BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI-Hyderabad Campus

## FIRST SEMESTER 2019-2020

Course Handout (Part II)

#### Date: 12/06/2019

In addition to part I (General Handout for all courses appended to the time table) this portion gives further specific details regarding the course.

Course No. : ME G511

Course Title : MECHANISMS & ROBOTICS

Instructor-in-charge : YVDRAO

**Course Description**: Page 309 in Bulletin 2010-2011.

Classification of robots & manipulators; fields of application; Synthesis of planar & spatial mechanisms; Methods of function & path generation; coupler curve synthesis; linkages with open loop; Actuators & drive elements; Microprocessor based application and control of Robots.

***Academic Honesty and Integrity Policy:****Academic honesty and integrity are to be maintained by all the students throughout the semester and no type of academic dishonesty is acceptable*

**Scope and Objective:**

This course provides a comprehensive knowledge of about the theory of Mechanisms and Robotics. In the first part of the course additional topics that are required for the design of mechanisms is dealt with. In the next part deals with manipulators called Robots that are used to replace or supplement human beings in various work‑sites. Good examples regarding the areas of applications of these robots are given. The required back ground for this area namely spatial mechanisms analysis is also dealt with. Finally, about the emerging field of Robotics which is one of the current important interdisciplinary areas of application and research is described.

The contents of the course will give an overall insight into the theory of Robotic technology with more emphasis on mechanical aspects. The course is designed to cover the areas like Basic Anatomy related to Robotics, Mechanisms which can be used in Robots, Robot Configurations, kinematic and dynamic analysis of Robots and Programming of Robots will be taught in detail along with suitable examples, applications and implementation principles of industrial robotics.

**Text Book:**

(T1) “Theory of Machines and Mechanisms*”*, John Joseph Uicker, Joseph Edward Shigley, Gordon R. Pennock, Oxford University Press, 3rd Edition, 2003.

(T2) “Robotics and Control*”*, Mittal R. K. & Nagrath I. J, TMH, 2003 (Reprint 2007 or later).

**Reference Books:**

(R1) “Kinematics, Dynamics, and Design of Machinery”, Kenneth J. Waldron& Gary L. Kinzel, 2nd Ed Wiley India, 2004.

(R2) “Mechanism and Machine Theory”, Ashok G. Ambekar, PHI, 2007.

(R3) "Theory of Machines and Machines” - Amitabh Ghosh and A.K. Malik, Allied East West Press Pvt. Ltd., 3rd Ed.

(R4) “Industrial Robotics”, Groover, M. P., et al., MGHISE, 1986.

(R5) “Robotic: Control, Sensing, Vision & Intelligence”, Fu, K. S., et al., MGHISE, 1987.

(R6) “Fundamentals of Robotics: Analysis and Control”, Robert J., Schilling, Prentice Hall, NJ, 2002.

