# Automotive Engineering Advising Document – *FALL 2013 entry or earlier*

## Master of Engineering in Automotive Engineering

| CURRICULUM | Semester Credit |
|---|---|
| Systems Engineering Core | 9 |
| Engineering Electives | 9 |
| Management and Human Factors | 6 |
| Automotive Engineering Seminar and Capstone Project | 6 |
| **TOTAL PROGRAM:** | **30** |

The M. Eng. Degree in Automotive Engineering requires a total of 30 credits—27 of which must be letter (A-E) graded. A minimum grade point average of 5.0/9.0 ("B" average) is required for graduation. Of the 30 credit hours, 24 must be 500 level or above. At most, 6 credit hours can be at the 400-level.

### SYSTEMS ENGINEERING CORE (9 credits)

Courses must be taken in each area.

**1. Powertrain**

| | | |
|---|---|---|
| AUTO 563 | Dynamics and Controls of Automatic Transmissions | 3 |
| MECHENG 438 | Internal Combustion Engines **OR** | 4 |
| MECHENG 538 | Advanced Internal Combustion Engines | 3 |

**2. Vehicle Dynamics**

| | | |
|---|---|---|
| AUTO/MECHENG 513 | Automotive Body Structures | 3 |
| MECHENG 458 | Automotive Engineering **OR** | 3 |
| MECHENG 542 | Vehicle Dynamics | 3 |

### ENGINEERING ELECTIVES (9 credits)

At least 6 credits must come from a selected specialty. An additional 3 credits may come from the selected specialty or any other specialty to create a cohesive, job-related plan of study.

**1. Design and Manufacturing**

| | | |
|---|---|---|
| AUTO 512 | Lean Program Engineering | 3 |
| AUTO/MFG 599B SpecTopic | Designing in Quality | 3 |
| EECS 569 | Production Systems Engineering | 3 |
| MECHENG 452 | Design for Manufacturability | 3 |
| MECHENG 567 | Introduction to Robotics | 3 |
| MECHENG 581 | Global Product Development | 3 |
| MECHENG 586 | Laser Materials Processing | 3 |
| MECHENG 587 | Global Manufacturing | 3 |
| MECHENG 588 | Assembly Modeling for Design and Manufacturing | 3 |
| MECHENG 589 | Ecological Sustainability in Design and Manufacturing | 3 |

**2. Energy and the Environment**

| | | |
|---|---|---|
| AUTO 533 | Advanced Energy Solutions | 3 |
| CEE 567 | Energy Infrastructure Systems | 3 |
| ESENG 501 | Seminars on Energy Systems, Technology and Policy | 3 |
| ESENG 505 | Energy Generation and Storage Using Modern Materials | 3 |
| MECHENG 432 | Combustion **OR** | **3** |
| MECHENG 537 | Advanced Combustion **OR** | 3 |
| AEROSP 533 | Combustion Processes | 3 |
| MECHENG 589 | Ecological Sustainability in Design and Manufacturing | 3 |

**3. Materials**

| | | |
|---|---|---|
| MATSCI 420 | Mechanical Behavior of Materials | 3 |
| MATSCI 514 | Composite Materials | 3 |
| MECHENG 517 | Mechanics of Polymers I | 3 |
| MECHENG 552 | Mechatronic Systems Design | 3 |
| MECHENG 553 | Microelectromechanical Systems | 3 |
| MECHENG 571 | Energy Generation and Storage Using Modern Materials | 3 |

**4. Noise, Vibration and Harshness**

| | | |
|---|---|---|
| MECHENG 440 | Intermediate Dynamics and Vibrations **OR** | 4 |
| MECHENG 540 | Intermediate Dynamics | 3 |
| MECHENG 524 | Advanced Engineering Acoustics | 3 |
| MECHENG 541 | Mechanical Vibrations | 3 |

**5. Powertrain**

| | | |
|---|---|---|
| AUTO 599 Spec Topic | Analysis and Control of Alternative Powertrains **OR** | 3 |
| MECHENG 566 | Modeling, Analysis and Control of Hybrid Electric Vehicles | 3 |
| CHE 696 | Fuel Cells and Fuel Processors | 3 |
| MECHENG 432 | Combustion **OR** | **3** |
| MECHENG 537 | Advanced Combustion **OR** | 3 |
| AEROSP 533 | Combustion Processes | 3 |

**6. Dynamics and Control**

| | | |
|---|---|---|
| AUTO 563 | Dynamics and Controls of Automatic Transmissions | 3 |
| MECHENG 440 | Intermediate Dynamics and Vibrations **OR** | 4 |
| MECHENG 540 | Intermediate Dynamics | 3 |
| MECHENG 461 | Automatic Control | 3 |
| MECHENG 542 | Vehicle Dynamics | 3 |
| MECHENG 560 | Modeling Dynamic Systems | 3 |
| MECHENG 564 | Linear Systems Theory (AERO 550/EECS 560) | 4 |
| MECHENG 568 | Vehicle Control Systems | 3 |
| MECHENG 569 | Control of Advanced Powertrain Systems | 3 |

