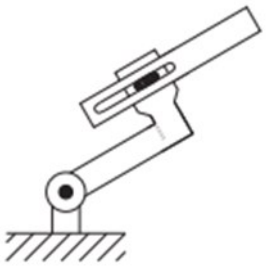
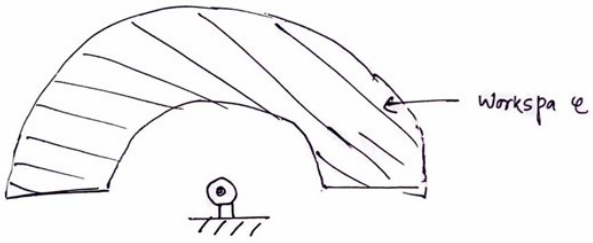
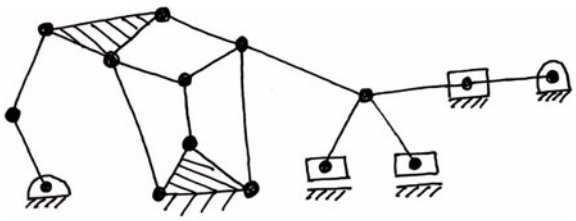
Question Paper Setter Information

Name of Examination	**Regular Final Assessment Test** (FAT), **Fall 2023-24**, (Nov 2023)			
Slot: C2+TC2			**Class Number (s):** VL2023240102308, VL2023240102311	
Course Code:	BECE312L	Course Title:	ROBOTICS AND AUTOMATION	
Emp. No:	19699	Faculty Name:	Dr. Mohiul Islam	School: SENSE
Contact No.	9854662380	Email:	mohiul.islam@vit.ac.in	

ANSWER KEY

Q. No.	Sub-division	Question Text	Marks	Unit / Module No.	CO	BL	Difficulty Level E/A/T
Answer all questions :			Total Marks for the section: 100				
1.	(a)	Define the workspace of a manipulator. Draw the approximate workspace for the two-link manipulator as shown in Figure 1 which has one revolute joint and one prismatic joint.  Figure 1	4	1	1	2	A
		a) workspace :  					
	(b)	Find the degree of freedom (DOF) of the following robot mechanism as shown in Figure 2 using Grubler's formula.  Figure 2	6	1	1	2	A

b)

no. of binary rotary joints = 10

" ternary " = 3

" Quaternary " = 2

no. of binary sliding joints = 2

Total no. of joints = $10 + (3\times2) + (2\times3) + 2$

$= 10 + 6 + 6 + 2 = 24$

Total no. of moving links = 16

DOF = $(16\times3) - (24\times2) = 0$

2.		A DC motor is used to drive a robot joint has a torque constant 2.5 *N-m/A* and a voltage constant of 20×10^{-3} *V/rpm*. The armature resistance is 4 *ohms*. A voltage of 30 V is applied at a point of time of robot cycle when the joint is stationary. Determine: (a) The torque of the motor immediately after the voltage is applied. (b) The back e.m.f. and the respective torque corresponding to rotational speed of 300 rpm and 600 rpm, respectively.	10	2	2	2	A

Solution: Data given: K_m = Torque constant = 2.5 *N-m/A*

K_b = Voltage constant = 20×10^{-3} *V/rpm*

R_a = Armature resistance = 4 *ohms*

V_{in} = Input voltage = 30 V

(a). Torque at the start of rotation,

$$T_m = K_m \cdot I_a = K_m \cdot \left(\frac{V_{in} - e_b}{R_a}\right) = K_m \cdot \left(\frac{V_{in} - K_b \cdot \omega}{R_a}\right)$$

At the start, $\omega = 0$.

$$\therefore T_m = K_m \frac{V_{in}}{R_a} = \frac{2.5 \times 30}{4} = 18.75 \text{ N-m}$$

(b). When speed of rotation, ω = 300 *rpm*

$$e_b = K_b \cdot \omega = 20 \times 10^{-3} \times 300 = 6 \text{ V}$$

and

$$T_m = K_m \cdot \left(\frac{V_{in} - e_b}{R_a}\right) = 2.5 \times \left(\frac{30 - 6}{4}\right) = 15 \text{ N-m}$$

