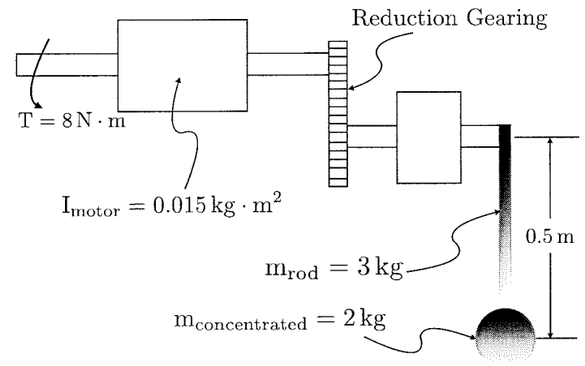

Figure 3: Set-Up of the Reduction Gearing System in Leyland's Robot

The End