**7. Electronics and Computer Software**

| | | |
|---|---|---|
| EECS 414 | Introduction to MEMS | 4 |
| EECS 515 | Integrated Microsystems | 3 |
| EECS 455 | Digital Communication Signals and Systems | 4 |
| EECS 552 | Fiber Optical Communications | *3* |
| MECHENG 552 | Mechatronic Systems Design | 3 |
| MECHENG 553 | Microelectromechanical Systems | 3 |

## MANAGEMENT and HUMAN FACTORS (6 credits)

Two courses must be taken in the Management and Human Factors core. (Business and Management, Ergonomics and Human Factors, Law and Professional Ethics, Operations Research, etc.)

| | | |
|---|---|---|
| AUTO 512 | Lean Program Engineering | 3 |
| ENGR 521 | Clean Tech Entrepreneurship *(Prerequisite: ENGR 520)* | 3 |
| ES 615 | New Venture Creation *(Prerequisite: Completion of MBA Core)* | 3 |
| ES 715 | Innovative New Business Design | 3 |
| IOE/MFG 440 | Operations Analysis & Management | 3 |
| IOE 434 | Human Error and Complex Systems | 3 |
| IOE 452/MFG 455 | Corporate Finance | 3 |
| IOE 453/456 | Derivative Instruments | 3 |
| IOE 461 | Quality Engineering Principles and Analysis | 3 |
| IOE 533/MFG 535 | Human Motor Behavior and Engineering Systems | 3 |
| IOE/MFG 543 | Scheduling | 3 |
| MECHENG 646 | Mechanics of Human Movement | 3 |
| MO 501 | Human Behavior and Organization | 3 |
| MKT 625 | New Product and Innovative Mgmt | 3 |
| NRE 559 | International Environmental Policy and Law | 3 |
| NRE 560 | Behavior & Environment | 3 |
| NRE 565 | Principles for Sustainability | 3 |
| NRE 571/ECON 471 | Environmental Economics | 3 |
| SI 519/PubPol 688 | Intellectual Property & Information Law | 3 |

Other courses offered by the Center for Entrepreneurship and The University of Michigan School of Business may qualify. A course description and syllabus must be submitted for prior approval of credit toward the Management and Human Factors requirement.

## AUTOMOTIVE ENGINEERING SEMINAR and CAPSTONE PROJECT (6 credits)

| | | |
|---|---|---|
| AUTO 501 (required) | Integrated Vehicle Systems Design | 3 |
| (should be taken within the first year of the program) | | |
| AUTO 503 (required) | Automotive Engineering Project | 3 |
| (must have a minimum of 15 credits completed toward the degree) | | |

## Master of Engineering in Automotive Engineering

### Curriculum and Courses

The M. Eng. Degree in Automotive Engineering requires a total of 30 credits - - 27 of which must be letter (A-E) graded. A minimum grade point average of 5.0/9.0 ("B" average) is required for graduation. Of the 30 credit hours, 24 must be 500 level or above. At most, 6 credit hours can be at the 400-level.

**Systems Engineering Core (9 credits)**
Courses must be taken in the area of Powertrain and Vehicle Dynamics

**Engineering Electives (9 credits)**
A minimum 6 credits must come from a selected specialty. An additional 3 credits may come from the selected specialty or any other specialty to create a cohesive, job-related plan of study.

**Management and Human Factors (6 credits)**
Two courses must be taken in the Management and Human Factors Core.(Business and Management, Ergonomics and Human Factors, Law and Professional Ethics, Operations Research, etc.)

**Automotive Engineering Seminar and Capstone Project (6 credits)**
AUTO 501 Integrated Vehicle Systems Design is a required course and should be taken within the first year.
AUTO 503 Automotive Engineering Project is required. Students must have a minimum of 15 credits completed toward the degree before registering.

| Designation of Course Term Offerings |
|---|
| I = Fall<br>II = Winter<br>III = Spring/Summer<br>IIIa = Spring<br>IIIb = Summer |
| Term offerings subject to change |

## COURSE DESRIPTIONS

**An asterisk ( * ) indicates that this course may be offered periodically through distance learning.**

**AEROSP 533. Combustion Processes**
*Prerequisite: AEROSP 225. I (3 credits)*
This course covers the fundamentals of combustion systems, and fire and explosion phenomena. Topics covered include thermochemistry, chemical kinetics, laminar flame propagation, detonations and explosions, flammability and ignition, spray combustion, and the use of computer techniques in combustion problems.

**AUTO 501. Integrated Vehicle Systems Design***
*Prerequisite: Graduate standing or permission of instructor. I (3 credits)*
This course is intended to examine the process by which a first layout is developed for a new vehicle platform. The course will focus on the layout of the major space-defining vehicle subsystems required to arrive at a preliminary vehicle package drawing. The process followed will be based on systems engineering: requirements-to-design concepts -to- performance prediction -to- comparison to requirements -to- iteration.

**AUTO 503. Automotive Engineering Project***
*Prerequisites: AUTO 501 and 15 credits minimum completed toward the degree. I, II, III (3 credits)*
As an essential component of the Master of Engineering in the Automotive Engineering degree program, students are required to participate in a sponsored project in automotive engineering. The intent of this project course is to provide students with a capstone project experience where they can apply the knowledge and skills acquired through the Automotive Engineering degree program to relevant automotive engineering problems. Each project must have a clearly defined problem or need; must show a solution methodology; and must be value-added to the sponsor.

