**What is a syllabet?**

The ABET syllabus, known locally as the syllabet, is a 2 page summary of the course description, course topics, educational outcomes and assessment procedure.

**Why is this important?**

1. Required for the ABET self-study
2. The topics and outcomes are to be discussed and agreed upon by faculty with a stake in a particular course. Once this agreement is reached, the syllabet is approved by the Sibley School Faculty and is changed only by vote of the faculty. Thus the syllabet is an agreement among us as to what a particular course entails. Instructors teaching a course are expected to adhere to this agreement and to base the course on the topics outlined in the syllabet.

**Criterion 3. ABET Program Outcomes**

Engineering programs must demonstrate that their students attain the following outcomes:

**(a)** an ability to apply knowledge of mathematics, science, and engineering

**(b)** an ability to design and conduct experiments, as well as to analyze and interpret data

**(c)** an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

**(d)** an ability to function on multidisciplinary teams

**(e)** an ability to identify, formulate, and solve engineering problems

**(f)** an understanding of professional and ethical responsibility

**(g)** an ability to communicate effectively

**(h)** the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context

**(i)** a recognition of the need for, and an ability to engage in life-long learning

**(j)** a knowledge of contemporary issues

**(k)** an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice. MOST RECENT SYLLABETS

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| **Course Number** | **Most Recent Revision** | **Revised by** | **Course Number** | **Most Recent Revision** | **Revised by** |
| [ENGRD 2020](#ENGRD2020) | 10/1/15 | W. Sachse & H. Ritz |  |  |  |
| [ENGRD 2210](#ENGRD2210) | 3/18/15 | E. Fisher |  |  |  |
| [ENGRG 2270](#ENGRG2270) | 7/25/16 | J. Callister |  |  |  |
| [ENGRI 1170](#ENGRI1170) | 4/3/15 | H. Ritz |  |  |  |
| [ENGRI 1510](#ENGRI1510) | 11/5/16 | P. Pepiot et. al. |  |  |  |
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**ENGRD 2020 / MAE 2020 Statics and Mechanics of Solids**

**4 credits**

**Contact Hours:** Three 50-minute lectures and one 50-minute recitation per week.

**Instructors:** Meredith Silberstein and Leigh Phoenix (F16), Hadas Ritz (S17)

**Textbook(s) and other required material:**

Beer, F.P, Johnston, E.R., DeWolf J.T. and Mazurek, D.F., *Statics and Mechanics of Materials*, McGraw-Hill, 2011, or equivalent.

**Course (catalog) description:** Fall, Spring. 4 credits.

Covers principles of statics, force systems, and equilibrium in solid structures. Topics include: free body diagrams in two and three dimensions; frames; mechanics of deformable solids; stress and strain; axial force, shear force, bending moment, and torsion in bars and beams; thermal stress; pressure vessels; statically indeterminate problems; buckling and yielding.

**Prerequisite(s):** PHYS 1112 (Physics I: Mechanics), co-registration in MATH 1920 (Multivariable Calculus for Engineers) or permission of instructor.

**Designation as a ‘Required’ or ‘Elective’ course:** Elective, but required by some majors.

**Course learning outcomes:**

Upon completion of the course, students should be able to:

1. Draw complete and correct free body diagrams. (ABET outcome a)

2. Apply the principle of equilibrium to calculate external and internal forces in simple, statically determinant mechanical systems, including simple shear and bending moment distributions. (ABET outcome a)

3. Understand the concepts of stress, strain, deformation and elasticity. Analyze the stress, strain and deformation in bars subject to axial, bending and torsional loads. (ABET outcome a)

4. Use the principles of elasticity and equilibrium to solve for stresses in simple statically indeterminate systems. (ABET outcome a)

**Topics covered:**

* Introduction to Statics; Forces
* 2D and 3D Force Systems including Moments and Couples
* Free Body Diagrams (FBDs) and Equilibrium in 2D/3D
* Internal forces in trusses, frames and machines.
* Centers of mass and loadings with distributed forces
* Axially-loaded Members: Stress (mechanical, thermal), Strain, and Linear Elasticity
* Statically-indeterminate axial systems
* Torsion of circular shafts

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* Beams in bending: Shear Forces, Bending Moments, Bending and Shear Stress, and Deflection of cantilever and simply-supported beams.
* Statically indeterminate beam problems
* Pressure vessels
* Failure including buckling and yielding in ID
* Hands-on demonstration experiments on relevant systems

**Contribution of course to meeting ABET curriculum requirements:** Basic engineering sciences with hands-on demonstrations. Can be used to partially satisfy the engineering distribution requirement.

**Outcome Assessment:** In addition to analyzing student surveys administered by the College, the instructor will assess the outcomes of the course by considering student results on specific questions on homework, quizzes, and exams.

**Person(s) who prepared this description and date of preparation:**

Alan T. Zehnder, Andy Ruina, Joe Burns, Wolfgang Sachse, Bing Cady, November 6, 2006

Alan T. Zehnder, Wolfgang Sachse, Petru Petrina, May 16, 2008

Hadas Ritz, Wolfgang Sachse, October 2015

**ENGRD 2210 / MAE 2210: Thermodynamics**

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**3 credits**

**Contact Hours:** Five 75 minute lectures a week.

**Instructor:** Elizabeth Fisher

**Textbook(s) and/or other required material:**

*Fundamentals of Engineering Thermodynamics*, Michael J. Moran & Howard N. Shapiro, Wiley & Sons, Sixth Edition, or similar.

**Course (catalog) description:** Fall, Summer. 3 credits.

Presents the definitions, concepts, and laws of thermodynamics. Topics include the first and second laws, thermodynamic property relationships, and applications to vapor and gas power systems, refrigeration, and heat pump systems. Examples and problems are related to contemporary aspects of energy and power generation and to broader environmental issues.

**Prerequisite(s):** MATH 1920 (Calculus for Engineers) and PHYS 1112 (Physics I: Mechanics) or permission of instructor.

**Designation as a ‘Required’ or ‘Elective’ course:** Required

**Course learning outcomes:**

Upon completion of this course, students will be able to:

1. Choose an appropriate system and identify interactions between system and surroundings (ABET outcome e);
2. Obtain values of thermodynamic properties for a pure substance in a given state, using table, relations for incompressible substances, and relations for gases (ABET outcomes a and e);
3. Apply energy and entropy balances in the control mass (closed system) and control volume formulations to the analysis of devices and cycles (ABET outcomes a and e).

**Topics covered:**

* Introduction
* Energy Balance for Control Mass
* Properties of Pure Substances
* Energy Balance for Control Volume
* 2nd Law Concepts
* Entropy "Balance" for Control Mass and Control Volume Systems
* Applications: Gas Power Cycles
* Applications: Vapor Power Cycles

**Contribution of course to meeting MAE/ABET curriculum requirements:** Required ME Major Course. Basic engineering sciences with experimental experience. May be used to partially satisfy the engineering distribution requirement.

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**Outcome Assessment:** Performance on specific problems from quizzes, 2 preliminary exams, final exam.

**Person(s) who prepared this description and date of preparation:**

# Frederick Gouldin, 2/10/04. David Erickson, 6/09/08

Hadas Ritz, 5 August 2009, Elizabeth M. Fisher, 3/18/15

**ENGRG/MAE 2270: Introduction to Entrepreneurship for Engineers**

**Contact Hours:** Two 75-minute lectures each week.

**Instructor:** John Callister

**Textbook(s) and other required material:**

*Business Model Generation,* Alexander Osterwalder and Yves Pigneur, Wiley, ISBN 978-0-470-87641-1, (2010).

Excerpts from: *Principles of Microeconomics*, Robert H. Frank, et al, 6th edition, McGraw-Hill, ISBN 0-07-351985-8 (2015).

**Course (catalog) description:** Fall. 3 credits.

A solid introduction to the entrepreneurial process to students in engineering. The main objective is to identify and to begin to develop skills in the engineering work that occurs in high-growth, high-tech ventures. Basic engineering management issues, including the entrepreneurial perspective, opportunity recognition and evaluation, and gathering and managing resources are covered. The fundamentals of supply and demand and other basic microeconomic terms are covered. Technical topics such as the engineering design process, product realization, and technology forecasting are discussed.

**Prerequisite(s):** Open to all Cornell students regardless of major. No prerequisites.

**Designation as a ‘Required’ or ‘Elective’ course:** Elective. Part of the Engineering Entrepreneurship minor.

**Course learning outcomes:**

Upon successful completion of this course, the student will be able to:

1. Define and describe business terms and have knowledge of basic marketing terms, marketing procedures, and issues involved in starting a business (ABET outcome h);

2. Define terms and be familiar with the general attributes of various funding sources (ABET outcome h);

3. Calculate the rate of growth for a business, profit and loss, earnings per share, cost of goods sold, stock valuation, breakeven, and technology substitution rates. (ABET outcome a);

4. Demonstrate familiarity with the basics of intellectual property terminology and laws in the USA (ABET outcome h);

5. Be familiar with the basics of microeconomics, such as supply and demand, externalities, and competition.

**Topics covered:**

• Definitions and History of Entrepreneurship

• Creativity and Innovation

• Economics

• Strategy

• Marketing

• Financing

• Legal Issues

• Intellectual Property

• Venture Capital and Investment

**Contribution of course to meeting the MAE/ABET curriculum requirements:** This course contributes to 5(c): a general education component that complements the technical content of the curriculum and is consistent with the program and institution objectives.

**Outcome Assessment:** Outcomes will be assessed using graded homework sets, a preliminary exam, a final exam, and a group project.