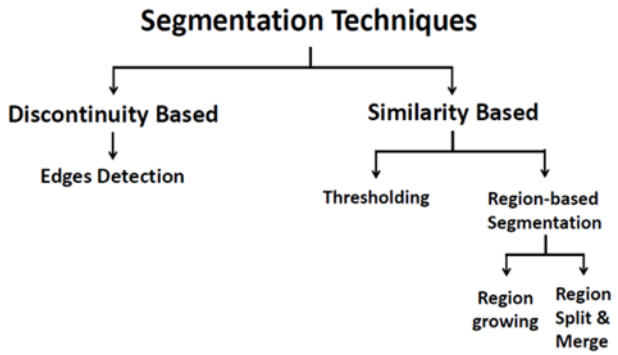
When speed of rotation, ω = 600 *rpm*

$$e_b = K_b \cdot \omega = 20 \times 10^{-3} \times 600 = 12 \text{ V}$$

and

$$T_m = K_m \cdot \left(\frac{V_{in} - e_b}{R_a}\right) = 2.5 \times \left(\frac{30\text{-}12}{4}\right) = 11.25 \text{ N-m}$$

3.	(a)	Classify various image segmentation methods and give your idea on the requirement of image segmentation.	3	3	3	2	E



	(b)	Perform region growing for the image illustrated in Figure 3. (i) with seed pixel at (4,4) and a threshold value $(T = 2)$ (ii) with seed pixel at (7,5) and a threshold value $(T = 2)$ Comment on the results obtained in (i) and (ii).	7	3	3	2	E

1	1	1	1	1	1	1	2
1	1	1	1	1	1	1	0
2	5	6	9	9	8	1	0
1	1	8	8	8	3	1	0
1	1	6	6	6	3	1	0
1	1	5	6	6	3	1	0
1	1	5	6	6	2	1	0
1	1	1	1	1	1	0	0

Figure 3

(i) with seed pixel at (4,4) and a threshold value $(T = 2)$

1	1	1	1	1	1	1	2
1	1	1	1	1	1	1	0
2	5	6	9	9	8	1	0
1	1	8	8	8	3	1	0
1	1	6	6	6	3	1	0
1	1	5	6	6	3	1	0
1	1	5	6	6	2	1	0
1	1	1	1	1	1	0	0

(ii) with seed pixel at (7,5) and a threshold value $(T = 2)$

1	1	1	1	1	1	1	2
1	1	1	1	1	1	1	0
2	5	6	9	9	8	1	0
1	1	8	8	8	3	1	0
1	1	6	6	6	3	1	0
1	1	5	6	6	3	1	0
1	1	5	6	6	2	1	0
1	1	1	1	1	1	0	0

Comment: Both are same

4.	(a)	Give a brief description for different image reduction techniques.	5	3	3	2	E

Image Data Reduction

Reason:

- Easier visualization and interpretation
- Less storage space requirement

Types:

- Digital conversion
  - Sampling
  - Quantization
- Windowing

Windowing involves using only a portion of the total image stored in the frame buffer for image processing and analysis. This portion is called windowing.

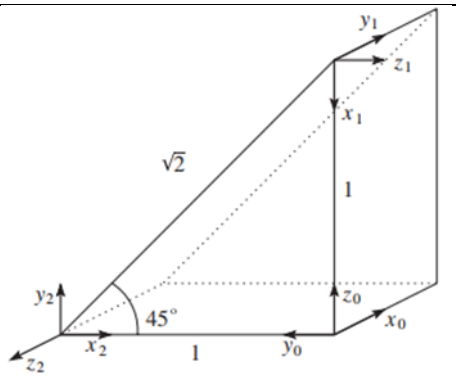
For example, for inspection of printed circuit boards, one may wish to inspect and analyze only one component on the board.

	(b)	Compute the number of bits that represent an image that has 32 gray levels and a size of 1024×1024 pixels. What is the time (in seconds) required to transmit this image over a 14.4 kbits/second modem?	5	3	3	2	E

The image that has 32 gray levels i.e. each pixel is represented by 5 ($2^5 = 32$) bits.
Image has a size of 1024×1024 pixels.
Hence total number of bits= $1024 \times 1024 \times 5 = 5242880$ bits