**AUTO 512. Lean Program Engineering***
*Prerequisite: Graduate standing or permission of the instructor. II (3 credits)*
Lean Program Engineering provides an opportunity to acquire and demonstrate mastery of critical lean product design engineering disciplines within the context of an automotive vehicle program team. The course identifies and integrates

engineering skills, tools and processes required for successful automotive vehicle project planning and completion consistent with lean product development principles.

**AUTO 513. Automotive Body Structures***
*(cross-listed with MECHENG 513, MFG 513) Prerequisite: MECHENG 311. I (3 credits)*
Emphasis is on body concept for design using first order modeling of thin walled structural elements. Practical application of solid/structural mechanics is considered to design automotive bodies for global bending, torsion, vibration, crashworthiness, topology, material selection, packaging, and manufacturing constraints.

**AUTO 533. Advanced Energy Solutions***
*(cross-listed with MECHENG 433) Prerequisite: MECHENG 235. I (3 credits)*
Introduction to the challenges of power generation for a global society using the thermodynamics to understand basic principles and technology limitations. Covers current and future demands for energy; methods of power generation including fossil fuel, solar, wind and nuclear; associated detrimental by-products; and advanced strategies to improve power densities, efficiencies and emissions.

**AUTO 563. Dynamics and Controls of Automatic Transmissions***
*Prerequisite: Graduate standing or permission of instructor. II (3 credits)*
Automatic transmission is a key element of automotive vehicles for improved driving comfort. This course will introduce the mechanisms, design and control of modern transmission systems. The emphasis will be on the dynamic analysis, and the application of modern control theories for the overall control design, analysis and synthesis problems.

**AUTO 599. Designing in Quality***
*II (3 credits)*
As organizations improve their operational quality, they recognize the need to apply more systematic analytical techniques to design quality into their products and services. This course provides methods and analysis tools for preventing quality and warranty concerns. This course focuses on the Design for Six Sigma Quality methodology: IDDOV. Using the IDDOV framework, this course examines tools and methods for identifying customer requirements, evaluating design concepts, and optimizing processes to meet quality objectives. The course integrates several tools from Voice of the Customer Analysis, Transfer Functions, Failure Mode Effects Analysis, TRIZ, DFX Analysis, Experimental Design, Taguchi Methods, Response Surface Methodology, Design for Reliability, and Tolerance Simulation and Analysis.

**CEE 567. Energy Infrastructure Systems***
*Prerequisite: Senior standing. II (3 credits)*
Technologies and economics of electric power generation, transmission, and distribution are discussed. Centralized versus distributed generation, and fossil fuels versus renewable resources, are considered in regard to engineering, market and regulatory principles. Students develop an understanding of energy challenges confronting society and investigate technologies that seek to address future needs.

**ChE 696. Fuel Cells and Fuel Processors***
*Prerequisite: Background in reaction engineering, thermodynamics, and transport phenomena. I (3 credits)*
The course is aimed at students interested in the fundamental science and engineering of fuel cells and fuel processors. The course covers the fundamentals of electrochemistry relevant for fuel cells, and the basics of fuel cell technology. Emphasis will be placed or fuel cells for automotive applications, and on solid oxide fuel cells for auxiliary power units. Concepts in catalysis for fuel reforming, w gas shift, and preferential oxidation of hydrocarbons will be covered, along with hydrogen storage and hydrogen safety.

**EECS 414. Introduction to MEMS***
*Prerequisite: MATH 215, MATH 216, and PHYSICS 240 or Graduate standing. I (4 credits)*
Micro electro mechanical systems (MEMS), devices, and technologies. Micro-machining and microfabrication techniques, including planar thin-film processing, silicon etching, wafer bonding, photolithography, deposition, and etching. Transduction mechanisms and modeling in different energy domains. Analysis of micromachined capacitive, piezoresistive, and thermal sensors/actuators and applications. Computer-aided design for MEMS layout, fabrication, and analysis.

**EECS 455. Digital Communication Signals and Systems**
*Prerequisites: EECS 216 or EECS 306, and EECS 401 or Graduate standing. I (4 credits)*
Digital transmission techniques in data communications, with application to computer and space communications; design and detection of digital signals for low error rate; forward and feedback transmission techniques; matched filters; modems, block and convolutional coding; Viterbi decoding. Discussion on Discrete-time LTI systems, Discrete-time Fourier Transforms (DTFT) along with homework problems.

**EECS 515. Integrated Microsystems***
*Prerequisite: EECS 414. I (4 credits)*
Review of interface electronics for sense and drive and their influence on device performance, interface standards, MEMS and circuit noise sources, packaging and assembly techniques, testing and calibration approaches, and communication in

integrated microsystems. Applications, including RF MEMS, optical MEMS, bioMEMS, and microfluidics. Design project using CAD and report preparation.