**Person(s) preparing this description and date:**

John Callister

July 25, 2016

**ENGRI 1170: Introduction to Mechanical Engineering**

**3 credits**

**Contact Hours:** Two 50-minute lectures and one 2.5-hour lab each week.

**Instructor:** Hadas Ritz

**Textbook(s) and/or other required material:** *An Introduction to Mechanical Engineering*, by Jonathan Wickert and Kemper Lewis, 3rd edition Cengage Learning, 2013, or equivalent; or a course packet distributed via the course website.

**Course (catalog) description:** Fall. 3 credits

Introduction to fundamentals of mechanical and aerospace engineering. Students learn and understand topics such as stress and strain, fluid mechanics, heat transfer, automotive engineering, and engineering design and product development. Emphasis is placed on critically examining problem solutions to begin developing engineering intuition. Key components of the class include in-class discussions, homework, laboratory experiments, and a group design project.

**Prerequisites:** none

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Course learning outcomes:**

Upon completion of this course, students will be able to:

1. Perform unit conversion, estimation, approximations, and think critically about engineering problems. (ABET outcomes a, e)

2. Have a basic understanding and ability to solve problems in major areas of the mechanical engineering curriculum (ABET outcomes a, e)

3. Have experience designing and building a device (e.g. a small battery-powered car), and performing and documenting laboratory experiments (ABET outcomes b, c, d, g)

4. Become comfortable identifying a system and its interactions with surroundings and using this approach to solve problems (ABET outcomes a, e)

**Topics covered:** The topics, listed below, may be changed at the discretion of the instructor, as long as they are representative of the mechanical engineering curriculum.

* Forces and Moments
* Materials and Stresses
* Design
* Motion of Machinery
* Fluids
* Thermal Sciences/Energy

**Contribution of course to meeting MAE/ABET curriculum requirements:** This course contributes to (b), the engineering topics portion of the professional component.

**Outcome Assessment:** Outcomes will be assessed using grades on specific homework and exam questions, lab reports, and design reports.

**Person(s) preparing this description and date of preparation:**

Elizabeth M. Fisher, 4/24/08, Alan Zehnder 3/3/2010, Hadas Ritz 4/3/2015

**ENGRI/MAE 1510: Modeling and simulation of real-world scientific problems**

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Course (catalog) description:** Spring. 3 credits

Hands-on introduction to scientific modeling and numerical simulations relevant to computational science and engineering. Students will learn how real-world problems can be solved using models, algorithms, and statistical tools. The course is organized around a set of team-based scientific computing projects drawn from various engineering and life science fields, using actual research and/or industrial computational codes. Leveraging simplified and user-friendly software interfaces and tutorials, the course focuses on the inductive learning of key concepts and topics such as physical and computational model formulation, verification and validation, uncertainty analysis, post-processing and data mining, and a high-level introduction to high performance computing. The course culminates with a community-engaged project, in which students are introduced to the basics of engineering design and team management to develop and animate a scientific computing activity in collaboration with, and tailored for, the Sciencenter Future Science Leaders program for middle- and high-schoolers. No prior programming experience is necessary, and a high-school math level is assumed. Enthusiasm for computer-based activities and interest in community outreach is strongly recommended.

**Prerequisites:** none

**Textbook(s) and/or other required material:** to be determined

**Course learning outcomes:**

Upon completion of this course, students will be able to:

1. Understand “corner stone” skills of CSE, including modeling, code verification and validation, error analysis (MAE/ABET outcomes a, ACS guidelines b)
2. Use and manipulate software packages to learn how science problems can be represented in computational programs (MAE/ABET outcomes a, e, k, ACS guidelines a, b, c)
3. Be confident in their ability to use computers to solve scientific and engineering problems (MAE/ABET outcomes i, ACS guidelines c)
4. Learn practical skills to improve their ability to lead a team, be a good teammate and communicate effectively (MAE/ABET outcomes g, ACS guidelines d)

**Topics covered (non-exhaustive):**

* Introduction to models and modeling
* Logic and scientific programming
* Data analysis and post-processing
* Verification and validation
* Introduction to probability and statistics
* Introduction to error and uncertainty analysis

**Class/laboratory schedule:** Two 75-minute lectures and one lab each week.

**Contribution of course to meeting Engineering ABET curriculum requirements:** This course contributes to (b), the engineering topics portion of the professional component.

**Outcome Assessment:** Outcomes will be assessed using grades on bi-weekly homework sets, one written and one oral mid-term examination, and a team-based project in collaboration with the Sciencenter Future Science Leaders program.

**Person(s) preparing this description and date of preparation:**

Nandini Ananth (Chemistry), Paulette Clancy (CBE), Perrine Pepiot (MAE)

November 2, 2016.

**MAE 1130: Introduction to Computer-Aided Manufacture (CAM)**

**1 credit**

**Contact Hours:** Attend classes: One 2-hour session per week for 8-10 weeks; Attend labs: One 2-hour session per week for 7-10 weeks

**Instructor:** Matt Ulinski

**Textbook(s) and/or other required material:** No Text Required.

Suggested Reading:

*Foundations of Mechanical Accuracy* (Moore)

*Precision Machine Design* (Slocum)

**Course (catalog) description:** Fall, approx. ten weeks (total 20 hrs. of instruction and 20 hrs. of lab). 1 credit. Limited enrollment.

Introduction to the fundamentals of computer-aided manufacture (CAM) and computer numerical control (CNC) programming. The course is a hands-on series on CAM. Provides practical applications of the use of G-code and solid modeling software, CNC mill and/or lathe setup, tool selection, and operation. The course is required for students wishing to use the CNC equipment in the Emerson Manufacturing Teaching Lab for team or research projects. It is also required for advanced CAM/CNC work offered on an individual basis in the spring. May not be used to fulfill any ME requirement.

**Prerequisite(s):** Enrollment limited to: Emerson Manufacturing Teaching Lab Green Apron Status or permission of instructor.

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Course learning outcomes:**

On completion of the course, students should:

1. Understand machine tools’ role in history and their role in current industry.
2. Be capable of programming, tooling, fixturing, and operating a modern CNC machine such as the Okuma VMC in the lab in a safe and effective manner. (ABET outcomes a, k)

**Topics covered:**

* History of Machine Tools/NC/CNC/CAM, Introduction to Manual G-Code programming and process planning.
* CAM software such as ProToolmaker.
* Design and Configuration of Machine Tools. Introduction to Manual G-Code programming and process planning.
* Design for machining including discussion of DFMA.
* Fixturing Design.
* Safety, cleanliness, maintenance
* Tooling Selection .
* Considerations & Methods for Calculating Feeds and Speeds.
* Milling Cycles.
* Machine Tool Selection –VMCs.

**Contribution of course to meeting MAE/ABET curriculum requirements:** This course is an elective and does not fulfill any ME major requirements. It contributes to the realization of physical systems in the mechanical systems area.

**Outcome Assessment:** Outcomes will be assessed using graded homework assignments, graded lab exercises, prelim and final examinations, and a final course project.

Lab Projects: 1) Manually G-coded project – “initials” 2) CAM project “C-Block” 3) CAM project of students own direction.

**Person(s) who prepared this description and date of preparation:**

Fenton O’Shea, Matt Ulinski

April 7, 2010

Emily Tompkins, April 23, 2015 (updated wording to match Courses of Study)

**MAE 2030:** **Dynamics**

**3 credits**

**Contact Hours:** Two 75 minute lectures per week. One 50 minute recitation or problem-solving session per week, scheduled as per normal recitation sessions.

**Instructor:** Dmitry Savransky

**Textbook(s) and/or other required material:**

*Engineering Mechanics: Dynamics*, J.L. Meriam and L.G. Kraige, John Wiley & Sons, 7th

Edition, 2012, or equivalent.

**Course (catalog) description:** Spring. 3 credits.

Newtonian dynamics of a particle, systems of particles, rigid bodies, simple mechanisms and simple harmonic oscillators. Impulse, momentum, angular momentum, work and energy. Two-dimensional (planar) kinematics including motion relative to a moving reference frame. Three dimensional rigid-body dynamics are introduced at the instructor’s option. Setting up the differential equations of motion and solving them both analytically and numerically with MATLAB. In-lecture laboratory demonstrations illustrate basic principles.

**Prerequisite(s):** ENGRD/MAE 2020 (Statics and Mechanics of Solids), Math 2930 (Differential Equations for Engineers), familiarity with MATLAB, or permission of instructor. Corequisite: MATH 2940.

**Designation as a ‘Required’ or ‘Elective’ course:** Required

**Course learning outcomes:**

On completion of this course, a student should be able to:

1. Draw free-body diagrams, distinguishing forces from inertial effects (ABET outcome a)

2. Describe particle and rigid-body motion in 1-D and 2-D employing Cartesian, polar, and path coordinates, and rotating coordinate systems. (ABET outcome a)

3. Apply Newton/Euler laws, momentum and work-energy principles to the motion of particles and rigid bodies to find equations of motion and conserved quantities (ABET outcome a)

4. Recognize simple harmonic motions for 1-degree-of-freedom mechanical systems. (ABET outcome a)

5. Solve equations of motion numerically, and analytically in simple cases, and graphically show the resulting motion(s). (ABET outcome a)

6. Understand measurement of displacement, velocity and acceleration - and use such data to characterize the kinematics of simple mechanisms and 1-degree-of-freedom mechanical systems. (ABET outcome a)

**Topics covered:**

* Review of free-body diagrams and vectors for mechanics
* Basic principles: Linear and angular momentum balance and work-energy.
* Kinematics of a particle and rigid body, including Cartesian, path and polar coordinates
* Relative and constrained motions of free and constrained particles and rigid objects
* Vibrations of single-DOF systems
* Simple mechanisms and finite systems of particles
* Numerical, and simple analytical, solution of the equations-of-motion ODEs.
* In-Lecture measurements and demonstrations, including, e.g., 1 DOF vibrations, normal modes, and slider-crank kinematics, some with data analysis assignments.