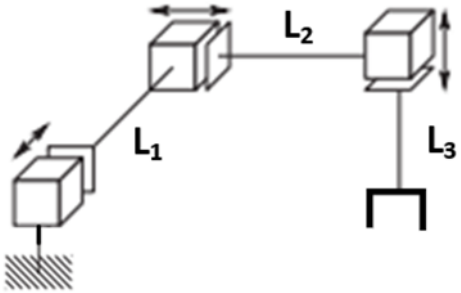
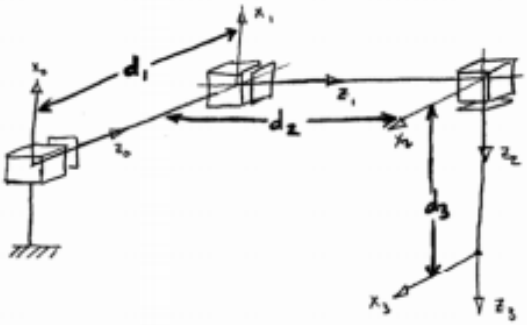
The modem sends 14.4 kbits/second, so the time (in seconds) required to transmit this image:

$$\frac{5242880}{14.4 \times 1024} = 355.55 \text{ seconds}$$

5.		 Figure 4 Consider the diagram of Figure 4. Find the homogeneous transformations H_1^0; H_2^0; H_2^1 representing the transformations among the three frames shown. Show that $H_2^0 = H_1^0 . H_2^1$	10	4	4	4	T

$$H_1^0 = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ -1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \end{bmatrix}; \quad H_2^0 = \begin{bmatrix} 0 & 0 & -1 & 0 \\ -1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}; \quad H_2^1 = \begin{bmatrix} 0 & -1 & 0 & 1 \\ 0 & 0 & -1 & 0 \\ 1 & 0 & 0 & -1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

6.		Consider the three-link Cartesian manipulator of Figure. Assign frames and tabulate the forward	10	4	4	4	T

		kinematic parameters using the DH convention. Also represent the homogeneous transformation matrix, ${}^{Base}T_{End\_effector}$.  Figure 4					
		 link | a_i | α_i | d_i | θ_i 1 | 0 | -90° | d_1 | 0 2 | 0 | 90° | d_2 | 90° 3 | 0 | 0 | d_3 | -90° $A_1 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & -1 & 0 & d_1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$; $A_2 = \begin{bmatrix} 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & d_2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$; $A_3 = \begin{bmatrix} 0 & 1 & 0 & 0 \\ -1 & 0 & 0 & 0 \\ 0 & 0 & 1 & d_3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$ $T_0^3 = A_1A_2A_3 = \begin{bmatrix} 0 & 0 & 1 & d_3 \\ -1 & 0 & 0 & d_2 \\ 0 & -1 & 0 & d_1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$					
7.		Derive the expressions for the Roll, Pitch and Yaw angles considering a rotation matrix R. Find the equivalent Roll, Pitch and Yaw angles for the following rotation matrix. $R = \begin{bmatrix} -0.5 & 0.866 & 0 \\ -0.557 & -0.321 & 0.766 \\ 0.663 & 0.383 & 0.643 \end{bmatrix}$	10	4	4	4	T

Given, Given, $R = \begin{bmatrix} -0.5 & 0.866 & 0 \\ -0.557 & -0.321 & 0.766 \\ 0.663 & 0.383 & 0.643 \end{bmatrix}$

Comparing with, $R = \begin{bmatrix} r_{11} & r_{12} & r_{13} \\ r_{21} & r_{22} & r_{23} \\ r_{31} & r_{32} & r_{33} \end{bmatrix}$

$$\phi_p = atan2\left(-r_{31}, \pm\sqrt{r_{32}^2 + r_{33}^2}\right)$$
$$= atan2\left(-0.663, \pm\sqrt{0.383^2 + 0.643^2}\right) = atan2(-0.663, \pm 0.748) = 41.55°$$

$$\phi_r = atan2\left(\frac{r_{21}}{cos\phi_p}, \frac{r_{11}}{cos\phi_p}\right)$$
$$= atan2\left(\frac{-0.557}{cos(-41.55°)}, \frac{-0.5}{cos(-41.55°)}\right) = atan2(-0.744, -0.668) = 45.08°$$

Or, $\phi_r = 45.08 - 180 = -131.9°$

$$\phi_y = atan2\left(\frac{r_{32}}{cos\phi_p}, \frac{r_{33}}{cos\phi_p}\right)$$
$$= atan2\left(\frac{0.383}{cos(-41.55°)}, \frac{0.643}{cos(-41.55°)}\right) = atan2(0.512, 0.86) = 30.77°$$