**EECS 552. Fiber Optical Communications**
*(cross-listed with APPPHYS 552) Prerequisite: EECS 434 or EECS 538 or permission of instructor. II (3 credits)*
Principles of fiber optical communications and networks. Point-to-point sys-tems and shared medium networks. Fiber propagation including attenuation, dispersion and nonlinearities. Topics covered include erbium-doped amplifiers, Bragg and long period gratings, fiber transmission based on solitons and non-return-to-zero, and time- and wavelength-division-multiplexed networks.

**EECS 569. Production Systems Engineering***
*II Alternate Years (3 credits)*
Production systems in large volume manufacturing (e.g., automotive, semiconductor, computer, etc.) are studied. Topics include quantitative methods for analysis of production systems; analytical methods for design of lean in-process and finished goods buffering; measurement-based methods for identification and elimination of production system bottlenecks; and system-theoretic properties of production lines.

**ENGR 521. Clean Tech Entrepreneurship**
*Prerequisite: Senior or Graduate standing. II (3 credits)*
This course teaches the students how to screen venture opportunities in various cleantech domains. Venture assessments are approached through strategic, financial and market screens, and consider the impact of policy and regulatory constraints on the business opportunity. A midterm, final project, and six homework assignments are required.

**ES 615. New Venture Creation**
*Prerequisite: Completion of MBA Core. I or II (3 credits)*
This course focuses on the preparation of the business plan for new ventures. Competitive positions, marketing policies, research surveys, production methods, financial projections and organizational assignments all have to be included in this document. The course is taught both through the case method and through team projects involving 4-6 students working on a business development project for the entire term. The business plan project requires a substantial amount of research, team and faculty meetings, detailed and carefully constructed deliverables, and the final delivery of a full business plan.

**ES 715. Innovative New Business Design**
*Prerequisites: Graduate student in the RSOB or COE. II (3 credits)*
This synthesis-focused, project-based course integrates elements of various business school and engineering courses into a high-level process for determining how to capture value from an innovation source—specifically a new technology. Designing a new business from an innovation source is the first step in creating a new business from a technological discovery. This course is focused on the design of the business: formulating a sound, detailed, market-driven, value-capturing business concept from a new technology. In this course the product offering (including its sustainable differentiation), a specific target market, and the company's core business model will all be specifically defined.

**ESENG 501. Seminars on Energy Systems, Technology and Policy***
*Prerequisite: Graduate standing or permission of instructor. I (3 credits)*
Leaders in policy and energy systems engineering discuss cutting-edge technologies and critical barriers in their disciplines. Speakers range from research leaders, to business leaders, to policy makers. The aim of the seminar series is to provide a view at multiple scales of challenges in developing and implementing new energy technologies. Industrial, governmental, and research perspectives will be given on promising technologies and policies that will shape our energy portfolio and its environmental consequences, in the decades to come. The need to create sustainable energy systems is a common theme, and the speakers will offer their own perspectives on how policy and technology can be effective in doing so. A portion of each lecture will be devoted to discussion.

**ESENG 505. Energy Generation and Storage Using Modern Materials***
*Prerequisites: MECHENG 382 and MECHENG 335 or equivalents. I or II (3 credits)*
Energy and power densities previously unattainable in environmentally-friendly energy technologies have been achieved through use of novel materials. Insertion of new materials into power supplies has changed the landscape of options. Design strategies for power systems are described, in the context of growing global demand for power and energy.

**IOE 434. Human Error and Complex Systems**
*Prerequisite: IOE 333 or IOE 536 or permission of instructor. II (3 credits)*
The course covers a wide range of factors contributing to system failures: human perceptual and cognitive abilities and limitations, the design of modern technologies and interfaces, and biases in accident investigation and error analysis. Recent concepts in the area of high reliability organizations and resilience engineering are reviewed. Students perform systems analysis of actual mishaps and disasters in various domains, including various modes of transportation, process control, and health care.

**IOE 440. Operations Analysis & Management**
*(cross-listed with MFG 440) Prerequisites: IOE 310 and 316 or Graduate standing, and no credit in OMS 605. I (3 credits)*
Principles and models for analyzing, engineering, and managing manufacturing and service operations as well as supply chains. Emphasis on capacity management; queueing models of operational dynamics (including cycle time, work-in-progress, inventory, throughput, and variability); operational flexibility; the math and physics of lean enterprises.

**IOE 452. Corporate Finance**
*(cross-listed with MFG 455) Prerequisites: IOE 201, IOE 310, IOE 366. I (3 credits)*
The goal of this course is to introduce a basic understanding of financial management. The course develops fundamental models of valuation and investment from first principles and applies them to problems of corporate and individual decision-making. The topics of discussion will include the net present valuation, optimal portfolio selection, risk and investment analysis, issuing securities, capital structure with debt financing, and real options.

**IOE 453. Derivative Instruments**
*(cross- listed with MFG 456) Prerequisite: IOE 201, IOE 310, IOE 366. Credit not granted for both IOE 453/MFG 456 and MATH 423. II (3 credits)*
The main objectives of the course are first, to provide the students with a thorough understanding of the theory of pricing derivatives in the absence of arbitrage, and second, to develop the mathematical and numerical tools necessary to calculate derivative security prices. We begin by exploring the implications of the absence of static arbitrage. We study, for instance, forward and futures contracts. We proceed to develop the implications of no arbitrage in dynamic trading models: the binomial and Black-Scholes models. The theory is applied to hedging and risk management.

