Controls/Robotics/Mechatronics MS Course Recommendations

Starting 2012	Autumn (E)	Winter (O)	Spring (O)	Autumn (O)	Winter (E)	Spring (E)
Required Courses						
Mechanical Eng. Analysis I	ME564					
Mechanical Eng. Analysis II		ME565				
Mathematical Foundations						
Math. Foundations of Sys.	ME510			ME510		
Manifold and Geometry					ME570 (E)	
Geometric Methods						ME580(E)
Applied Linear Algebra				Amath584		
Applied Prob. & Statistics						Amath506
Mechatronics, Controls and Robotics						
Linear Systems Theory	ME547					
Linear Multivariable Cont.		ME548				
Estimation and Sys. Id.			ME549			
Digital Control		ME581			ME581	
Nonlinear Control Systems			ME583(O)			
Robust Control			ME594(O)			
Feedforward Control						ME593(E)
Nonlinear Optimal Control				ME550(O)		
Optimization in Systems		ME578			ME578	
Intro. Discrete Event Sys.						ME582(E)
Syst. ID & Adaptive Control						ME585(E)
Models of Robot Manipulation		ME543(O)				
Networked Dynamic Systems						ME597(E)
Dynamics						
Dynamics and Vibrations	ME588			ME588		
Vibrations					ME589(E)	
Principles of Dynamics	AA571			AA571		
Flight Controls						
Stability/Control: Flight Vehicles	AA516			AA516		
Aut. Control of Flight Vehicles			AA518(O)			
Spacecraft Dyn. & Control		AA528			AA528	
Undergraduate Courses						
Automatic Control	ME471			ME471		
Instrumentation	ME473			ME473		
Embedded Computing		ME477			ME477	
Dynamics	ME469			ME469		
Electric Circuits Laboratory I		Phys344			Phys 334	
Electric Circuits Laboratory II			Phys 335			Phys 335

(O) Stands for odd year offerings, (E) for even year.
A suggested sequence is highlighted in yellow. Discuss with Faculty Advisor about alternate sequences.
Consider taking ME520 Seminar or research credits (as needed).
ME543 can be considered instead of ME581 in winter of first year
If controls background is not strong, take ME471 instead of ME510 in first year

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Consider taking ME520 Seminar or research credits (as needed).
ME589 can be considered instead of ME581 in winter of first year
If controls background is not strong, take ME471 instead of ME510 in first year

Recommended Courses for
Mechanical Engineering Graduate Students
focusing on Control, Mechatronics, or Robotics

General Comments

A list of recommended courses for Mechanical Engineering graduate students whose interests focus on one or more of control systems, mechatronics, and robotics follows. There is a huge variety of courses in this list, including some application-focused courses (e.g., ME 477) and many theory-focused courses (e.g., ME 510).

Subject to your background and interests, the arguably "core" undergraduate courses from this list include ME 469, ME 471, ME 473, and ME 477. At the graduate level, the albeit unofficial core courses include ME 588 and ME 547, along with ME 564 and ME 565.

Applied Mathematics

ME 535 Computational Techniques in Mechanical Engineering (3) Emery
Advanced heat transfer studies of interest to mechanical engineers. Subject coverage varies from year to year. Prerequisite: permission of instructor. Offered: Sp.

AMATH 506 Applied Probability and Statistics (4)
Discrete and continuous random variables, independence and conditional probability, central limit theorem, elementary statistical estimation and inference, linear regression. Emphasis on physical applications. Prerequisite: some advanced calculus and linear algebra. Offered: jointly with STAT 506; Sp.

AMATH 584 Applied Linear Algebra and Introductory Numerical Analysis (5)
Numerical methods for solving linear systems of equations, linear least squares problems, matrix eigenvalue problems, nonlinear systems of equations, interpolation, quadrature, and initial value ordinary differential equations. Offered: jointly with MATH 584; A.

ME 564 Mechanical Engineering Analysis (3) Storti
Application of mathematical methods to the description and analysis of systems in mechanical engineering. Analogies in heat transfer, fluid flow, stress distribution, dynamics, and feedback control. Prerequisite: graduate standing in mechanical engineering or permission of instructor. Offered: A.

ME 565 Mechanical Engineering Analysis (3) Storti
Applications of vectors, matrices, and partial differential equations to mechanical engineering systems, including computational techniques and analogies. Prerequisite: graduate standing in mechanical engineering or permission of instructor. Offered: W.

