GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Bachelor of Engineering
Level: UG
Branch: Robotics and automation
Subject Code: BE04041011
Subject Name: Elements of Robots and Kinematics

w.e.f. AcademicYear:	2024-25
Semester:	4
Category of the Course:	Professional Core Course

Prerequisite:	Nil
Rationale:	The subject should enable the students to understand the principles of Kinematics, importance of of it. To learn the concepts of Robotics, kinematics of robot, principles of robot drives and controls, gripper , sensors used in robots and differential motion of robot

Course Outcomes:

At the end of the course, students will be able to:

Sr. No.	CO statement	Marks% weightage
CO-1	Explain the history, classifications and basic terminologies of robotics and various configuration of robots.	**U-30**
CO-2	Analyze forward kinematic model for planar and spatial robot manipulator.	**N-25**
CO-3	Evaluate inverse kinematic model for multi-DOF robot manipulators.	**E-25**
CO-4	Solve Jacobian matrix for differential motion of robot.	**A-20**

Teaching and Examination Scheme:

Teaching / Learning Scheme (in Hours per semester)					Total Credits	Assessment Pattern and Marks					Total Marks
						Theory		Tutorial / Practical			
L	T	P	SL	Total no of hours per semester		ESE (E)	PA / CA (M)	PA/CA (I)	TW/ SL (I)	ESE (V)	
45	0	30	45	120	4	70	30	20	30	50	200

*** Problem Based Learning (PBL) aims to accommodate learning beyond syllabus as per clause 9.4 of NBA manual.**

Content:

Sr.No.	Content	Total Hrs
1	**Fundamentals** Introduction, What is a Robot? Classification of Robots, What Is Robotics? History of Robotics, Advantages and Disadvantages off Robots, Robot Components, Robot Degrees of Freedom, Robot Joints, Robot Coordinates, Robot Reference, Frames, Programming Modes, Robot Characteristics, Robot Workspace, Precision, Repeatability & Accuracy, Robot Languages, Robot Applications, Selection and Application of Serial Manipulators, Other Robots and Applications, Social Issues	**08**

2	**Robot Actuators and Grippers** Electric Actuators , Hydraulic Actuators , Pneumatic Actuators, Selection of Motors, Grippers, Considerations in Gripper Selection and Design	**06**
3	**Robot Sensors, Controllers, Vision and Signal Conditioning** Sensor Classification , Internal Sensors , External Sensors, Vision, Signal Conditioning, Sensor Selection, Basic Control Systems Concepts and Models, Controllers	**07**
4	**Kinematics of Robots: Position Analysis** Introduction, Robots as Mechanisms, Conventions, Matrix Representation, Representation of a Point in Space, Representation of a Vector in Space, Representation of a Frame at the Origin of a Fixed Reference Frame, Representation of a Frame Relative to a Fixed Reference Frame, Representation of a Rigid Body, Homogeneous Transformation Matrices, Representation of Transformations, Representation of a Pure Translation, Representation of a Pure Rotation about an Axis, Representation of Combined Transformations, Transformations Relative to the Rotating Frame, Inverse of Transformation Matrices, Forward and Inverse Kinematics of Robots, Forward and Inverse Kinematic Equations: Position, Cartesian (Gantry, Rectangular)Coordinates, Cylindrical Coordinates, Spherical Coordinates, Articulated Coordinates, Forward and Inverse Kinematic Equations: Orientation, Roll, Pitch, Yaw (RPY)Angles, Euler Angles, Articulated Joints, Forward and Inverse Kinematic Equations: Position and Orientation, Denavit-Hartenberg Representation of Forward Kinematic Equations of Robots, The Inverse Kinematic Solution of Robots, General Solution for Articulated Robot Arms, Inverse Kinematic Programming of Robots, Degeneracy and Dexterity, Degeneracy, Dexterity, The Fundamental Problem with the Denavit-Hartenberg Representation	**15**
5	**Differential Motions and Velocities** Introduction, Differential Relationships, Jacobian, Differential versus Large-Scale Motions, Differential Motions of a Frame versus a Robot, Differential Motions of a Frame, Differential Translations, Differential Rotations about the Reference Axes, Differential Rotation about a General Axis, Differential Transformations of a Frame, Interpretation of the Differential Change, Differential Changes between Frames, Differential Motions of a Robot and its Hand Frame, Calculation of the Jacobian, How to Relate the Jacobian and the Differential Operator, Inverse Jacobian	**08**
	TOTAL	**45**

Suggested Specification table with Marks(Theory):(For B.E. only)

Distribution ofTheory Marks					
RLevel	ULevel	ALevel	NLevel	ELevel	CLevel
	30%	20%	25%	25%	

R: Remembrance; U: Understanding; A: Application; N: Analyze;E: Evaluate;C: Create and

above Levels (Revised Bloom's Taxonomy)

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

Reference Books:

1. Mikell P. Groover, "Industrial Robotics", McGraw Hill, 2nd edition, 2012.
2. John J. Craig, "Introduction to Robotics", 3rd Edition, Addison Wesley, ISE 2020.
3. S K Saha, Introduction to Robotics, Tata McGraw-Hill, ISBN: 9789332902800, Second Edition, 9789332902800, 2019.
4. Arthor Critchlow, "Introduction to Robotics", 1st edition, Macmillan, 2009.
5. Mohsen Shahinpoor, "A Robot Engineering Text Book", 1st edition, Harper and Row, 2004.
6. Deb S.R., "Robotics Technology and Flexible Automation", 2nd edition, Tata McGraw - Hill Publis Robotics: Control and Programming. 2010.
7. J. Srinivas, R. V. Dukkipati, K., "Robotics: Control and Programming", Narosa Publishing House, 2009.
8. Tsuneo Yohikwa, Foundations of Robotics Analysis and Control, Prentice Hall of India Pvt. Ltd., 2016.
9. Bijay K. Ghosh, Ning Xi, T.J. Tarn, Control in Robotics and Automation Sensor - Based integration, Academic Press, 1999.

List of Experiments:

1	Study of Robot terminology, robot components and robot configuration.
2	Study of Robot work volume for different robot configurations.
3	Study of different robot grippers and design of the grippers.
4	Demonstration of Robot movements through robot programming.
5	Demonstration of simple robot application e.g. Pick and place and its programming.
6	Write the computer codes for robot position analysis.
7	Write computer codes for forward kinematics of different robot configurations.
8	Write computer codes for inverse kinematics of different robot configurations.
9	Write computer codes for Jacobian matrix of different robot configurations.

Major Equipment:

List of Open Source Software/learning website:

1	NPTEL resources

- **List of suggested activities for Problem Based Learning:**

Sl. No.	Name of the activity	No. of hours	Evaluation Criteria
1.	Industry/Research laboratory visit	Visit = 5hrs., Report preparation = 5hrs. Total = 10hrs.	Based on report submitted. Report should contain observations and calculations based on industry/ lab data.
2.	Technical Video based learning related to the subject	Duration of video = 5hrs. Report preparation = 5hrs. Total = 10hrs.	Report /presentation based on the video learning outcomes.

3.	Assignment writing. Numericals based assignment is preferable.	5 assignments of 4hrs. each. Total = 20hrs.	Based on the correctness of submittedassignment.
4.	Problem solving/Coding using C, C++, MATLAB, Python, SCILAB,modeling and Analysis software or any other software	5 small coding-based assignment of 2hrs. each. Total = 10hrs.	Based on the coding solution submitted.
5.	Self-learning online course	Minimum duration of the course should be 10hrs.	Examination based assessment at the end of course. Based on the certificate produced.
6.	Identification and solution of Complex problem	Maximum 2 problems. Study of the problem and solution finding, Total = 10hrs.	Based on the depth of the solution submitted.
7	Videos on Industrial safety/Disaster Management aspects based on subject	Duration of video = 5hrs. Report preparation = 5hrs. Total = 10hrs.	Based on quiz/report submitted
8	Technical paper reading and summarization of research papers based on relevant subject	5 research papers = 20 hrs.	Summarize research paper and evaluation critical parameters
9.	Poster/chart/power point preparation on technical topics	Duration = 6 hrs.	Based on poster/chart preparation and presentation skills
10	Working/non-working model on technical topics	Working = 12 hrs. Non- working = 8 hrs.	Based on inter department/external evaluation
11	Industrial exposure for 2-3 days to observe and provide tentative solutions on society/environment/health/ sustainability/any other issue	Duration = 15 hrs. for industrial exposure Problem identification and tentative solution = 10 hrs. Total = 20 hrs.	Based on evaluation of critical problems and solutions
12	Group Discussion on emerging/trending technical topics based on subject	Duration = Min. 1 hr.per subject. Max. 3 hrs. per subject	Based on performance in group discussion, technical depth, knowledge etc.
13.	Real world case studies-based learning	Duration of data collection/study = 5hrs. Report preparation = 5hrs. Total = 10hrs.	Based on in-depth study, technical depth, data collected, fact finding, etc.
14.	Application/Software development	Duration = 10 hrs.	Depending on the complexity of the Application/Software

15.	Research paper publication	Duration = 10 hrs.	Based on submission of proof of publication
16.	Upgradation/Reverse engineering studies of existing equipment of the laboratory	Duration 10 hrs.	Based on the performance of the equipment
17.	Expert lecture/session	Duration 3 hrs. For attending the lecture/session– 2 hrs. and for report writing 1 hr.	Based on the proof of attendance and report submitted
18.	Annotated Video Explanation of Concept/Problem	10h (Preparation + Recording + Submission)	Based on accuracy of explanation, clarity, and presentation style.
19.	Patent Search and Innovation Gap Identification	10h (Search + Report)	Based on number of relevant patents analyzed and identification of innovation scope.

Note:
1. All the suggested activity should be related to the subject.
2. The number of hours are suggestive. Faculty can sub-divide the number of hours based on the activity. However, total number of hours is fixed.
3. Rubrics for the evaluation can be prepared by the faculty.
4. Subject teacher can add the relevant activities other than those listed above, with the consent of head of the department and DQAC.

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