**Course Plan:**

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| --- | --- | --- | --- |
| Lecturer No. | Learning Objectives | Topics to be covered | Reference  Chap./Sec. |
| 1 | Design of Planar linkages | Motion, Path and Function generation tasks | T1-11  R1-6 |
| 2,3 | Synthesis of mechanisms | Introduction to Synthesis of planar mechanisms- Graphical and Analytical Methods | T1- 11  R2-6 |
| 4 | Coupler- Curves | Coupler curves, Cognate linkages | T1- 11  R3-3 |
| 5 | Analytical methods | Bloch Method and Freudenstein equation | T1- 11  R3-3 |
| 6,7 | Spatial Mechanisms | Introduction to Spatial Mechanism, Position analysis of Spatial Mechanism | T1-11  R3-5 |
| 8 | Introduction | Automation and Robotics. Robotics in Science Fiction, Progressive Advancement. The Robotics trends and the future prospects. | T2-1 |
| 9 | Fundamentals of Robot Technology | Robot Anatomy – Links, Joints and Joint Notation scheme, Degrees of Freedom (DOF), Required DOF in a Manipulator | T2-1  R4-2 |
| 10 | Configuration and end effector | Arm Configuration, Wrist Configuration; The End-effector, Human arm characteristics, Design & Control issues | T2-2  R4-2 |
| 11, 12, 13 | Mapping | Introduction to co-ordinate frames mapping, Mapping between Rotated frames, Mapping between Translated frames, Mapping between Rotated & Translated frames. | T2-2  R4-4  R5-2 |
| 14, 15 | Transformation of frames | Description of objects in space, Transformation of vectors - Rotation & Translation of vectors, Composite transformations. | T2-1  R6-2 |
| 16, 17 | Homogeneous Transformation matrix | Inverting a Homogeneous Transform, Fundamental Rotation Matrices – Principle axes Rotation fixed, Euler and Equivalent angle axis Representations | T2-2  R4-4  R6-2 |
| 18 | Practice on theory | Examples on mapping transformation | T2-2 |
| 19,20 | Kinematic modelling of Manipulators | The kinematic Modeling of Manipulator, Direct kinematics model mechanical structure & Notations Description of links & Joints, | T2-3  R4-4 |
| 21,22 | Denavit Hartenberg Notation | Denavit – Hartenberg Notation, kinematic Relationship between links, Manipulator transformation matrix, Examples. | T2-3  R5-2 |
| 23 | Practice problems on Forward Kinematics | Examples of direct Kinematics | T2-4, R4-3 |
| 24,25 | Inverse kinematics of manipulator | The Inverse kinematics of manipulator: workspace, solvability of inverse kinematic model. Solution technique, closed form solutions. | T2-4  R4-4 |
| 26 | Algorithms for inverse kinematics | Algorithms Examples of inverse kinematics | T2-4, R5-2 |
| 27 | Practice problems on Inverse Kinematics | Examples of inverse Kinematics |  |
| 28 | Singularities in work space | Singularities of manipulators | T2-5, R6-3 |
| 29 | Robot end-effectors | Types of end-effectors, methods of holding, Mechanical grippers, Mechanisms for grippers, Consideration in gripper selection & design, Gripping Force. | R4-5 |
| 30,31 | Differential Motion and Statics | Differential kinematics, linear and angular velocity of a Rigid Body, Relationship between Transformation matrix and angular velocity, mapping velocity vectors, velocity propagation along links. | T2-5  R4-5  R6-5 |
| 32,33 | Jacobian of a manipulator | Manipulator Jacobian, Jacobian Inverse, Jacobian singularities, Static Analysis. Jacobian in statics, Examples. |  |
| 34-39 | Dynamics of Mechanisms | Introduction, Lagrangian Mechanics, Lagrange – Euler formulation - Velocity of a point on the manipulator, The inertia tensor, The kinetic energy, the potential energy. Equations of Motions, the Lagrangian-Euler (LE) Dynamic model algorithm. Examples on Dynamic modeling. | T2-6  R5-3  R6-6  R4-4 |
| 40 | Trajectory Planning | Definition and planning tasks, Joint space techniques, Cartesian Space techniques, Joint space versus Cartesian Space TP | T2-7 |
| 41 | Robot Control | Control of movements of mechanical joints, control sequence,  n-joints manipulator control system, system performance, control system with damping, control strategy, Architecture of control systems. | T2-8  R5-5  R4-8  R6-7 |
| 42 | Robot Programming | Robot Programming issues, optimization position definitions, interpolation language command, data object command, motion commands, gripper command, tool commands, sensors command, other command, Writing programs for different tasks | R4-8, 9  R5-9  R6-9 |

Home Assignments, Laboratory and Project: There will be three components under this head. First one is Literature Survey, second one is Research Summaries and third part is: Each student has to work on a project assigned. The project will have seminars and culminate in submission of a written report and presentation of work done.

**Evaluation:**

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| --- | --- | --- | --- | --- |
| Component | Duration | Weightage (%) | Date & Time | Remarks |
| Mid semester Test | 90 Mins | 20 (40 M) | 03/10 , 11:00 – 12:30 PM | CB |
| Assignment | -- | 10 (20 M) | --- | OB |
| Project | -- | 10 (20 M) | --- | OB |
| Lab work | -- | 20 (40 M) | --- | OB |
| Compre. Exam | 180 Mins | 40 (80 M) | 09/12 AN | CB |

Chamber Consultation Hour: As announced in the Class Room.

**Notices:** All notices concerning the course are displayed on CMS.

**Make-up Policy:** No make up for Assignments/Project/Lab.

(Y V D Rao)

Instructor-in-charge

ME G511