ME 510 Mathematical Foundations of Systems Theory (4) Damborg
Mathematical foundations for system theory presented from an engineering viewpoint. Includes set theory; functions, inverse functions; metric spaces; finite dimensional linear spaces; linear operators on finite dimensional spaces; projections on Hilbert spaces. Applications to engineering systems stressed. Prerequisite: graduate standing or permission of instructor. Offered: jointly with AA 546/CHEME 510/EE 510; A.

ME 547 Linear Systems Theory (4)
Linearity, linearization, finite dimensionality, time-varying vs. time-invariant linear systems, interconnection of linear systems, functional/structural descriptions of linear systems, system zeros and invertibility, linear system stability, system norms, state transition, matrix exponentials, controllability and observability, realization theory. Recommended: either AA 447, EE 447 or ME 471. Offered: jointly with EE 547/AA 547; A

ME 570 Manifolds and Geometry for Systems and Control (3) Morgansen
Introduction to fundamentals of calculus on manifolds and group theory with applications in robotics and control theory. Topics include: manifolds, tangent spaces and bundles, Lie groups and algebras, coordinate versus coordinate-free representations. Applications from physics, robotics, and control theory. Offered: jointly with AA 570 and EE 570; W, even years.

ME 578 Optimization in System Sciences (3) Mesbahi
Covers convex sets, separation theorems, theorem of alternatives and their applications, convex analysis, convex functions, conjugation, subgradients, convex optimization, duality and applications, linear and semi-definite programming. Linear matrix inequalities, optimization algorithms, applications in system theory and control, bilinear, rank minimization, optimization software. Recommended: AA 547/ME 547/EE 547. Offered: jointly with AA 578/EE 578; W.

Dynamics

ME 469 Applications of Dynamics in Engineering (4) Storti
Application of the principles of dynamics to selected engineering problems, such as suspension systems, gyroscopes, electromechanical devices. Includes introduction to energy methods, Hamilton' s principle and Lagrange equations, and the design of dynamic system. Prerequisite: ME 374. Offered: A.

ME 588 Dynamics and Vibrations (3) Shen
Variational techniques, Hamilton' s principle, Lagrange' s equations applied to dynamics of particles and rigid bodies. Vibration analysis of multi-degree-of-freedom and continuous systems. Prerequisite: graduate standing in engineering or permission of instructor. Offered: A.

ME 589 Vibrations (3) Storti
Study of systems with nonlinear damping and restoring forces excited by deterministic or random inputs. Applications in measurement, testing, and design of mechanical systems. Nonlinear systems are emphasized. Prerequisite: ME 588 or permission of instructor. Offered: W, even years.

AA 571 Principles of Dynamics I (3)
Systems of particles, rotating axes, rigid-body dynamics; calculus of variations. Lagrangian mechanics. Hamilton's principle. Kane' s equations. Periodic and quasi-periodic motion. Stability of dynamical systems. Offered: A.

Instrumentation

ME 473 Instrumentation (4) Garbini
Principles and practice of industrial and laboratory measurement. Dynamics of instrument response; generalized performance analysis of sensor systems; theory of transducers for motion, force, pressure, flow, and other measurements. Lecture and laboratory. Prerequisite: ME 374. Offered: A.

Embedded Computing

ME 477 Embedded Computing in Mechanical Systems (4) Garbini
Analysis of electromechanical systems employing microcomputers for control or data acquisition. Microcomputer architecture, memory organization, C language programming, interfaces, and communications. Particular emphasis on design of hardware and software interfaces for real-time interaction with mechanical systems. Weekly laboratory. Prerequisite: ME 374. Offered: W.

Estimation and System Identification

ME 549 Estimation and System Identification (3)
Fundamentals of state estimation for linear and nonlinear systems. Discrete and continuous systems. Probability and stochastic systems theory. Models with noise. Kalman-Bucy filters, extended Kalman filters, recursive estimation. Numerical issues in filter design and implementation. Prerequisite: either AA 547, EE 547, or ME 547. Offered: jointly with AA 549/EE 549; Sp, odd years.

Control

ME 471 Automatic Control (4) Berg
Dynamic system modeling; control system stability and performance analysis; compensator design by Bode and root-locus methods. Prerequisite: ME 374. Offered: A.

ME 548 Linear Multivariable Control (3)
Introduction to MIMO systems, successive single loop design comparison, Lyapunov stability theorem, full state feedback controller design, observer design, LQR problem statement, design, stability analysis, and tracking design. LQG design, separation principle, stability robustness. Prerequisite: AA 547/EE 547/ME 547. Offered: jointly with AA 548/EE 548; W.