8.		The first rotary joint of a manipulator starts from rest with an initial angle of 10°. It is desired to move the joint in a smooth trajectory to 60° in a time duration of 4 seconds. Assuming the manipulator to rest at the goal, use a suitable polynomial trajectory to accomplish this task. Find the coefficients of the polynomial function. Plot the position, velocity, and acceleration as a function of time.	10	5	5	3	A

Q.8

As per question, $\theta = \theta_i = 10^\circ$ at $t = t_i = 0$

$\theta = \theta_f = 60^\circ$ at $t = t_f = 4$ sec

Also $\ddot{\theta} = 0$ at $t = t_i = 0$

$\dot{\theta} = 0$ at $t = t_f = 4$ sec

So we can consider a cubic polynomial

Hence $C_0 = \theta_i = 10$

$C_1 = 0$

$$C_2 = \frac{3(\theta_f - \theta_i)}{t_f^2}$$

$$= \frac{3(60-10)}{4^2} = 9.375$$

$$C_3 = \frac{-2(\theta_f - \theta_i)}{t_f^3} = \frac{-2(60-10)}{4^3}$$

$$= -1.5625$$

Position

$$\theta(t) = C_0 + C_1 t + C_2 t^2 + C_3 t^3$$

$$= 10 + 9.375\, t^2 - 1.5625\, t^3$$

Similarly, Velocity

$$\dot{\theta}(t) = C_1 + 2C_2 t + 3C_3 t^2$$

$$= 18.75t - 4.6875\, t^2$$

Acceleration

$$\ddot{\theta}(t) = 2C_2 + 6C_3 t$$

$$= 18.75 - 9.375\, t$$

Plot the graphs:

9.		Write an algorithm to program a robot to pick up a part from point A and move it to point B, followed by a move to a neutral position. Points A and B are to be defined by the programmer within the robot's work volume. Then the robot should pick up the part at point B and move it back to point A, followed by a move to the previous neutral position. The robot can be operated continually in the "run" mode to repeat the motion pattern over and over.	10	6	6	4	T
		Ans: *Students can write their own algorithm which are logically correct and practically realizable for the given task given in this problem using all the basic knowledge of*					

		Robotics and Automation subject.					
		OR					
		Write a pseudo code program for the Robot manipulator which is programmed to the detect currency notes, separate them from the coins, and collect them in a basket. The currency notes and coins are placed on a table.	10	6	6	4	T
		Ans: *Students can write their own algorithm which are logically correct and practically realizable for the given task given in this problem using all the basic knowledge of Robotics and Automation subject.*					
10.		Discuss the industrial applications of robotics and enlist the specifications of an industrial robot.	10	7	1	1	E
		Industrial Applications: There are certain industrial tasks robots do very well like **material transfer**, **machine loading**, **spot welding**, continuous **arc welding**, **spray coating**, **material removal**, **cutting** operations, **assembling operations, part inspection, part sorting, part cleaning, part polishing**, and a dozen more specialized tasks. Brief idea on these topics is required. **Performance Specifications of Industrial Robots** • Size of the working envelope • Precision of movement Spatial resolution, Accuracy, Repeatability • Lifting capability • Number of robot axes • Speed of movement maximum speed, acceleration/deceleration time • Motion control path control, velocity control • Types of drive motors: Hydraulic, Electric, pneumatic					
		OR					
		Elaborate on the role and significance of service robots within the healthcare industry.	10	7	1	1	E
		Robots in the medical field are transforming how surgeries are performed, streamlining supply delivery and disinfection, and enabling providers to focus on engaging with and caring for patients. Intel offers a diverse portfolio of technology for the development of medical robots, including surgical-assistance, modular, and autonomous mobile robots. Service robots relieve the daily burden on healthcare workers by handling routine logistical tasks. Many of these robots function autonomously and can send a report when they complete a task. These robots set up patient rooms, track supplies and file purchase orders, restock medical supply cabinets, and transport bed linens to and from laundry facilities. Having some routine tasks performed by service robots gives healthcare workers more time to focus on immediate patient needs and can help with increasing job satisfaction. Service robots can also help with cleaning and disinfection. These AMRs may use					

		ultraviolet (UV) light, hydrogen peroxide vapours, or air filtration to help reduce infection and to sanitize reachable places in a uniform way. *Similar other roles and significance of Robotics in Health Sector may be written.*