Dynamics

The field of Dynamics embraces the study of forces and induced motions of rigid and deformable material systems within the limitations of classical (Newtonian) mechanics. The field is intended to serve graduate students in the fields of aerospace or mechanical engineering who are interested in studying the dynamical behavior of a wide range of mechanical systems subject to applied forces (e.g., aerospace vehicles, robots, structures).

Summary of Major Field Body of Knowledge:

Students should master the major field body of knowledge covered in the following courses:
MAE 155, 169A, 255A, 269A
and a selection of 3 courses from:
MAE 254B, 255B, 263A, 263B, 263C, 263D, 269B, 269C, 269D (with the constraint of a least one from 255B, 263C, 269B).

The written qualifying (preliminary) examination covers the entire major field body of knowledge

More details concerning the major field body of knowledge can be found in the **Syllabus for the Major Field**, on the next page.

Minimum Requirements for Ph.D. Major Field Students:

The student must pass a written examination in the major field and satisfy other program requirements for the Ph.D. in the MAE Department besides completing all other formal University requirements.

Format of Written Qualifying Examination:

The exam consists of a 4-hour closed book part and a 4-hour open book part.

Timing of Written Qualifying Examination:

Normally offered every Spring Quarter, subject to demand, or in Fall Quarter if required.

Link to old exams:

http://stdntsvcs.mae.ucla.edu/exam/index.htm

Ph.D. Minor Field Requirements:

Minor field requirements can be satisfied by completion of the following courses with grades of B or better and at least one A: MAE 155, 255A, 269A

Students who have taken an intermediate dynamics course equivalent to MAE 155 in undergraduate status should substitute a course from the following list for the MAE 155 requirement: MAE 254B, 255B, 263A, 263B, 263C, 263D, 269B, 269C, 269D

Syllabus for the Major Field in Dynamics

Undergraduate Prerequisites:

The undergraduate preparation for this field includes the subjects of statics and dynamics of particles and (planar) rigid bodies and introductory vibration theory as they are normally taught in undergraduate programs in aerospace and mechanical engineering. It also includes undergraduate topics in applied mathematics such as differential equations and Laplace transforms.

Syllabus:

The topics which make up the field of Dynamics are outlined in sections I through XIII on the following pages. All students are required to have a thorough knowledge of the Dynamics Core material described in sections I through VI. In addition, students are responsible for three Specialty Areas selected from sections VII through XIV. In selecting the topics for the Specialty Areas, students must observe the following constraints:

1. Choose one Specialty Area from among:
    - VII Mathematical Methods in Dynamics
    - VIII Robotics
    - IX Advanced Dynamics of Structures
2. Choose two additional Specialty Areas from among:
    - VII Mathematical Methods in Dynamics
    - VIII Robotics
    - IX Advanced Dynamics of Structures
    - X Electromechanical Systems
    - XI Space Vehicle Dynamics
    - XII Helicopter Dynamics and Aeromechanics
    - XIII Advanced Robotics: Motion Planning and Control
    - XIV Probabilistic Dynamics
    - XV Aeroelastic Effects in Structures

Specialty areas must be selected in consultation with a member of the Dynamics Field Committee, and approved by the Field Committee Chair. Students wishing to propose alternative specialty programs should consult the guidelines set forth under Recommended Course Preparation.

Dynamics Core:

I. Fundamental Principals of Dynamics
    - A. Newton's Laws [155]
    - B. Variational Principles [155, 255A, 269A]

II. Methods of Formulating Equations of Motion
    - A. Newton's Second Law [155]
    - B. Work: Energy Principle [155]
    - C. Impulse Momentum Principle [155]
    - D. Angular Momentum Principle [155, 255A]
    - E. D'Alembert's Principle [155, 255A]
    - F. Principle of Virtual Work [155, 255A]
    - G. Hamilton’s Principle [155, 255A, 269A]
    - H. Lagrange's Equations [155, 255A, 269A]
    - I. Hamilton's Equations [155. 255A]
    - J. Kane's Equations [255A]