**IOE 461. Quality Engineering Principles and Analysis***
*Prerequisite: IOE 366. I (3 credits)*
This course provides students with the analytical and management tools necessary to solve manufacturing quality problems and implement effective quality systems. Topics include voice of the customer analysis, the Six Sigma problem solving methodology, process capability analysis, measurement system analysis, design of experiments, statistical process control, failure mode and effects analysis, quality function deployment, and reliability analysis.

**IOE 533. Human Motor Behavior and Engineering Systems**
*(cross-listed with MFG 535) Prerequisite: IOE 333 and IOE 366. I (3 credits)*
This course is designed to provide a basic perspective of the major processes of human motor behavior. Emphasis will be placed on understanding motor control and man-(machine)-environment interaction. Information processing will be presented and linked to motor behavior. Application of theories to the design of the workplace, controls and tools will be underlined and illustrated by substantial examples.

**IOE 543. Scheduling**
*(cross-listed with MFG 543) Prerequisites: IOE 316, IOE 310. II (3 credits)*
The problem of scheduling several tasks over time, including the topics of measures of performance, single-machine sequencing, flow shop scheduling, the job shop problem, and priority dispatching. Integer programming, dynamic programming, and heuristic approaches to various problems are presented.

**MATSCI 420. Mechanical Behavior of Materials**
*I (3 credits)*
Macroscopic and microscopic aspects of deformation and fracture. Plasticity, general continuum approach. Microscopic hardening mechanisms. Rate and temperature dependent deformation. Deformation and fracture mechanism maps. Fracture mechanics. Fatigue behavior.

**MATSCI 514. Composite Materials***
*(cross-listed with MFG 514) Prerequisite: MATSCI 350. II (3 credits)*
Behavior, processing, and design of composite materials, especially fiber composites. Emphasis is on the chemical and physical processes currently employed and expected to guide the future development of the technology.

**MECHENG 432. Combustion**
*Prerequisites: MECHENG 336 preceded or accompanied by MECHENG 320. I (3 credits)*
Introduction to combustion processes; combustion thermodynamics, reaction kinetics, and combustion transport. Chain reactions, ignition, quenching, and flammability limits. Detonations, deflagrations, and flame stability. Introduction to turbulent premixed combustion. Applications in IC engines, furnaces, gas turbines, and rocket engines.

**MECHENG 438. Internal Combustion Engines***
*Prerequisites: MECHENG 235, MECHENG 336 advised. I (4 credits)*

Analytical approach to the engineering problem and performance analysis of internal combustion engines. Study of thermodynamics, combustion, heat transfer, friction, and other factors affecting engine power, efficiency, and emissions. Design and operating characteristics of different types of engines. Computer assignments. Engine laboratories.

**MECHENG 440. Intermediate Dynamics and Vibrations**
*Prerequisite: MECHENG 240. I (4 credits)*
Newton/Euler and Lagrangian formulations for three-dimensional motion of particles and rigid bodies. Linear free and forced responses of one and two degree of freedom systems and simple continuous systems. Applications to engineering systems involving vibration isolation, rotating imbalance and vibration absorption.

**MECHENG 452. Design for Manufacturability***
*(cross-listed with MFG 452) Prerequisite: MECHENG 350. I (3 credits)*
Conceptual design. Design for economical production, Taguchi methods, design for assembly, case studies. Product design using advanced polymeric materials and composites; part consolidation, snap-fit assemblies; novel applications. Design projects.

**MECHENG 458. Automotive Engineering***
*Prerequisite: MECHENG 350. I or II (3 credits)*
Emphasizes systems approach to automotive design. Specific topics include automotive structures, suspension steering, brakes, and driveline. Basic vehicle dynamics in the performance and handling modes are discussed. A semester team-based design project is required.

**MECHENG 461. Automatic Control**
*Prerequisites: MECHENG 360. I (3 credits)*
Feedback control design and analysis for linear dynamic systems with emphasis on mechanical engineering applications; transient and frequency response; stability; system performance; control modes; state space techniques; digital control systems.

**MECHENG 505. Finite Element Methods in Mechanical Engineering***
*Prerequisites: MECHENG 501, MECHENG 311 or MECHENG 320. I or II (3 credits)*
Theoretical and computational aspects of finite element methods. Examples from areas of thermal diffusion, potential/irrotational flows, lubrication, structural mechanics, design of machine components, linear elasticity, and Navier-Stokes flows problems. Program development and modification are expected as well as learning the use of existing codes.

**MECHENG 517. Mechanics of Polymers I**
*Prerequisites: MECHENG 511 or permission of instructor. I or II (3 credits)*
Constitutive equation for linear small strain viscoelastic response; constant rate and sinusoidal responses; time and frequency dependent material properties; energy dissipation; structural applications including axial loading, bending, torsion; three dimensional response, thermo-viscoelasticity, correspondence principle, Laplace transform and numerical solution methods.