**Contribution of course to meeting MAE/ABET curriculum requirements:**

This is a course in basic engineering sciences.

**Outcome Assessment:** The instructor will assess the enumerated outcomes of the course by considering studentresults in specific questions on homework assignments and exams. The instructor will also analyzestudent surveys administered by the College to assess student views as to what learningmechanisms were most useful.

**Person(s) who prepared this description and date of preparation:**

Alan T. Zehnder, Andy Ruina, Joe Burns, Wolfgang Sachse, March 11, 2004

David Gries, Related outcomes to (a), June 19, 2004

Alan T. Zehnder, Andy Ruina, Joe Burns, May 19, 2008

Alan T. Zehnder, Bing Cady and Joe Burns, May 8, 2009

Andy Ruina, Wolfgang Sachse, Oct. 15, 2013

Dmitry Savransky, March 23, 2015

**MAE 2120: Mechanical Properties and Selection of Engineering Materials**

**3 credits**

**Contact Hours:** Two 75-minute lectures each week and one non-mandatory recitation.

**Instructor:** Christopher J. Hernandez

**Textbook(s) and/or other required material:**

Beer, F.P, Johnston, E.R., DeWolf J.T. and Mazurek, D.F., *Statics and Mechanics of Materials*, McGraw-Hill, 2011(also required for ENGRD 2020).

Dowling, N.E.*,* *Mechanical Behavior of Materials,* 4th Edition

Ashby, M.F., *Materials Selection in Mechanical Design,* 2nd Edition (Free online).

Required software: Cambridge Engineering Selector (CES available for purchase or in MAE computer labs)

**Course (catalog) description:** Spring. 3 credits.

Mechanics of deformable bodies and a reinforcement of the concept of "simple engineering elements" for mechanical analysis associated with design. There is an introduction to the broad range of properties and behaviors of engineering materials as they relate to mechanical performance. Emphasis is placed on general states of stress and strain, on elasticity and combined loading effects. Failure criteria including yielding, buckling, fracture, fatigue and environmental effects are developed. A general introduction to the function/constraints/objectives approach to material selection associated with mechanical design is provided with candidate material systems coming from metals, polymers, ceramics and/or composites. A general overview of material processing will be presented within this context of material selection.

**Prerequisite(s):** ENGRD 2020: Statics and Mechanics of Solids

**Designation as a ‘Required’ or ‘Elective’ course:** Required

**Course learning outcomes:**

On completion of the course, students should:

1. Understand the most basic analytical tools for mechanical analysis and be able to solve simple boundary value problems stress, strain and displacement fields (ABET outcomes a, e and k).
2. Know and understand fundamentals failure modes associated with mechanical design. Equipped with skills associated with outcome 1, students should be able to predict failure by excessive stress (yielding and fracture), stress in the presence of cracks and flaws (using fracture mechanics) and fatigue (ABET outcomes a, e and k)
3. Have a basic understanding of the structure, processing and properties of the basic classes of engineering materials: metals, polymers, ceramics and composites (ABET outcomes a and k).
4. Understand and utilize a properties/function-based method to systematically choose materials for mechanical designs (ABET outcomes a, c, e, and k).

**Topics covered:**

* Stress, strain, elasticity, multiaxial stress and strain states, strain gages
* Combined loading conditions
* Failure criteria including: yielding and fracture (excessive stress), fracture mechanics, buckling, stress and strain-based approaches to fatigue and fatigue crack growth.
* Fundamentals of mechanical testing: measures of strength and ductility, definitions of true vs. engineering stress and strain, strain hardening
* Overview of the structure, processing, properties relationships for broad classes of engineering materials including metals, polymers, ceramics and composites.
* Development of simple Matlab-based code for solving elementary mechanics problems.
* Material selection including the concept of material indices and incorporating considerations of mechanical performance, weight, cost, sustainability, carbon footprint and embedded energy.

**Contribution of course to meeting MAE/ABET curriculum requirements:** This course partially fulfills the mechanics track of the MAE major program.

**Outcome Assessment:** Outcomes are assessed by analyzing grades on all assignments including preliminary and final exams, homework assignments, in-class quizzes and Matlab-based projects. A midterm student survey is administered as is the traditional online student assessment.

**Person(s) who prepared this description and date of preparation:**

Matthew Miller

March 15, 2010

Christopher J. Hernandez

June 2, 2015

**MAE 2250: Mechanical Synthesis**

**4 credits**

**Contact Hours:** Three 50-minute lectures and one 2-hour-and-30-minute lab each week.

**Instructor:** Robert Shepherd

**Textbook(s) and/or other required material:**

*Engineering Design: A Materials and Processing Approach,* Dieter, McGraw-Hill, 2000 (suggested textbook), or equivalent.

Website: blackboard.cornell.edu. Course information and handouts are posted on the website for download.

**Course (catalog) description:** Spring, 4 credits. Lab fee.

A hands-on introduction to the mechanical design process, from conceptualization through prototype construction and testing. Design projects provide experience in basic prototyping skills using machine tools, 3D printing and laser cutting, as needed, as well as basic instruction in CAD and technical sketching.

**Prerequisite(s):** ENGRD 2020 (Mechanics of Solids). Pre- or corequisite: ENGRD 2030 (Dynamics).

**Designation as a ‘Required’ or ‘Elective’ course:** Required

**Course learning outcomes:**

On completion of the course, students should:

1. Be familiar with the product realization process and its documentation (ABET outcome c);
2. Be able to formulate and solve simple mathematical models to analyze a design (ABET outcomes a and e);
3. Appreciate wider issues of design including ethics, liability, safety, environmental and safe disposal (ABET outcomes f and h);
4. Be able to run simple tests of their designs (ABET outcome b);
5. Be familiar with basic oral communication and documentation techniques (ABET outcome g);
6. Be familiar with basic tools of design and manufacturing such as CAD and machine tools (ABET outcome k);
7. Be cognizant of safety in manufacturing (ABET outcome k);
8. Function effectively in a team (ABET outcome d);

**Topics covered:**

* + The design process: from customer needs to specifications; from concept generations and exploration to detailed design and analysis; from prototyping to fabrication.
	+ Project planning, team dynamics and project economics.
	+ At least one team-based project to experience the product development process, with a working prototype.
	+ Additional topics: for example, safety; FEA; CAD; sketching; prototyping technology; controls; tolerancing; lubrication; manufacturability; green design; patents; ethics; ergonomics; liability; design automation; embedded systems.

**Contribution of course to meeting MAE/ABET curriculum requirements:** This course partially fulfills the engineering design track of the ME major.

**Outcome Assessment:** Outcomes are assessed through graded projects and exercises; student presentations; written and oral surveys.

**Person(s) who prepared this description and date of preparation:**

Michel Louge

March 17, 2015

**MAE 3050: Introduction to Aeronautics**

**3 credits**

**Contact Hours:** Two 75-minute lectures per week.

**Instructor:** Perrine Pepiot

**Textbook(s) and/or other required material:**

*Introduction to Flight,* John D. Anderson, Jr., Prentice-Hall, Seventh Edition.

Alternate text used in other years: *Fundamentals of Flight,* Richard S. Shevell, Prentice-Hall, Second Edition, 1989.

**Course (catalog) description:** Fall. 3 credits.

Principles of incompressible and compressible aerodynamics, boundary layers, and wing theory. Calculation of lift and drag for aircraft. Analysis of aerodynamic performance; introduction to stability, and control. Introduction to aircraft design.

**Prerequisite(s):** MAE 2030 (Dynamics); Pre or corequisites: one of the following thermodynamics classes: ENGRD 2210 or BEE 2220 and one of the following fluid mechanics classes: MAE 3230 or CHEME 3230 or BEE 3310 or CEE 3310; or permission of instructor.

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Course learning outcomes:**

Upon completion of the course, students should be able to:

* 1. Understand the basic elements of aerodynamic lift, drag, and moments forming the basis for flight (ABET outcomes a and e).
	2. Analyze the motion of aircraft to obtain performance, stability and control information (ABET outcomes a and e).
	3. Be able to obtain computer based solutions of problems related to aeronautics (ABET outcomes a and k).

**Topics covered:**

* + Aircraft Morphology
	+ Aerodynamic Forces
	+ The Standard Atmosphere
	+ Elements of Fluid Mechanics, Balance of Mass, Momentum, Energy
	+ Potential Flow and Vorticity, Numerical Solutions by Singularity Distributions
	+ Nozzle Flows, Speed of Sound
	+ Viscosity, Boundary Layers, Boundary Layer Separation
	+ Airfoils
	+ Dimensional Analysis and Wind Tunnel Modeling
	+ Aerodynamic Data and Its Interpretation and Use
	+ Stall and Maximum Lift Coefficient, High Lift Devices
	+ Wings, Lifting Line Theory, Induced Drag, Drag Polar, Form Drag
	+ Prandtl-Glauert Rule, Critical Mach Number and Its Estimation
	+ Effect of Wing Sweep
	+ Supersonic Flight, Wave Drag
	+ Airplane Performance
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	+ Thrust Required and Thrust Available, Maximum Velocity
	+ Power Required and Power Available, Maximum Velocity
	+ Effects of Altitude on Thrust and Power Available
	+ Gliding flight, Rate of Climb, Absolute and Service Ceilings, Range and Endurance
	+ Stability and Control
	+ Equilibrium Flight, Trim Conditions
	+ Moment Balance, Contributions of Wing, Tail, and Fuselage
	+ Static Stability, Neutral Point, Static Margin

**Contribution of course to meeting MAE/ABET curriculum requirements:** This course partially fulfills the requirement to complete two upper level MAE courses as a Major Approved Elective. It can also be used to fulfill the Technical Elective requirement.

