Topic Areas for AsE/EM Doctoral Qualifying Exam in Dynamics and Control

All Dynamics and Control majors in AsE/EM must demonstrate basic knowledge of the theory and techniques in the areas of engineering mechanics, basic modeling of dynamical systems, and control theory. The fundamental level of knowledge expected of doctoral students is found in typical undergraduate classes in these areas, e.g. Mechanics II and Mechanics III in the UC Engineering College, and Modeling and Simulation of Dynamic Systems (AEEM 313) and Fundamentals of Control Theory (AEEM 403) in the Department.

All Dynamics and Control doctoral students must also have a working knowledge of the topics covered in the two courses required for the MS degree with a major in Dynamics and Control: Analytical Dynamics I (AEEM 603) and Introduction to Modern Control (EGFD 615). All Dynamics and Control doctoral students should also be familiar with the concepts from mathematics used in analyzing dynamical systems and control systems, including:

- Differential equations
- Linear algebra
- Matrix manipulation
- Vector calculus
- Multi-variable calculus
- Complex variables
- Laplace transform theory

In addition, students specializing in Dynamics or Orbital Mechanics must demonstrate knowledge of the topics typically taught in the MS-level courses Analytical Dynamics II (AEEM 604), Spacecraft Dynamics (AEEM 636), and Orbital Mechanics (AEEM 695), including those listed below. Students specializing in the Controls area must demonstrate knowledge of topics beyond those covered in EGFD 615 Modern Control that are relevant to their chosen research area, including those listed below.

At minimum, all Dynamics and Control doctoral students must be familiar with the following basic topics from fundamental material and AEEM 603 and EGFD 615:

- Kinematics and curvilinear coordinate systems.
- Fundamentals of rigid body motion, including Euler angles and Euler’s equations, moment-free motion, and applications to such problems as rolling hoops and gyroscopic instruments.
- Lagrange’s equations and Gibbs-Appell equations, quasicoordinates, and stabilization methods.
- Transfer functions and block diagrams to represent control system behavior.
- Responses of linear dynamical systems and performance specifications.
- Nyquist stability criterion.
- Graphical methods for control system analysis and design, including root locus and Bode techniques.
- Basic compensator design, including lead-lag and PID.
- State space representation of dynamical systems and transformations to alternate forms, including Jordan canonical form (modal decomposition).
- State transition matrix for solving for the response of a state space representation.
- Controllability and observability of state space models.
- State feedback for altering the closed loop behavior of state space systems.
- State observers
In addition to the basic topic areas listed above, Dynamics and Orbital Mechanics students must have a working knowledge of the following topics:

- Mathematics of rotations (quaternions).
- Advanced rigid-body mechanics.
- Orbital 2-body problem, Kepler’s equation, orbital elements, impulsive orbit transfers, rendezvous equations.
- Euler and Lagrange equations for the dynamics of spacecraft, gravity gradient problem, momentum wheels, attitude control devices and dynamics.

In addition to the basic topic areas listed above, Controls students must have a working knowledge of the following topics:

- Lyapunov stability theory.
- Discrete time system dynamics and their relationship to continuous system dynamics.
- Singular value robustness concepts for MIMO systems.