Indian Institute of Technology Kanpur
Proposal for a New Course

Course Number: ISXXX

Course Title: Dynamics for Robotics

Course Structure: Three Lectures/Week; Full Semester

Proposing department/IDP: Department of Intelligent Systems

Other departments/IDPs may be interested in the proposed course: Departments of Aerospace/Electrical/Mechanical Engineering

Proposing instructor: Prof. Shakti S Gupta

Other faculty members interested in teaching the proposed course: None at this point of time.

Objectives/Outcome: To prepare a senior undergraduate and a graduate student to analyse/synthesize multi-link robots; static or mobile. It is expected that by the end of the course a student will be able to develop skills to employ existing commercial/open-source codes, effectively.

Pre-requisites: Exposure to planar dynamics of rigid bodies.

Course description:

Module 1: Mathematical Foundations & Advanced Kinematics (8 Hours)
Vectors, Tensors, and Reference Frames; Orientation & Parametrization; Angular Velocity & Acceleration; Translational Kinematics; Introduction to Spatial Kinematics; Screw Theory Fundamentals; Kinematics of Serial Chains; Jacobian & Singularities.

Module 2: Kinetics & Analytical Mechanics (8 Hours)
Mass Distribution & Inertia; Newton-Euler Formulation; Variational Principles; Lagrangian Dynamics; Hamiltonian Mechanics; Extended Hamilton's Principle; Comparison of Formulations.

Module 3: Multi-Body Dynamics Formulation (8 Hours)
Topology of Multi-Body Systems; Kinematic Constraints; Joint Modeling; Constrained Dynamics; Reduction Methods; Maggi's & Kane's Equations; Contact & Impact Mechanics.

Module 4: Numerical Methods & Algorithms (8 Hours)
Forward vs. Inverse Dynamics; Solving Ordinary Differential Equations (ODEs); Implicit Integration Schemes; Solving Differential-Algebraic Equations (DAEs); Constraint Stabilization; Symplectic Integrators; Computational Efficiency.

Module 5: Computer Simulation & Software Implementation (8 Hours + Term Projects)
Introduction to Computational MBD; MATLAB/Simscape Multi-body; MSC ADAMS: Basics and Advanced Dynamics; Robotics Simulators: MuJoCo; MuJoCo: Implementation; Comparing Solvers in Software.

References (Latest editions of the following books):

1. Rigid Body Dynamics Algorithms, Roy Featherstone
2. Dynamics of Multi-body Systems, Ahmed A. Shabana
3. Fundamentals of Robotic Mechanical Systems: Theory, Methods, and Algorithms, Jorge Angeles
4. Mechanics of Robotic Manipulation, Matthew T. Masaon
5. Advanced Engineering Dynamics, Donald T. Greenwood
6. A Mathematical Introduction to Robotic Manipulation, Richard M. Murray, Zexiang Li, and S. Shankar Sastry
7. Classical Mechanics, Herbert Goldstein, Charles P. Poole, and John Safko
8. Computer-Aided Kinematics and Dynamics of Mechanical Systems: Basic Methods, Edward J. Haug
9. Computer Methods for Ordinary Differential Equations and Differential-Algebraic Equations, Uri M. Ascher and Linda R. Petzold
10. MATLAB, ADAMS, and MuJoCo Documentation

Date: 15 Apr 2026. Proposer: Shakti S Gupta

Date:_____ DPGC Convenor: _____

Course is approved or not approved.

Chairman, SPGC