**Outcome Assessment:** The outcomes are assessed by the assignments of weekly homework, prelims, and final examinations. A student evaluation administered by the College of Engineering at the conclusion of the term provides an overall assessment of the course.

All examination outcomes are recorded question by question, making it possible to track student understanding of the specific topics covered in the course syllabus, and to map student comprehension to the stated course objectives. The level of understanding is assessed by evaluating the statistics, mean and standard deviation, of the scores on each question. Homework is treated similarly.

**Person(s) who prepared this description and date of preparation:**

D. A. Caughey

11/12/09

P. Pepiot 3/18/15

**MAE 3100: Introduction to Applied Mathematics I**

**3 credits**

**Contact Hours:** Two 75-minute lectures each week.

**Instructor:** Richard Rand

**Textbook(s) and/or other required material:**

*Elementary Differential Equations and Boundary Value Problems*, William E. Boyce and Richard C. DiPrima, 10th ed. Wiley

*Probability and Statistics*, 4th Ed, Spiegel, Schiller and Srinivasan, Schaum’s Outline Series

**Course (catalog) description:** Fall. 3 credits.

Covers initial value, boundary value, and eigenvalue problems in linear ordinary differential equations. Also covers special functions, linear partial differential equations. Includes an introduction to probability and statistics. Use of computers to solve problems is emphasized.

**Prerequisites:** MATH 2930 and MATH 2940

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Course learning outcomes:**

On completion of the course, students should:

* + - 1. Be able to apply knowledge of mathematics (ABET outcome a)

**Topics covered:**

* + - Solution of linear and non-linear ordinary differential equations
		- Power Series methods
		- Eigenvalues and Boundary Value Problems
		- Special Functions
		- Probability
		- Introduction to Statistics

**Contribution of course to meeting MAE/ABET curriculum requirements:** This course may be used to satisfy the Math Elective requirement

**Outcome Assessment:** Outcomes will be assessed using graded homework assignments, graded computer exercises, preliminary and final examinations.

**Person(s) who prepared this description and date of preparation:**

Richard Rand

March 22, 2015

**MAE 3230: Introductory Fluid Mechanics**

**4 credits**

**Contact Hours:** Three 50-minute lectures and one 50-minute recitation/review/demonstration or further lecture each week.

**Instructor:** Charles Williamson

**Textbook(s) and/or other required material:**

*Fluid Mechanics,* F.M. White, McGraw-Hill, 7th Edition, 2010, or equivalent.

**Course (catalog) description:** Fall. Usually offered in the summer through the Engineering Cooperative Program. 4 credits.

Topics include physical properties of fluids, hydrostatics, conservation laws using control volume analysis and using differential analysis, Bernoulli's equation, potential flows, simple viscous flows (solved with Navier-Stokes equations), dimensional analysis, pipe flows, boundary layers. Introduction to compressible flow.

**Prerequisite(s):** ENGRD 2020 (Statics and Mechanics of Solids) and MAE 2030 (Dynamics), pre or corequisite: ENGRD 2210 (Thermodynamics), or permission of instructor.

**Designation as a ‘Required’ or ‘Elective’ course:** Required.

**Course learning outcomes:**

On completion of this coursestudents should:

1. Be able to use the fundamental principles and mathematical basis underlying the conservation equations (ABET outcome a).
2. Be able to identify the guiding principles in a given fluid problem, to formulate the governing equations, and so to solve basic engineering problems (ABET outcome e).
3. Recognize the difference between an ideal fluid and a viscous fluid, and to understand the limitations of the solutions for real practical fluid flows. Understand the difference between a simple solution and a real practical problem (ABET outcomes a and e).
4. Understand where their analysis might involve approximations and empirical approaches; for example, pipe flows and boundary layer flows (ABET outcomes a and e).
5. Have improved their ability to formulate an ordered approach to problem solving, using words of explanation in derivations, and algebra before substituting numerical values that allows neat analytical solutions and dimensional analysis (ABET outcome g).

**Topics covered:**

* Introduction to Fluids and Basic Concepts
* Hydrostatics
* Basic Integral Relations (Conservation Laws, and Control Volume)
* Differential Relations (Conservation Laws, and Navier-Stokes Equations)
* Potential Flows
* Simple Viscous Flows
* Dimensional Analysis and Similitude
* Viscous Flows in Ducts
* Boundary Layer Flows
* Introduction to Compressible Flow

**Contribution of course to meeting the MAE/ABET curriculum requirements:** This course partially fulfills the fluids and thermal science track of the ME major.

**Outcome Assessment:** Assessments are made on the basis of: homework; exams; brief survey ("MAE 3230 Course Improvement Survey"); standard form evaluations at end of semester.

**Person(s) who prepared this description and date of preparation:**Charles Williamson 30 March 2010

E. Tompkins 3/19/15

**MAE 3240: Heat Transfer**

**3 credits**

**Contact Hours:** Two 75-minute lectures each week.

**Instructor:** C. Thomas Avedisian

**Textbook(s) and/or other required material:**

*Heat and Mass Transfer: Fundamentals and Applications,* Cengel & Ghajar, 5th Edition, McGraw Hill (2014).

**Course (catalog) description:** Spring. Also offered in the summer through the Engineering Cooperative Program. 3 credits.

Topics include the following: steady and unsteady heat conduction; forced and free convection; external and internal flows; radiation heat transfer; and heat exchangers

**Prerequisite(s):** MAE 3230 (Introductory Fluid Mechanics) or permission of instructor.

**Designation as a ‘Required’ or ‘Elective’ course:** Required.

**Course learning outcomes:**

On completion of the course, students should know how to do the following:

1. Become proficient with energy balances to develop models of heat flow in various systems (ABET outcome a);
2. Learn terminology and physical principles of heat transfer (ABET outcome a);
3. Develop broad understanding of basic modes of heat transfer (conduction, convection, radiation) and become proficient at predicting heat transfer rates for these modes including computing the heat transfer coefficient for forced and natural convection (ABET outcome a);
4. Become proficient at computing radiative exchange between surfaces (ABET outcome a);
5. Apply basic heat exchanger theory to predict heat exchanger performance for standard designs (ABET outcome a).

**Topics covered:**

Conduction

* Conservation equations in differential and integral form
* Energy balances on differential control volumes
* Steady state conduction
	+ thermal resistance concept
	+ shape factors for multidimensional steady conduction
* Transient conduction
	+ lumped approximation
	+ 1-D distributed systems
	+ multi-dimensional effects by products of 1-D transient distributed solutions

Convection

* Presentation of conservation equations
* Scale analysis to solve differential equations
* Boundary layer approximation for external flows
* Integral momentum and energy equations
* Heat transfer/fluid flow analogy
* Internal flows (fully developed and developing)
* Correlations for Nusselt number

Heat Exchangers

* Log-mean temperature and ε-NTU methods for heat exchanger analysis
* Heat Exchanger design
	+ determining area, flow conditions, temperatures, flow rates, etc., for specified conditions

Radiation

* Black and gray body radiation
* View factor algebra
* Thermal resistance concept for radiation exchange between surfaces
* Mixed mode heat transfer (radiation with conduction and convection)

**Contribution of course to meeting the professional component:** This course partially fulfills the fluids and thermal science track of the ME major.

**Outcome Assessment:** The extent to which course outcomes are satisfied will be tracked by quizzes and homework problems. The quizzes will require students to answer selected questions pertaining to the outcomes. Homework assignments leading up to the quizzes will be chosen to give students practice at solving problems relevant to the outcomes.

**Person(s) who prepared this description and date of preparation:**

C. Thomas Avedisian, 4/10/10

E. Tompkins, 3/19/15

**MAE 3250: Analysis of Mechanical and Aerospace Structures**

**3 credits**

**Contact Hours:** Two 75-minute lectures with a 50-minute recitation each week.

**Instructor:** Andy Poshadel

**Textbook(s) and/or other required materials:**

 *Advanced Mechanics of Materials and Applied Elasticity*, A. C. Ugural and S. K. Fenster, 5th Edition, Prentice Hall PTR, 2003.

**Course (catalog) description:** Fall. Also offered in the summer through the Engineering Cooperative Program. 3 credits.

Topics in mechanics of materials applied to analysis and design of structural components encountered in mechanical and aerospace systems. Includes: torsion, bending, buckling, stress concentrations, and statically indeterminate structures. Solutions obtained using strength-of-materials approximations and elementary finite element formulations.

**Prerequisite(s):** ENGRD 2020 (Statics and Mechanics of Solids) and MAE 2120 (Mechanical Properties and Selection of Engineering Materials).

**Course learning outcomes:**

On completion of the course, students should be able to:

1. Manipulate and interpret stress and strain matrices arising from multi-axial loading (ABET outcome a);

2. Apply strength-of-materials approaches to applications involving bending and torsion loading modes (ABET outcomes a, e);

3. Perform elementary, two-dimensional, finite element analyses of the elastic response of mechanical components (ABET outcomes a, e, k);

4. Relate numerical solutions to analytical solutions, where available (ABET outcomes a, k).

**Topics covered:**

1. • Introductory Concepts
2. • Governing Equations of Deformable Solids
3. • “Strength-of-Materials Approach”
4. • Strength-of-Materials Topics: Bending, Torsion, and Buckling
5. • Beyond the Strength-of-Materials Approach: Basic Concepts of the Finite Element Method
6. • Basic Concepts of the Finite Element Method
7. • Using the Finite Element Method
8. • Applications of Finite Element Analysis Including Stress Concentrations

**Contribution of course to meeting MAE/ABET curriculum requirements:** This course partially fulfills the mechanics track of the ME major.