**MECHENG 524. Advanced Engineering Acoustics**
*Prerequisites: MECHENG 424 or BIOMEDE 424. I or II (3 credits)*
Derivation of the acoustic wave equation and development of solution techniques. Transmission and reflection from solids, plates and impedance boundaries. Radiation and scattering from non-simple geometries. Green's functions; boundary element and finite element methods. Sound in ducts and enclosures. Introduction to structural-acoustic coupling. Automotive and other applications considered.

**MECHENG 537. Advanced Combustion**
*Prerequisites: MECHENG 432 or equivalent. II (3 credits)*
Advanced treatment of fundamental combustion processes. Conservation equations for reacting gas mixtures. The structure of one-dimensional diffusion and premixed flames; introduction to activation energy asymptotics. Two-dimensional Burke-Schumann flames and boundary layer combustion. Flame instabilities and flame stretch; turbulent combustion.

**MECHENG 538. Advanced Internal Combustion Engines***
*Prerequisite: MECHENG 438. II (3 credits)*
Modern analytical approach to the design and performance analysis of advanced internal combustion engines. Study of thermodynamics, fluid flow, combustion, heat transfer, and other factors affecting the design, operating and emissions characteristics of different engine types. Application of course techniques to engine research projects.

**MECHENG 540. Intermediate Dynamics**
*(cross-listed with AEROSP 540) Prerequisite: MECHENG 240. I (3 credits)*

Newton/Euler and Lagrangian formulations for three dimensional motion of particles and rigid bodies. Principles of dynamics applied to various rigid-body and multi-body dynamics problems that arise in aerospace and mechanical engineering.

**MECHENG 541. Mechanical Vibrations**
*Prerequisites: MECHENG 440. II (3 credits)*
Time and frequency domain mathematical techniques for linear system vibrations. Equations of motion of discrete non-conservative systems. Vibration of multi-degree-of-freedom systems. Small oscillation theory. Free vibration eigenvalue problem. Undamped system response. Viscously damped systems. Vibration of continuous systems. Modes of vibration of bars, beams, membranes, plates.

**MECHENG 542. Vehicle Dynamics***
*Prerequisite: MECHENG 440. II (3 credits)*
Dynamics of the motor vehicle. Static and dynamic properties of the pneumatic tire. Mechanical models of single and double-track vehicles enabling prediction of their response to control forces/moments and external disturbances. Directional response and stability in small disturbance maneuvers. The closed-loop driving process. Behavior of the motor vehicle in large perturbation maneuvers. Ride phenomena treated as a random process.

**MECHENG 552. Mechatronic Systems Design**
*(cross-listed with MFG 552) Prerequisites: MECHENG 350, MECHENG 360, EECS 314 or equivalent. I (3 credits)*
Mechatronics is the synergistic integration of mechanical disciplines, controls, electronics and computers in the design of high-performance systems. Case studies, hands-on lab exercises and hardware design projects cover the practical aspects of machine design, multi-domain systems modeling, sensors, actuators, drives circuits, simulation tools, DAQ, and controls implementation using microprocessors.

**MECHENG 553. Microelectromechanical Systems**
*(cross-listed with MFG 553) Prerequisites: Senior or Graduate standing. I or II (3 credits)*
Basic integrated circuit (IC) manufacturing processes; electronics devices fundamentals; microelectromechanical systems fabrications including surface micromachining, bulk micromachining, LIGA and others. Introduction to micro-actuators and microsensors such as micromotors, grippers, accelerometers and pressure sensors. Mechanical and electrical issues in micromachining. IC CAD tools to design microelectromechanical structures using MCNC MUMPs service. Design projects.

**MECHENG 560. Modeling Dynamic Systems**
*(cross-listed with MFG 562) Prerequisites: MECHENG 360. I or II (3 credits)*
A unified approach to the modeling, analysis and simulation of energetic dynamic systems. Emphasis on analytical and graphical descriptions of state-determined systems using Bond Graph language. Analysis using interactive computer simulation programs. Applications to the control and design of dynamic systems such as robots, machine tools and artificial limbs.

**MECHENG 564. Linear Systems Theory**
*(cross-listed with AERO 550, EECS 560) Prerequisite: Graduate standing. I (4 credits)*
Linear spaces and linear operators. Bases, subspaces, eigenvalues and eigenvectors, canonical forms. Linear differential and difference equations. Mathematical representations: state equations, transfer functions, impulse response, matrix fraction and polynomial descriptions. System-theoretic concepts: causality, controllability, observability, realizations, canonical decomposition, stability.

**MECHENG 567. Introduction to Robotics**
*(cross-listed with EECS 567, MFG 567) Prerequisites: Graduate standing or permission of instructor. II (3 credits)*
Introduction to the central topics in robotics, including geometry, kinematics, differential kinematics, dynamics, and control of robot manipulators. The mathematical tools required to describe spatial motion of a rigid body will be presented in full. Motion planning including obstacle avoidance is also covered.

**MECHENG 568. Vehicle Control Systems***
*Prerequisite: MECHENG 461 or equivalent. I (3 credits)*
Design and analysis of vehicle control systems such as cruise control, traction control, active suspensions and advanced vehicle control systems for Intelligent Vehicle-Highway Systems (IVHS). Human factor considerations such as driver interfaces. This course may be used as part of the IVHS certification program.