III. Kinematics

A. Differentiation of Vectors in Rotating Frames [155, 255A]
B. Angular Velocity [I55,255A]
C. Partial Velocities; Partial Angular Velocities [255A]
D. Euler Angles; Euler Parameters [155, 255A]
E. Kinematics of Free and Interconnected Bodies [255A]

IV. Rigid Bodies Dynamics
A. Inertia Properties [155, 255A]
B. Euler's Equations [l55.255A]
C. Dynamics of Interconnected Rigid Bodies [155, 255A]

V. Structural Dynamics and Vibrations
A. Vibration of Systems with One and Two Degrees of Freedom [169A]
B. Undamped and Damped Motion of Simple Systems [169A]
C. Impulse and Duhamel's Integral [169A]
D. Hamilton's Principle and Lagrange's Equations for Structural Dynamic Systems [269A, 169A]
E. Representation of Simple Structural Dynamic Systems Using the Finite Element Approach [269A]
F. Structural Dynamics Eigenvalue Problem for Discrete and Continuous Systems and its Solutions [269A]
G. Rayleigh's Quotient and Approximate Methods for Solving the Structural Dynamics Eigenvalue Problem [269A]
H. Damping in Structural Dynamics [169A, 269A]
I. Normal Mode Method and Dynamic Response of Structures [169A, 269A]

VI. Analytical Mechanics
A. Generalized Coordinates; Generalized Speeds [155, 255A]
B. Configuration Constraints; Motion Constraints [155, 255A]
C. Generalized Active Forces; Generalized Inertia Forces; Constraint Forces; Conservative Forces [155, 255A]
D. Lagrange's Equations; Kane's Equations [155. 255A]
E. Lagrange Multipliers and Constraint Forces [155, 255A]
F. Cyclic Coordinates; Routh's Equations [155, 255A]
F. Lagrange's Equations for Continuous Systems [255A, 269A]
G. Integrals of the Motion; Energy and Momentum Integrals [155, 255A]

Specialty Areas:

VII. Mathematical Methods in Dynamics
A. Geometric Theory of 2nd Order Dynamical Systems; Ph~ Plane. Singular Points., Limit Cycles [255B]
B. Definition and Interpretation of Liapunov stability, Orbital Stability, Asymptotic Stability [255B]
C. Linearization [255B]
D. Stability Analysis of Linear Variation Equations with Constant and Periodic Coefficients; Forms of Solutions, Parametric Excitation, Floquet Theory, Infinite Determinants [255B]
E. Liapunov's Direct Method, Complete Damping, the Hamiltonian as a Liapunov Function, Cyclic Coordinates, Integrals of the Motion [255B]
F. Perturbation Methods; Lindstedt's Method, Averaging, Multiple Time Scalars; Single and Multi Degree of Freedom Systems; Jump Phenomenon, Subharmonic Oscillations, Nonlinear Resonance [255B]

VIII. Robotics
A. Homogeneous Transformation [263C]
B. Forward/Inverse Kinematics; Workspace; Dexterity [263C]
C. Multi-body Dynamics; Recursive Newton-Euler Formulation; Recursive Lagrangian Formulation; Design Considerations; Linearization and Simplifications of Robot Dynamics [263C]

D. Trajectory Planning; Straight-line Motion; General Curved Motions; Path Trajectory Conversion; Cartesian Motion [263C]
E. Static Forces; Compliance [263C]
F. Task Planning [263C]

IX. Advanced Dynamics of Structures
A. Free and Forced Vibrations of Damped n-Degree of Freedom Systems; Mode Displacement and Mode Acceleration [269B]
B. Finite Element Treatment of Structural Dynamic Systems Applied to Timoshenko Beam and Plate Vibrations [269B]
C. Integral Equation Formulation of Free Vibration Problem and Subspace Iteration [269B]
D. Structural Dynamics of Rotating Systems [269B]
E. Structural Dynamics of Periodic Systems; Floquet Theory [269B]
F. Component Mode Synthesis [269B]
G. Direct Integration Methods for Obtaining Structural Dynamic Response [269B]