**Outcome Assessment:** Outcomes are assessed using graded homework assignments, two projects, two preliminary examinations, one final examination, and student feedback on course evaluations.

**Person(s) who prepared this description and date of preparation:**

Paul Dawson 1/26/04

Elizabeth Fisher (amended objectives) 10/12/07

Yingxin Gao (Updated) 11/12/09

Paul Dawson, 3/19/15

Andrew Poshadel, 1/27/16

**MAE 3260: System Dynamics**

**4 credits**

**Contact Hours:** Three 50-minute lectures each week, or alternatively two 75-minutes lectures each week. Labs meet five to seven times during the semester for 2 hours and 30 minutes each, depending on the size of the class and the length of the semester (e.g. summer semester is shorter).

**Instructor:** Hadas Ritz

**Textbook(s) and/or other required material:**

*System Dynamics,* K. Ogata, Prentice Hall, Fourth edition, 2004, or equivalent

*Experimental Systems and Nonlinear Dynamics,* M.L. Psiaki, Gnomon Copy, Ithaca, N.Y.,

Third edition, 2000, or equivalent.

**Course (catalog) description:** Spring. Usually offered in the summer through the

Engineering Cooperative Program. 4 credits.

Dynamic behavior of mechanical systems: modeling, analysis techniques, and applications; vibrations of single- and multi-degree-of-freedom systems; feedback control systems.

Computer simulation and experimental studies of vibration and control systems.

**Prerequisite(s):** MATH 2940 (Engineering Mathematics), ENGRD 2030 (Dynamics). Junior standing required.

**Designation as a ‘Required’ or ‘Elective’ course:** Required

**Course Learning Outcomes:**

On completion of this course, students will have:

* An ability to build up a correct dynamic model of a complex mechanical or electromechanical system by a divide-and-conquer approach that makes use of physics, constitutive laws, geometry, and whatever other information one may have about the system (MAE/ABET a, e).
* An ability to use linear and nonlinear system simulation and analysis tools to study transient and frequency response of systems (MAE/ABET a, e and k).
* An ability to work with modern dynamics lab equipment (MAE/ABET b and k).
* An ability to design dynamic parameters in order to meet dynamic performance requirements such as a bound on vibration transmission (MAE/ABET c, e).
* An ability to understand and design rudimentary feedback controllers to meet performance specifications on dynamic response (MAE/ABET a, c and e).

**Topics covered:**

* Laplace Transforms
* Review of Mechanical Systems Modeling
* Electrical Systems Modeling
* Electro-Mechanical Systems Modeling
* Transfer Function System Models
* Linear Vibrations and Response to Sinusoidal Forcing
* Bode Frequency Response Plotting
* Frequency Response Applications
* Linearization of Nonlinear Systems about Equilibria
* Linear System Transient Response
* State Space System Models
* Numerical Simulation of Linear and Nonlinear Systems
* Introduction to Feedback Control
* Block Diagrams and Algebra
* P, PI, and PID Controllers
* Transient Response Analysis and Specifications
* Design of Feedback to Meet Transient Response Specs
* Experimental Investigations of ...

 Dynamics Laboratory Instrumentation

Vibrations in Rotating Machinery

 General Linear Vibrations

 Nonlinear Vibrations

 Feedback-Controlled Systems

**Contribution of course to meeting the MAE/ABET Curriculum Requirements:** This engineering science course partially fulfills the dynamics track of the ME major.

**Outcome Assessment:** Outcomes will be assessed using graded homework assignments,

graded lab reports and lab exercises, 2 prelim examinations, a final examination, and student

comments on course evaluations.

**Person(s) who prepared this description and date of preparation:**

Mark Psiaki

11/18/2009

Boris Kogan on 4/3/2015

**MAE 3272: Mechanical Property and Performance Laboratory**

**2 credits**

**Contact Hours:** One lab and one lecture per week

**Instructor:** Wolfgang Sachse

**Textbook(s) and/or other required material:** Class handouts and notes.

**Course (catalog) description:** Spring. 2 Credits.

This course provides an introduction to the experimental methods, instrumentation and data analyses associated with material property determination and mechanical performance of materials. Emphasis is placed on integration of theory and analysis with experimental methods.

**Prerequisite(s):** MAE 2120 (Mechanical Properties and Selection of Engineering Materials) and MAE 3250 (Analysis of Mechanical and Aerospace Structures).

**Designation as a ‘Required’ or ‘Elective’ course:** Required

**Course learning outcomes:**

Upon completion of this course, students will:

1. Be able to use a variety of methods to determine mechanical properties and performance measures of engineering materials (ABET outcomes a and b).
2. Be able to use material properties and relationships to design, build and test transducers. (ABET outcomes a, b and c)
3. Be able to analyze and experimentally test components in dynamic mechanical systems. (ABET outcomes a, b and k)

**Topics covered:**

* Mechanical Testing: Uniaxial Tension, Hardness, Ultrasonic.
* Transducers, Instrumentation and Measurement Systems
* Theory and Use of Strain Gages
* DAQ and LabView
* Wheatstone Bridge Circuits
* 3D Modeling with ANSYS
* Rosette strain gages and strain transformations
* Measurements in Dynamic Mechanical Systems

**Contribution of course to meeting MAE/ABET curriculum requirements:** This course partially fulfills the mechanics track of the ME major.

**Outcome Assessment:** Notebooks, Quizzes, Completion of Projects and Final Presentation Slides.

**Person(s) who prepared this description and date of preparation:**

Matt Ulinski

5/25/05

Last Updated: Hadas Ritz, 5/20/09

**MAE 3780/3783: Mechatronics**

**4 credits**

**Contact Hours:** Lecture meets for three 50 minute or two 75 minute periods. Laboratory meets once a week for 2½ hours.

**Instructor:** Yang Xie

**Textbook(s) and/or other required material:**

*Recommended*

Alciatore, D.G., and Histand, M.B., *Introduction to Mechatronics and Measurement Systems*, 4th Edition, McGraw Hill, 2011.

Additional References

* Rizzoni, G., *Principles and Applications of Electrical Engineering*, 5th Edition, McGraw-Hill, 2003.
* Schwarz, S.E., and Oldham, W.G., *Electrical Engineering an introduction*, 2nd Edition, Oxford University Press, 1993.
* Bishop, R., The Mechatronics Handbook, CRC Press, 2002

**Course (catalog) description:** Fall, 4 credits.

At the intersection of mechanical and electrical engineering, Mechatronics involves technologies necessary to create automated systems. This course introduces students to the functional elements of modern controlled dynamic systems. Topics include analog circuits (both passive and active components); filter design; diodes; transistors, MOSFETs and power amplification; pulse width modulation; transduction; mechanical and electro-mechanical devices such as electromagnetic systems; piezoelectric and shape memory material transduction; gear trains; optical encoders; discretization; aliasing; and microprocessors and programming. Lab experiments culminate in the design, fabrication, and programming of a microprocessor-controlled robotic vehicle, which laboratory groups enter into a class-wide competition.

**Prerequisite(s):** MATH 2930, PHYS 2213, or permission of instructor.

**Designation as a ‘Required’ or ‘Elective’ course:** elective

**Course learning outcomes:**

On completion of the course, students should be able to:

1. Apply Kirchoff’s laws to modern circuits and electro-mechanical devices. Students solved for the dynamic response of first order systems. (ABET outcomes a and e)
2. Perform experiments on electrical circuits containing modern components and electro-mechanical systems; laboratory reports were delivered for each formal experiment and the final project. (ABET outcomes a, b, c, and g)
3. Design and construct a robotic vehicle which using sensors to determine where it is with respect to its environment. Each robotic vehicle system utilized unique sensor configurations and software for each project. The software controlled a small microprocessor that the vehicle carried, in addition to a sensor suite, motor drivers, actuators, and battery pack. (ABET outcomes a, b, c, d, e, g, and k)

**Topics covered:**

* Electronics and Circuits
	+ - analog circuits: passive and active components
	+ - active circuit dynamics: summers, integrators, differentiators
	+ - power circuits: transistors, diodes, MOSFETs, power amplifiers and H-bridge motor controllers, element characterization and modeling
* Sensing: rotational position: analog tachometers, potentiometers & optical encoders, tactile sensing, sonar, signal conditioning
* Electromechanical Actuation: mechanical transmissions (gear trains and levers) for servomotors, electromagnetics: motors & solenoids
* An introduction to simple analog controllers: open loop controllers: pre-amps, coupling circuits to electromechanical systems, power amplification issues, speed control loop
* Microprocessors
	+ - sampling, aliasing, discretization errors, A/D & D/A conversion
	+ - pulse width modulation approaches to control
	+ - programming languages: C++ , microprocessor development systems: ATMEL Mega32

**Contribution of course to meeting MAE/ABET curriculum requirements:** This is one of three courses that can be used to satisfy the ME electrical circuits requirement. This course partially fulfills the requirement to complete two upper level MAE courses as a Major Approved Elective (if not used to fulfill electrical circuits requirement). It contributes engineering sciences and engineering design topics to the curriculum and contributes to the realization of physical systems in the mechanical systems area.

**Outcome Assessment:** A review of the two prelims, the final project and final exam will be utilized to determine to which students mastered the subject. In addition to this traditional approach of measuring student learning, a questionnaire will be distributed to the student to determine how the students feel about what they have learned from this course. The questionnaire will be specific with regard to areas of learning and which learning methodologies were most effective.