**MECHENG 569. Control of Advanced Powertrain Systems**
*Prerequisites: MECHENG 360; preceded or accompanied by MECHENG 461. I or II (3 credits)*
Will cover essential aspects of electronic engine control for spark ignition (gasoline) and compression ignition (diesel) engines followed by recent control developments for direct injection, camless actuation, active boosting technologies,

hybrid-electric, and fuel cell power generation. Will review system identification, averaging, feedforward, feedback, multivariable (multiple SISO and MIMO), estimation, dynamic programming, and optimal control techniques.

**MECHENG 571. Energy Generation and Storage Using Modern Materials**
*(cross-listed with ESENG 505) Prerequisites: MECHENG 382 and MECHENG 335 or equivalent. I or III (3 credits)*
Energy and power densities previously unattainable in environmentally-friendly energy technologies have been achieved through use of novel materials. Insertion of new materials into power supplies has changed the landscape of options. Design strategies for power systems are described, in the context of growing global demand for power and energy.

**MECHENG 581. Global Product Development**
*(cross-listed with MFG 574) Prerequisite: Graduate standing. I (3 credits)*
A project-based course in which each (global) student team comprised of students from three universities will be responsible for development of a product for the global market. Teams will use collaboration technology tools extensively. Several case studies on global product development will be presented and follow-up lectures will focus on the issues highlighted.

**MECHENG 586. Laser Materials Processing**
*(cross-listed with MFG 591) Prerequisites: Senior or Graduate standing. I (3 credits)*
Application of lasers in materials processing and manufacturing. Laser principles and optics. Fundamental concepts of laser/material interaction. Laser welding, cutting, surface modification, forming, and rapid prototyping. Modeling of processes, microstructure and mechanical properties of processed materials. Transport phenomena. Process monitoring.

**MECHENG 587. Global Manufacturing***
*(cross-listed with MFG 587) Prerequisite: one 400-level MF or DES or BUS class. I (3 credits)*
Globalization and manufacturing paradigms. Product-process-business integration. Product invention strategy. Customized, personalized and reconfigurable products. Mass production and lean production. Mathematical analysis of mass customization. Traditional manufacturing systems. Reconfigurable manufacturing systems. Reconfigurable machines. System configuration analysis. Responsive business models. Enterprise globalization strategies. The global integrated enterprise.

**MECHENG 588. Assembly Modeling for Design and Manufacturing***
*(cross-listed with IOE 588, MFG 588) Prerequisites: MECHENG 481 and MECHENG 401 or equivalent. I (3 credits)*
Assembly on product and process. Assembly representation. Assembly sequence. Datum flow chain. Geometric Dimensioning & Tolerencing. Tolerance analysis. Tolerance synthesis. Robust design. Fixturing. Joint design and joining methods. Stream of variation. Auto body assembly case studies.

**MECHENG 589. Sustainable Design of Technology Systems***
*Prerequisites: Senior or Graduate standing. I (3 credits)*
Scientific perspectives on grand challenges to environment and society created by the production of energy, water, materials, and emissions to support modern life styles. Integration of economic indicators with life cycle environmental and social metrics for evaluating technology systems. Case studies: sustainable design of consumer products, manufacturing, and infrastructure systems.

**MECHENG 599. Modeling, Analysis and Control of Hybrid Electric Vehicles***
*Prerequisites: no credit in Auto 599 Analysis and Control of Alternative Powertrains. Knowledge in Internal Combustion Engine (ME 438) and Automatic Control (ME 461) are helpful but are not required. The computer package MATLAB/SIMULINK will be used extensively for example problems and homework problems. Therefore, prior experience with MATLAB is strongly recommended. II (3 credits)*
To cover the modeling, analysis and control of vehicles with electrified propulsion systems, including electric vehicles, hybrid vehicles, plug-in and fuel cell vehicles. Introduce the concepts and terminology, the state-of-the-art development, energy conversion and storage options, modeling, analysis, system integration and basic principles of vehicle controls. Upon completion of this course, students should be able to follow the literature on these subjects and perform modeling, design, analysis and development work in this field.

**MECHENG 646. Mechanics of Human Movement**
*(cross-listed with BIOMEDE 646) Prerequisites: MECHENG 540, AEROSP 540, MECHENG 543, or equivalent. II (3 credits)*
Dynamics of muscle and tendon, models of muscle contraction. Kinematics and dynamics of the human body, methods for generating equations of motion. Mechanics of proprioceptors and other sensors. Analysis of human movement, including gait, running, and balance. Computer simulations and discussion of experimental measurement techniques.

**MKT625. New Product and Innovation Mgmt**
*Advisory Prerequisites: MKT 501 or 503. II (3 credits)*

Innovation and development of new products and services are essential for the success of any organization. At the same time, designing and launching new products is risky. Managing the new product development process therefore involves identifying new product ideas that have great potential and lowering the risk of their failure. This course discusses the stages in the new product development process and avenues for making the process more productive. Specific topics covered include creative techniques for idea generations, designing new products and series using analytical techniques, sales forecasting, testing, and tactics and strategies for new product launch. The course uses lectures, cases, and outside speakers. Moreover, the course includes a project wherein student teams will use the creativity techniques covered in this class to come up with new product ideas and perform a concept test in order to evaluate their feasibility. The course has a quantitative focus and delves on issues that are very relevant to managers on a day to day basis. The course will be especially useful for those interested in product/brand management, management consulting, and entrepreneurship.