ME 550 Nonlinear Optimal Control (3)
Calculus of variations for dynamical systems, definition of the dynamic optimization problem, constraints and Lagrange multipliers, the Pontryagin Maximum Principle, necessary conditions for optimality, the Hamilton-Jacobi-Bellman equation, singular arc problems, computational techniques for solution of the necessary conditions. Prerequisite: graduate standing; recommended: AA 548 or EE 548. Offered: jointly with AA 550/EE 550; A, odd years.

ME 580 Geometric Methods for Non-Linear Control Systems (3) Morgansen
Analysis and design of nonlinear control systems focusing on differential geometric methods. Topics include controllability, observability, feedback linearization, invariant distributions, and local coordinate transformations. Emphasis on systems evolving on Lie groups and linearly uncontrollable systems Prerequisite: AA 570/EE 570/ME 570. Offered: jointly with AA 580/EE 580; Sp, even years.

ME 581 Digital Control (3) Chizeck
Sampled-data systems, and z-transform. Frequency domain properties. Sampling D/A and A/D conversion. Controller design via discrete-time equivalents, direct methods, state feedback and observers. Quantization effects. LQR control and introduction to LQG optimal control. Prerequisite: EE 548/AA 548/ ME 548. Offered: jointly with AA 581/EE 581; W. [Last offered 2009]

ME 582 Introduction to Discrete Event Systems (3) Berg
Modeling DES with automata and Petri nets. Languages. State estimation and diagnostics. Control specifications. Feedback control. Dealing with uncontrollability and unobservability. Dealing with blocking. Timed automata and Petri nets. Prerequisite: AA 447/EE 447/ ME 471. Offered: jointly with AA 582/EE 582; Sp, even years.

ME 583 Nonlinear Control Systems (3) Berg
Analysis of nonlinear systems and nonlinear control system design. Phase plane analysis. Lyapunov stability analysis. Describing functions. Feedback linearization. Introduction to variable structure control. Prerequisite: AA 447/EE 447/ME 471. Offered: jointly with EE 583/AA 583; Sp, odd years.

ME 585 System Identification and Adaptive Control (3)
Theory and methods of system identification and adaptive control. Identification of linear-in-parameter systems, using recursive LS and extended LS methods; model order selection. Indirect and direct adaptive control. Controller synthesis, transient and stability properties. Recommended: either AA 547, EE 547, or ME 547. Offered: jointly with ME 585/EE 585; Sp, even years.

ME 593 Feedforward Control (3) Devasia
Design feedforward controllers for precision output tracking; inversion-based control of non-minimum-phase systems; effect of plant uncertainty on feedforward control; design of feedforward controllers for applications such as vertical take off and landing aircraft, flexible structures and piezo-actuators. Prerequisite: AA 547/EE 547/ME 547. Offered: jointly with AA 593/ EE 593; Sp, even years.

ME 594 Robust Control (3)
Basic foundations of linear analysis and control theory, model realization and reduction, balanced realization and truncation, stabilization problem, coprime factorizations, Youla parameterization, matrix inequalities, H-infinity and H2 control, KYP lemma, uncertain systems, robust H2, integral quadratic constraints, linear parameter varying synthesis, applications of robust control. Prerequisite: AA 547/EE 547/ME 547. Offered: jointly with AA 594/EE 594; Sp, odd years.

AA 516 Stability and Control of Flight Vehicles (3)
Static and dynamic stability and control of flight vehicles in the atmosphere. Determination of stability derivatives. Effects of stability derivatives on flight characteristics. Flight dynamic model. Responses to control inputs and external disturbances. Handling qualities. Control system components, sensor characteristics. Stability augmentation systems. Offered: A.

AA 518 Automatic Control of Flight Vehicles (3)
Specifications of flight vehicle performance. Synthesis of stability augmentation systems and autopilot control laws in the frequency-domain and using multivariable control methods. Reduced-order controller synthesis, digital design, and implementation. Use of computer-aided control design packages. Prerequisite: AA 516 and AA 548. Offered: Sp, odd years. [Last offered in 2007]

AA 528 Spacecraft Dynamics and Control (3)
Examines spacecraft dynamics and control. Includes basic orbital mechanics - the restricted three body problem, Hill' s theory, perturbation theory, orbit determination, rigid body kinematics and dynamics, attitude control, and spacecraft formation flying. Prerequisite: MATH 307; MATH 308. Offered: W, odd years.

<u>Robotics</u>

EE 543 Models of Robot Manipulation (3)
Mathematical models of arbitrary articulated robotic (or biological) arms and their application to realistic arms and tasks, including the homogeneous coordinate model of positioning tasks, the forward and inverse kinematic models, the Jacobian Matrix, and the recursive Newton-Euler dynamic model. Prerequisite: linear algebra and graduate standing or permission of instructor. Offered: W, odd years.