**Person(s) who prepared this description and date of preparation:**

Ephrahim Garcia, 22 April 2010

E. Tompkins (added Major Approved Elective note), 3/19/15

Yang Xie, (updated recommended textbook and additional reference books), 12/23/2015

**MAE 4020/4021/5020: Wind Power**

**4020: 3 cr.; 4021: 4 cr.; 5020: 3 cr.**

**Contact Hours:** Two 75-minute lectures each week.

**Instructors:** Rebecca Barthelmie and Zellman Warhaft

**Textbook(s) and/or other required material:**

*Wind Energy Explained: Theory, Design and Application,* J. F. Manwell, J.G. McGowan and A. I. Rogers, 2nd Edition, or *Aerodynamics of Wind Turbines,* M.O.L. Hansen

**Course (catalog) description:** Fall. 3 credits

Main features of energy conversion by wind turbines. Emphasis on characterization of the atmospheric boundary layer, aerodynamics of horizontal axis wind turbines, and performance prediction. Structural effects, power train considerations, siting and wind farm planning.

**Prerequisite(s):** MAE 3230 (Introductory Fluid Mechanics) or equivalent or MAE 3050 (Introduction to Aeronautics), MAE 3250 (Analysis of Mechanical and Aerospace Structures).

**Designation as a ‘Required’ or ‘Elective course:** Elective

**Course learning outcomes:**

On completion of this course, students should:

1. Understand the need for carbon-free energy production and the functions of wind turbines (ABET outcomes f and j)
2. Be able to calculate mean wind fields (ABET outcomes a and b)
3. Analyze the aerodynamics of wind turbine blades (ABET outcome a)
4. Predict efficiency of energy extraction (ABET outcomes a, e, and k)
5. Understand the basics of electrical generators and mechanical to electrical energy conversion (ABET outcomes a and e)
6. Know how to choose sites for turbines and wind farms (ABET outcomes a and e)
7. When MAE 4021 is taken, demonstrate the ability to design a wind power system or component (ABET outcome c)

**Topics covered:**

* Introduction. World and national energy demand. Global environmental impact: the

 greenhouse effect and greenhouse gases.

* Characterization of the wind: Generation of planetary winds. The atmospheric boundary layer, and atmospheric turbulence. Flow over terrain. Geographical distribution of mean wind, and statistical characteristics at given locations.
* Aerodynamics of wind turbines: Actuator disc analysis. Inclusion of wake rotation. Airfoils. Blade element analysis. Wind shear and unsteady effects.
* Loading of rotor structure and mechanical response. Aeroelastic response, Vibrations, fatigue. Tower loads.
* Wind turbine siting. Offshore installations. Turbine wakes, and wind farm layouts.

**Contribution of course to meeting MAE/ABET curriculum requirements:** This course partially fulfills the requirement to complete two upper level MAE courses as a Major Approved Elective. It may also be used to fulfill the Technical Elective requirement. The Senior Design version of this course, MAE 4021, can fulfill the Senior Design Elective.

**Outcome Assessment:**

* Knowledge of fundamental principles is assessed by homework assignments, two prelims, and a final examination
* Competence in problem identification, formulation, and solution will be assessed by open ended problem assignments
* Competence in use of techniques and tools of modern engineering practice will be assessed by ability to employ computational tools such as software distributed by NREL
* At the end of the course, students will be asked to complete the course evaluation form supplied by the College, with supplementary questions.

**Person(s) who prepared this description and date of preparation:**

Sidney Leibovich

April 11, 2007

Updated March, 2009

Z. Warhaft, 3/19/15

Updated April 18, 2016

Rebecca J Barthelmie

**MAE 4060: Introduction to Spaceflight Mechanics**

**3 credits**

**Contact Hours:** Three 50-minute or two 75-minute lectures per week.

**Instructor:** Dmitry Savransky

**Textbook(s) and/or other required material:**

* *Space Mission Engineering: The New SMAD (Space Technology Library, Vol. 28*, Microcosm Inc., 2011, or equivalent
* *Course Notes on Propulsion and Attitude Control Technologies*

**Optional:**

* P. Hughes, *Spacecraft Attitude Dynamics*, ISBN 0486439259
* W. Weisel, *Spacecraft Dynamics*: Third Edition, ISBN 1452879591
* D. Vallado, *Fundamentals of Astrodynamics and Applications*, 4th ed., ISBN 1881883183

**Course (catalog) description:** Fall. 3 credits.

Introduction to spacecraft orbit mechanics, attitude dynamics, and the design and implementation of spaceflight maneuvers for satellites, probes, and rockets. Topics in celestial mechanics include orbital elements, types & uses of orbits, coordinate systems, Kepler’s equation, the restricted three-body problem, interplanetary trajectories, the rocket equation and staging, Clohessy-Wiltshire equations and relative formation flight, drag and orbital decay, and propulsive maneuvers. Topics in attitude dynamics include kinematics, Euler’s equations, stability of spinning spacecraft, attitude perturbations such as gravity-gradient and magnetic torques, equations of motion of rigid spacecraft with momentum actuators and thrusters, attitude maneuvers such as nutation control and reorientation, low-speed fluid behaviors, and elementary feedback control of linearized attitude and orbit dynamics. Principles of spacecraft propulsion technology and attitude-control technology are introduced. Discussions of current problems and trends in spacecraft operation and development.

**Prerequisite(s):** MATH 2930, MATH 2940, and MAE 2030, or permission of instructor.

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Course learning outcomes:**

Upon completion of the course, students should be able to:

1. Students will understand the fundamentals of spaceflight mechanics, and how high-level mission requirements drive the design of orbits and attitude for contemporary spacecraft (ABET outcome c);
2. Students will understand the application of Kepler’s laws for orbital motion, how to propagate an orbit, and calculate parameters associated with mission operations, including launch, insertion, and interplanetary transfers (ABET outcomes a and e);
3. Students will understand the application of Euler’s equations for rigid-body motion to spacecraft dynamics, attitude representations, attitude kinematics, how to predict and model spacecraft attitude motions, and how to achieve desirable attitude-dynamics behaviors (ABET outcomes a and e);
4. Students will be able to simulate a spacecraft in orbit using state of the art tools and identify and characterize the astrodynamics capabilities of a preliminary spacecraft design (ABET outcomes a, e and k).

**Topics covered:**

* Two Body Problem
* Orbital Elements
* Kepler's Laws
* Orbital Perturbations
* Orbital and Interplanetary Transfers
* Propulsion Systems; Launch Vehicles
* Attitude Representations
* Attitude Kinematics
* Euler’s Equations
* Attitude Determination and Control Systems, Actuators, and Sensors

**Contribution of course to meeting MAE/ABET curriculum requirements:** This course partially fulfills the requirement to complete two upper level MAE courses as a Major Approved Elective. It can be used to fulfill the Technical Elective requirement.

This course has been designed to anticipate MAE 4160/4161/5160, a follow-on course in spacecraft technology that uses the same text.

**Outcome Assessment:**

* Each student's knowledge of fundamental principles is assessed by examination questions.
* Each student's competence in problem identification and formulation is assessed by open-ended exam questions, short in-class quizzes, and by short design problems assigned as individual homework.
* Each student’s ability to apply knowledge of engineering and ability to communicate is assessed using a project in the areas of space systems, science, or engineering.
* Instructor’s ability to present each individual discipline is assessed using several focused questionnaires spread throughout the semester.
* Instructor’s individual lectures are self-evaluated after each lecture, and summarized at the end of the semester.
* Instructor’s ability to present the knowledge for learning is assessed using year-end evaluations.

**Person(s) who prepared this description and date of preparation:**

Mark Campbell, Lynette Gelinas, 1/8/04 (was MAE 306)

Mason Peck, 1/9/07 (was MAE 3060)

Mason Peck, 8/21/14

Dmitry Savransky, 4/19/16

**MAE 4120/4121: Community Wind Energy Research**

**4020: 1 cr.; 4121: 4 cr.**

**Contact Hours:** Two 1 hour 15 minute lectures per week for 6 weeks, followed by intensive engagement in a comprehensive design project (in both the laboratory and field) with bi-weekly project discussion sessions.

**Instructor:** Rebecca Barthelmie

**Textbook(s) and/or other required material:**

*AWEA Wind Energy Siting Handbook* by Tetratech Available for download from; http://www.awea.org/Issues/Content.aspx?ItemNumber=5726

or

*Wind Energy Meteorology* by Stefan Emeis, Springer ISBN: 978-3-642-30522-1 (Print) 978-3-642-30523-8 (Online)

**Course (catalog) description:** Spring 3 credits 4120, 4 credits 4121 (senior design version)

This is a project based design course. Students will be instructed in the tools and techniques used in planning and developing wind farms and then will work in teams building their own projects focused on an aspect of data collection (atmospheric, environmental, acoustic, wind turbine) and/or analysis at a local wind farm or wind energy facility. Projects can include developing and deploying new sensors, modeling and data comparison, deploying existing instrumentation in a new configuration or for a particular campaign. The projects must be of utility to the wind farm and /or the surrounding community. All students engage in a 2-4 person wind farm design project. In addition, MAE 4121 students undertake this project with the reporting expectations of a senior-design project. If used to fulfil the senior design requirement it must have a significant mechanical engineering design component.

**Prerequisite(s):** MAE 4020 or EAS 2500 or consent of instructor

**Designation as a ‘Required’ or ‘Elective course:** Elective

**Course learning outcomes:**

On completion of this course, students should:

1. Understand scientific/engineering /environmental issues in developing/operating a wind farm (ABET outcomes a and j)
2. Understand the fundamentals of operation and deployment of atmospheric, acoustic and environmental measurements (ABET outcomes a, b, and j)
3. Demonstrate an ability to select and use the techniques and engineering tools necessary to design a project to address their research goals (ABET outcomes b, c, e, and g)
4. Be able to analyze and present their data as a technical report describing their project and make clear and effective technical presentations and to scientific and general audiences (ABET outcomes b and g)

**Topics covered**

* Fundamentals of in situ and remote sensing atmospheric instrumentation
* Introduction to acoustic and environmental monitoring
* Wind farm SCADA data and wind farms measurements/monitoring
* Field work and professional good practice
* Project design and implementation
* Development of skills in data analysis and wind farm modeling tools
* Effective presentation: Communicating results to specialist and non-specialist audiences

**Contribution of course to meeting MAE/ABET curriculum requirements:** This course partially fulfills the requirement to complete three upper level MAE courses as a Major Approved Elective. With an optional design project, with a significant mechanical engineering component and meeting the reporting expectations of a senior-design project , it can serve as a senior design elective, MAE 4121.