X. Electromechanical Systems
A. Electromechanics; Electrostatics, Magnetostatics, Induction, Maxwell's Equations, Dielectrics, Ferromagnetics, Electromagnetic Energy, Electromechanical Transduction [263A]
B. Electric Machines: Permanent Magnetic DC Motor, Variable Reluctance and Permanent Magnetic Stepper Motors, Electrostatic Motors, Piezoelectric and Magnetostrictive Motors [263A]
C. Control/Electromechanics Interaction: Energy Storage and Dissipation, Stability of Colocated and Non-Colocated Systems, Effects of Sensor/Actuator Dynamics, Pole/Zero Pairing, Minimum Phase/Non-Minimum Phase Systems [263A]
D. Residual Vibration: Point-to-Point Control, Minimum Time, Minimum Energy, Minimum Jerk, Frequency Shaping [263A]
E. Active Piezoelastic Damping: Piezoelasticity, Piezopolymer Laminar, Distributed Sensing/Control, Modal Sensor/Actuator [263A]

XI. Space Vehicle Dynamics
A. Spinning Design [263B]
B. Stability of Spinners and Dual Spinners; Internal Energy Dissipation; Energy Sink Analysis [263B]
C. Effects of Asymmetries, Unbalances [263B]
D. Nutation Resonance, Precession Phase Lock, Minimum Energy Trap [263B]
E. Rocket Dynamics; Jet Damping; Effects of Internal Mass Motion [263B]
F. Variable Mass Systems; Rectilinear and Rotational Motion; Momentum Approach, Control Volume Approach [263B]
G. Modeling Large Flexible Spacecraft [263B]
H. Model Reduction, Balance Realization, Asymptotic Formulas for Lightly Damped Systems [263B]
I. Space Environment; Gravitational Field of Earth, Gravity Gradient Torques
J. Passive Stabilization [263B]
K. Control Moment Gyros [263B]

XII. Helicopter Dynamics and Aeromechanics
A. Introduction to Helicopter Flight Mechanics [254B]
B. Flapping Dynamics in Forward Flight [254B]
C. Stability and Control of Helicopters [254B]
D. Automatic Stabilization of Helicopters [254B]
E. Helicopter Rotor Dynamics [254B]
F. Aeroelastic Stability of Rotor Blades [254B]
G. Coupled Rotor Fuselage Dynamics [254B]
H. Aeromechanical Problems - Air and Ground Resonance [254B]

XIII. Advanced Robotics: Motion Planning and Control

A. Kinematics: Exponential Representation of Rotations; Screw Coordinates and Dual Numbers; Kinematic Redundancies; Pseudo Inverse; Stiffness and Compliance [263D]
B. Kinematics of Grasping; Grasping Stability [263D]
C. Multibody Dynamics: Efficient Lagrangian and Newton-Euler Formulations; Force Transformations [263D]
D. Acceleration Mapping [263D]
E. Nonlinear Joint Control: Linearization and PD Control; Sliding Mode Control [263D]
F. Trajectory Planning: Dynamic Scaling; Time Optimal Motion Planning; Nonholonomic Motion Planning [263D]
G. Obstacle Avoidance: Configuration Space Obstacles; Voroni Diagrams [263D]

XIV. Probabilistic Dynamics
A. Probability Theory [269C]
B. Systems with Random Properties [269C]
C. System Identification [269C]
D. Random Process Theory [269C]
E. Stationary and Nonstationary Response of Multi-Degree of Freedom Systems [269C]
F. Applications: Gust Response of Aircraft, Wind-Induced Vibrations of Structures, Wave Induced Motion of Offshore Structures [269C]
G. Nonlinear System Response [269C]

XV. Aeroelastic Effect in Structures
A. Static Aeroelasticity [269D]
B. Formulation of Aeroelastic Problems Using Variational Principles [269D]
C. Unsteady Subsonic, Supersonic and Transonic Aerodynamics [269D]
D. Flutter of Wings and Panels [269D]
E. Nonlinear Flutter and Divergence in Transonic MAE [269D]
F. Aeroelastic Problems in Rotary-Wing Aircraft (Helicopters) [269D]
G. Aeroelastic Problems in Turbomachines [269D]
H. Applications to Mechanical and Civil Engineering [269D]