2. RAI 819 – Advanced Kinematics for Robotic Systems

a. **Textbook**

- Robotics: Modelling, Planning and Control by Bruno Siciliano et al.
- Modern Robotics by Kevin Lynch.
- Complex Robotic Systems by Pasquale Chiacchio and Stefano Chiaverini.
- Rigid Body Dynamics Algorithms by Roy Featherstone.
- Handouts and research articles may also be used by the instructor.

b. **Objective**

- Gain in-depth knowledge of advanced kinematic concepts for complex robotic systems.
- Analyze robot motion capabilities and limitations using advanced kinematic analysis techniques.
- Develop expertise in applying optimization methods for solving complex kinematic problems.
- Implement robot control algorithms with dynamics.
- Explore current research areas in robot kinematics and their potential applications.

c. **Course Outcome:** This course delves into advanced concepts of kinematics for robotic systems, equipping students with the theoretical foundation and practical skills to analyze, design, and control complex robot motions. Through this course, the students will explore advanced topics, optimization techniques, and cutting-edge research areas in robot kinematics.

d. **Course Outline**

- **Review of Fundamental Kinematics**
  - Homogeneous transformations and D-H parameters
  - Forward and inverse kinematics of serial manipulators
  - Differential kinematics: Jacobian matrices and robot velocities
- **Robot Dynamics:**
  - Lagrange's Equations and application to robot dynamics
  - Newton-Euler equations for rigid body dynamics
  - Dynamic modelling of serial and parallel manipulators
  - Introduction to dynamic parameters: inertia, mass, center of mass
- **Kinematic Analysis**

- Singularity analysis: identification and avoidance of singular configurations
- Workspace analysis: determining reachable and manipulable regions of the robot
- Dexterity analysis: evaluating manipulability of the robot at different configurations

- **Optimization in Robot Kinematics**
  - Trajectory optimization: planning optimal robot motions considering various objectives (e.g., minimal time, energy)
  - Inverse kinematics with optimization: utilizing optimization techniques for efficient inverse kinematics solutions
  - Kinematic path planning: optimizing robot motion paths within the workspace

- **Kinematics of Special Robotic Systems**
  - Kinematics of redundant manipulators
  - Kinematics of parallel manipulators: advanced analysis techniques for closed-loop kinematic chains
  - Kinematics of unconventional robots: exploring kinematics of legged robots, snake robots, and other non-traditional robot designs
- **Control Systems with Robot Dynamics**
  - Linear control design for robotic systems: utilizing feedback control with dynamic models
  - Nonlinear control techniques for robots: exploring advanced control methods for complex dynamics
  - Impedance control: controlling the interaction between robots and their environment
  - Adaptive control: designing controllers that adapt to changing robot dynamics