**Outcome Assessment:**

* Knowledge of fundamental principles will be assessed by a mid-term exam
* Competence in problem identification, formulation, and solution will be assessed by assessment of project design
* Competence in use of instruments or tools of modern engineering practice will be assessed by demonstrated ability to employ computational tools such as software distributed by NREL, WAsP or in field based data collection as documented in the design project report
* Competence in communication will be assessed by a presentation of project results to a general audience at an event organized in collaboration with external partners .
* At the end of the course, students will be asked to complete the course evaluation form supplied by the College, with supplementary questions.

**Person(s) who prepared this description and date of preparation:**

Professor and Croll Faculty Fellow Rebecca J Barthelmie

April 18, 2016

MAE 4130/4131: Mechanics of Composite Structures

4130: 3 cr.; 4131: 4 cr.

**Contact Hours:** Two 75 minute sessions every week (Tues, Thurs). The Tuesday session is a lecture. The Thursday session is designed as a recitation section to introduce the laboratory or to review material. Students will schedule lab sessions on their own to perform the laboratory projects.

**Instructor:** Matthew Miller

**Textbook(s) and/or other required material:**

Text: *Mechanics of Fibrous Composites*, Herakovitch, Wiley, 1998

Software: Cambridge Engineering Selector (purchased during MAE 2120)

**Course (catalog) description:** Fall. 4130: 3 credits, 4131 (senior design version): 4 credits

Covers the fundamentals of mechanical analysis and material selection for composite materials. Topics include an overview of composite types, advantages, applications and fabrication; anisotropic elasticity; specific composite constitutive equations including plane stress and lamination theory; failure analysis; boundary value problems using composite materials; experimental methods and an introduction to micromechanics. Lectures cover essential background material and theoretical developments. Labs provide hands-on experiences for understanding composite materials properties and performance.

**Prerequisite(s):** MAE 2120 and MAE 3250, rigidly enforced.

**Designation as a ‘Required’ or ‘Elective course:** Elective

**Course Learning Outcomes:**

On completion of this course, students should:

1. Understand the advantages, the potential applications and the fabrication methods associated with several classes of composite materials (ABET outcomes c, h, j);
2. Be able to conduct critical mechanical analyses associated with the deformation and failure of composites accounting specifically for characteristic property anisotropy (ABET outcomes a, e, k);
3. Be able to approximate composite mechanical properties based on properties of constituent phases. Understand mechanical tests employed to measure composite properties (ABET outcomes a, b, e);
4. Be able to properly select composite materials for mechanical designs and to understand the advantages and liabilities of employing composites over monolithic materials (ABET outcomes a, c, j, k);

**Topics covered:**

* Overview of composite materials, their applications and synthesis.
* Mechanics review: stress & strain tensors, transformations, principal values, stress equilibrium, compatibility
* Anisotropic elasticity
* Experimental methods for determining composite properties
* Constitutive models including lamination theory
* Solution methods for boundary value problems using composite materials
* Failure analysis
* Determination of composite properties using micromechanics

**Contribution of course to meeting the professional component:** This course partially fulfills the requirement to complete two upper level MAE courses as a Major Approved Elective. The course may be used to fulfill the Technical Elective requirement. The Senior Design version of this course, MAE 4131, can fulfill the Senior Design Elective.

**Outcome Assessment:** Outcomes will be assessed using homework assignments, lab exercises, prelim and final examinations.

**Person(s) who prepared this description and date of preparation:**

Matt Miller – 10/1/2012

E. Tompkins, 3/19/15

**MAE 4140: Mechanics of Lightweight Vehicles**

**(no longer taught; last taught Fall 2014)**

**3 credits**

**Contact Hours:** Two 50 minute lectures weekly; one 90 minute laboratory weekly

**Instructor:** Paul Dawson

**Textbook(s) and/or other required materials:**

*Fundamentals of Automobile Body Structure Design*, Donald E. Malen, Society of Automotive Engineers, 2011.

Several other textbooks are on library reserve but are not required.

**Course (catalog) description:** Fall. 3 credits.

Combined lecture and laboratory course covering fundamentals of vehicle mechanics for several classes of vehicles (bicycles, light cars, airframes). Topics include: summary of types of vehicle structures; review of pertinent aspects of mechanical behavior including elastic and inelastic responses; static and dynamic behavior of vehicles under elastic loading; and mechanics of crashworthiness. Lectures cover essential background material for understanding of vehicle mechanics; laboratories provide hands-on experiences in the major components of the course.

**Prerequisite(s):** MAE 2120 (Mechanical Properties and Selection of Engineering Materials), 3250 (Analysis of Mechanical and Aerospace Structures) and 3272 (Mechanical Property and Performance Laboratory) or equivalent. Programming in MATLAB. Equivalent to this set of courses: senior standing in MAE.

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Course learning outcomes:**

Upon completion of this course, students should be able to:

* Perform analyses of the mechanical responses of tubular and semimonocoque vehicle structures under static and dynamic loadings (ABET outcomes a and k)
* Perform bound analyses of the inelastic collapse behavior of vehicle structures associated with crashworthiness (ABET outcomes a, j and k])
* Conduct experiments to measure the collapse vehicle structures, the mechanical response of vehicle structures under static and oscillatory loading, and the mechanical properties of materials used to build vehicle structures. (ABET outcomes b, g, k)

**Topics covered:**

* Mechanical performance of vehicle structural types: frames, semimonocoque and monocoque,
* Review of mechanical properties associated with stiffness and strength
* Modal analyses of dynamic loading of tubular vehicular structures,
* Stress analyses for airframe (semimonocoque and monocoque) structures,
* Bounding analyses for collapse response associated with crashworthiness.

**Contribution of course to meeting MAE/ABET curriculum requirements:**  This course partially fulfills the requirement to complete two upper level MAE courses as a Major Approved Elective. The course may be used to fulfill the Technical Elective requirement. The Senior Design version of this course, MAE 4141, can fulfill the Senior Design Elective.

**Outcome Assessment:** Assessment consists of two components: a critique of the student performance on topical exercises respect to stated outcomes and exit survey to determine aspects of the course that were most and least successful.

**Person(s) who prepared this description and date of preparation:**

Paul Dawson, 20 June 2013.

E. Tompkins (added contribution to curriculum requirements) 3/19/15

**MAE 4141: Mechanics of Lightweight Vehicles**

**(no longer taught; last taught Fall 2014)**

**4 credits**

**Contact Hours:** Two 50 minute lectures weekly; one 90 minute laboratory weekly; one 50 minute design team meeting weekly.

**Instructor:** Paul Dawson

**Textbook(s) and/or other required materials:**

*Fundamentals of Automobile Body Structure Design*, Donald E. Malen, Society of Automotive Engineers, 2011.

Several other textbooks are on library reserve but are not required.

**Course (catalog) description:** Fall. 4 credits.

Combined lecture and laboratory course covering fundamentals of vehicle mechanics for several classes of vehicles (bicycles, light cars, airframes). Topics include: summary of types of vehicle structures; review of pertinent aspects of mechanical behavior including elastic and inelastic responses; static and dynamic behavior of vehicles under elastic loading; and mechanics of crashworthiness. Lectures cover essential background material for understanding of vehicle mechanics; laboratories provide hands-on experiences in the major components of the course; design project provides an opportunity to apply course concepts toward novel ideas for improving performance of vehicle structures.

**Prerequisite(s):** MAE 2120, 3250 and 3272 or equivalent, MAE 4300 (pre-or co-requisite). Programming in MATLAB. Equivalent to this set of courses: senior standing in MAE.

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Course learning outcomes:**

Upon completion of this course, students should be able to:

* Perform analyses of the mechanical responses of tubular and semimonocoque vehicle structures under static and dynamic loadings (ABET outcomes a and k)
* Perform bound analyses of the inelastic collapse behavior of vehicle structures associated with crashworthiness (ABET outcomes a, j and k)
* Conduct experiments to measure the collapse vehicle structures, the mechanical response of vehicle structures under static and oscillatory loading, and the mechanical properties of materials used to build vehicle structures. (ABET outcomes b, g, k)

**Topics covered:**

* Mechanical performance of vehicle structural types: frames, semimonocoque and monocoque,
* Review of mechanical properties associated with stiffness and strength
* Modal analyses of dynamic loading of tubular vehicular structures,
* Stress analyses for airframe (semimonocoque and monocoque) structures,
* Bounding analyses for collapse response associated with crashworthiness.

**Contribution of course to meeting MAE/ABET curriculum requirements:**  This course may be taken to partially fulfill the design criteria of the ME major.

**Outcome Assessment:** Assessment consists of two components: a critique of the student performance on topical exercises respect to stated outcomes and exit survey to determine aspects of the course that were most and least successful.

**Person(s) who prepared this description and date of preparation:**

Paul Dawson, 20 June 2013

**MAE 4150/5150 GPS: Theory and Design**

**4 credits**

**Contact Hours:** Two 75-minute lectures each week. Labs meet nine times during the semester for2 hours and 30 minutes each.

**Instructor:** Mark Psiaki

**Textbook(s) and other required materials:**

*Global Positioning System Theory and Design, 3rd ed*, Kintner and Psiaki, text-style course packet, 2013.