**MO 501. Human Behavior and Organization**
*Prerequisite: No credit in MO 503 or MO 552. I or II (3 credits)*
The purpose of this course is to improve your effectiveness as a manager by introducing you to frameworks for understanding organizational processes and by giving you experience in applying these frameworks. The field of management and organizations is at the intersection of several social science disciplines and focuses on applying their insights to solving organizational problems and building organizational competencies. Topics include improving decision making, building networks, negotiation, power and politics, organization design, motivation and compensation systems, and leading (and surviving) organizational change.

**NRE 559. International Environmental Policy and Law**
*II (3 Credits)*
This course will examine how society manages - and sometimes fails to manage - environmental issues that fall beyond the authority or capability of a single national government. The course will examine relevant theoretical literatures from political science, law, and policy analysis, in order to characterize the systematic problems of making and implementing international policy to manage collective risks and resources; examine the approaches that have been proposed to mitigate these problems; and assess the available evidence of the effectiveness of these approaches. Topics to be considered will include scientific and technical assessment, negotiation of formal treaties as well as declarations, statements of principle, workplans, and other soft-law instruments; the establishment and management of international organizations; implementation and compliance systems, and initiatives by non-state actors as alternatives or supplements to government action; and the linkage of international environmental issues to issues of trade, international economic policy, security, and development. In addition, the course will examine past and present policy on several international environmental issues (including both pollution and resource-management issues). For each issue considered, the course will take distinct perspectives of description, explanation, and assessment. We will describe the history and present status of attempts to manage the issue, and our knowledge about it. We will employ casual reasoning, attempting to explain the policy outcomes we see. And we will look to assess the effectiveness with which the issue is being managed, relative to its apparent severity and urgency. Overall, the perspective of the course will be synthetic: it will seek to apply insights from research and scholarship to help advance practical understanding of what is happening, why, and how things might be done better. The bridge between theory and practice will go both ways: we will both use theoretical concepts to help understand specific issues, and use the evidence from these issues to help criticize and refine theoretical claims.

**NRE 560. Behavior & Environment**
*I (3 credits)*
This course deals with two central themes. First, environmental problems are people problems requiring an understanding of how people think, what they care about, and the conditions under which they behave most reasonably. Second, human behavior makes the most sense when studied in the context of the environment, both present and evolutionary. The course builds a model of human nature based upon research in the field of environmental psychology. The course will explore such topics as environmental perception and knowledge, preferred environments and coping with the failure of preference, and mental attention fatigue and restoration. It then applies this model to such issues as common property resource management and the psychology of sustainability. The course is cross-disciplinary both in emphasis and student population with the disciplines of natural resource policy, planning and management, environmental education, conservation behavior, psychology, landscape architecture and urban planning typically represented.

**NRE 565. Principles for Sustainability**
*Prerequisites: Graduate standing. Students are expected to be familiar with the biophysical conditions driving global environmental trends. II (3 credits)*
What would an economy, indeed a society, look like if the material security of its citizens and the ecological integrity of its resource base was a top priority? How would it organize itself, structure its industry, shape its consumption? How would a local-global culture operate if no party could solve its environmental problems by displacing costs onto others? What are the conditions in which humans tend not to increase their use of material and energy? To answer questions like these, many people use terms like "sustainability" and "sustainable development." These terms are much debated, much used, and much abused. Some would even say they have lost all meaning. This course addresses these questions and attempts to give meaning to sustainability, both in its implications for reversing trends in environmental degradation and for promoting policies that address long-term, ecological and social goals. It does this by developing a framework of analysis

focusing on: i. institutions, formal and informal rules and norms ranging from the local and regional to the international and global; and ii. sustainability, issues of durable resource use, production and consumption, property, development, local-global interaction, trade, international cooperation, ethics and equity. A major goal is to build analytic tools a policymaker, analyst, citizen activist or businessperson can use in a variety of environmental situations from the local to the global. The course encourages active student engagement with cases, discussions and simulations.

**NRE 571. Environmental Economics**
*(cross-listed with ECOC 471) Prerequisite: ECON 401 or Graduate standing. I (3 credits)*
Economic analysis of market failures due to externalities and imperfect transmission of information and of normative recommendations for efficient government behavior creating and implementing policies for air pollution, water pollution, hazardous wastes and occupational health.

**SI 519. Intellectual Property & Information Law**
*(cross-listed with PubPol 688) I (3 credits)*
Explores related and sometimes competing legal and policy frameworks for the development and dissemination of ideas and expression in the Information Age. The ways in which principles of free speech and expression compare and contrast with intellectual property rights are explored in relation to the advancement of knowledge and innovation, with particular focus on the impact of the Internet and new technology. The impact of other legal considerations and values on the development and dissemination of ideas and information (such as security, privacy, local control vs. national and international considerations, competition, and the protection of minors) are also examined. The course draws upon the contexts of education, business, and government.

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