*Global Positioning System, Signal, Measurements, and Performance,* Misra and Enge, Ganga-Jamuna Press, 2006

**Course (catalog) description:** Fall. 4 credits

Analysis of GPS operating principles and engineering practice with a culminating project. GPS satellite orbital dynamics, navigation data modeling, position/navigation/timing solution algorithm, receiver and antenna characteristics, analysis of errors and accuracy, velocity solutions, differential GPS.

**Prerequisite(s):** 3000-level engineering course with advanced math content (e.g., ECE 3030 or MAE 3260)

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Course Learning Outcomes:**

On completion of this course, students will have:

* An understanding of orbital mechanics with non-Keplerian perturbations and reference frames adequate to calculate GPS satellite positions in absolute and local coordinates (ABET outcomes a and k).
* An ability to use to use the GPS observables, their physical models, and the multi-variable version of Newton's nonlinear equation-solving method to calculate a navigation solution and a velocity solution (ABET outcomes a, e, and k).
* An understanding of the sources of ranging errors and how they map to navigation errors (ABET outcomes a and k).
* An ability to collect raw GPS data in a laboratory environment, to analyze its properties, including its noise properties, and to use it to derive useful position, navigation, timing, and velocity information (ABET outcomes b, e, and k).
* An ability to implement an advanced analysis or design solution to a GPS problem, test it experimentally, and effectively communicate the results in a final report (ABET outcomes a, b, c, e, g, and k).

**Topics covered:**

* Linear Algebra, the multi-variable Newton-Raphson method, linearization, and nonlinear least-squares estimation.
* Reference Frames: Earth-Centered Inertial and Earth-Fixed, WGS-84, local vertical/east/north, elevation and azimuth.
* Orbital Mechanics: Keplerian two-body solution, ephemerides, secular and harmonic corrections.
* The spread-spectrum signal, GPS observables (pseudorange, beat carrier phase, carrier Doppler shift), and the GPS navigation message.
* Navigation Algorithms: Position/clock-error solutions from pseudorange and beat carrier phase.
* Ranging Errors: Propagation in ionosphere and neutral atmosphere, multipath, thermal noise.
* Dilution of Precision: Mapping of ranging errors to navigation errors.
* Velocity/Clock-Error-Rate estimation based on Doppler shift measurements and nonlinear least-squares.
* Differential GPS methods to reduce ranging errors and improve accuracy.
* Design & Analysis Projects, including a suggested list with detailed descriptions and the possibility of other projects conceived by students.

**Contribution of course to meeting the MAE/ABET Curriculum Requirements:** This elective course can be used as a technical elective, a major approved elective, or an advisor approved elective.

**Outcome Assessment:** Outcomes will be assessed using graded homework assignments, graded pre-lab assignments, graded lab reports, 2 prelim examinations, a take-home final examination (MAE 5150 only), a final design or analysis project, and student comments on course evaluations. Separate evaluations of MAE 5150-specific metrics, i.e., the extra take-home final and the projects, will be used to assess whether the goal is achieved of having the MAE 5150 students learn the material better, on average, than the MAE 4150 students.

**Person(s) who prepared this description and date of preparation:**

Mark Psiaki 9/4/2013

**MAE 4160/4161/5160: Spacecraft Technology and Systems Architecture**

**4160: 3 cr.; 4161: 4 cr.; 5160: 4 cr.**

**Contact Hours:** Three 50-minute or two 75-minute lectures per week.

**Instructor:** Daniel Selva

**Textbook(s) and/or other required material:**

Wertz et al., Eds., *Space Mission Engineering: The New SMAD (Space Technology Library, Vol. 28*, Microcosm Inc., 2011, or equivalent

**Optional material:**

Fortescue et al., *Spacecraft Systems Engineering* (Wiley, 2011).

Griffin and French, *Space Vehicle Design, 2nd Ed.,* (AIAA, 2008)

**Course (catalog) description:** Spring. 3-4 credits.

A survey in contemporary space technology from satellite subsystem design through launch and mission operations, focusing on the classical subsystems of robotic and human-rated spacecraft, rockets, planetary rovers, and habitats, and with an emphasis on issues of spacecraft-system architecture and design. Includes a senior-design project option as MAE 4161. Includes an MEng project option as MAE 5160. Topics covered include subsystem technologies and the systems-engineering principles that tie them together into a spacecraft architecture. Subsystem technologies discussed include communications, thermal subsystems, structure, guidance/navigation/control, spacecraft power, space propulsion, payloads (remote sensing, in-situ sensing, human life support), entry/descent/landing, surface mobility, and flight-computer hardware and software. The final project consists of architecting a complete spacecraft system with appropriate subsystems, with designs supported by parametric analysis and simulation Discussions of current problems and trends in spacecraft operation and development. MAE 4160 students (3 credits) engage in a 2-4 person space-system design project. MAE 4161 students undertake this project with the reporting expectations of a senior-design project. MAE 5160 students (4 credits) also conduct an in-depth study of a space-technology problem to be integrated with a space-system design project.

**Prerequisite(s):** MAE 3260 and MAE 4060, or permission of instructor.

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Course learning outcomes:**

Upon completion of the course, students should be able to:

1. Students will understand, at a higher systems level, space missions and systems, and how the space environment and mission requirements drive spacecraft design (ABET outcome c);

2. Students will understand the basic fundamentals of spacecraft subsystems, including propulsion, attitude determination and control, power, structures, thermal, communications, and command and data handling (ABET outcomes a and e);

3. Students will understand typical practices for designing space systems in a contemporary context of US commercial space and government agencies (ABET outcomes a and e);

4. Students will be able to simulate a spacecraft in operation using state of the art tools, and identify and characterize subsystems for a preliminary spacecraft design (ABET outcomes a, e and k).

**Topics covered:**

* Review of Orbit Mechanics and Attitude Dynamics
* Launch Vehicle, Satellite, Probe, Rover, and Human Space Vehicle Architectures
* Space Systems and Spacecraft Subsystem Engineering
* Commercial and Government Practices and Regulatory Issues
* Space Environment
* Propulsion Systems; Launch Vehicles
* Attitude Determination and Control
* Thermal
* Structure
* Communications
* Command and Data Handling
* Power
* Ground Systems

**Contribution of course to meeting MAE/ABET curriculum requirements:** This course partially fulfills the requirement to complete two upper level MAE courses as a Major Approved Elective. It can be used to fulfill the Technical Elective requirement. The Senior Design version of this course, MAE 4161, can fulfill the Senior Design Elective.

**Outcome Assessment:**

* Each student's knowledge of fundamental principles is assessed by examination questions.
* Each student's competence in problem identification and formulation is assessed by open-ended exam questions, short in-class quizzes, and by short design problems assigned as individual homework.
* Each student’s ability to apply knowledge of engineering and ability to communicate is assessed using a group project in the areas of space systems, science, or engineering.
* Instructor’s ability to present each individual discipline is assessed using several focused questionnaires spread throughout the semester.
* Instructor’s individual lectures are self-evaluated after each lecture, and summarized at the end of the semester.
* Instructor’s ability to present the knowledge for learning is assessed using year end evaluations.

**Person(s) who prepared this description and date of preparation:**

Mason Peck, 9/20/14

E. Tompkins, 3/19/15

**MAE 4180/CS 3758: Autonomous Mobile Robots**

**3 credits**

**Contact Hours:** Two 75-minute lectures each week. Labs meet every third week for 2.5 hours.

**Instructor:** Hadas Kress-Gazit

**Textbook(s) and/or other required material:**

 *Introduction to Autonomous Mobile Robots,* R. Siegwart and I. Nourbakhsh, MIT Press 2004.

 *Planning Algorithms*, S. LaValle, Cambridge University Press, 2006.

**Course (catalog) description:** Spring. 3 credits.

Creating robots capable of performing complex tasks autonomously requires one to address a variety of different challenges such as sensing, perception, control, planning, mechanical design, and interaction with humans. In recent years many advances have been made toward creating such systems, both in the research community (different robot challenges and competitions) and in industry (industrial, military, and domestic robots). This course gives an overview of the challenges and techniques used for creating autonomous mobile robots. Topics include sensing, localization, mapping, path planning, motion planning, obstacle and collision avoidance, and multi-robot control.

**Prerequisite(s):** MATLAB programming experience.

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Course learning outcomes:**

On completion of the course, students should:

1. 1. Understand and implement localization and mapping algorithms using different sensor modalities. (ABET outcomes a, c and j)
2. 2. Be able to generate a path and the motion for a robot moving around an area with obstacles. (ABET outcomes a and c)
3. 3. Understand the concepts of different approaches for motion planning such as roadmaps, feedback control and sampling based methods. (ABET outcomes a and j)
4. 4. Understand and implement collision avoidance algorithms. (ABET outcomes a and c)
5. 5. Be able to apply the tools learned in the class to physical robots (ABET outcomes a and k)

**Topics covered:**

* Robots : Reference frames
* Sensors
* Actuators
* Kinematic models
* Locomotion
* Sensing and perception : Localization (beacons, range measurements, vision)
* Intro to Kalman Filter
* Simultaneous Localization and Mapping (SLAM)
* Planning and control : Path and motion planning
* Obstacle avoidance
* Roadmaps, Voronoi decomposition
* Bug algorithms
* Navigation functions
* Sampling based methods
* Multi-robot: Centralized Vs decentralized
* Collision avoidance
* Swarms

**Contribution of course to meeting MAE/ABET curriculum requirements:** This course can be used to partially fulfill the requirement to complete two upper level, Major Approved Elective courses or it can be used to fulfill the Technical Elective requirement. It contributes to engineering design and to the realization of physical systems in the mechanical systems area.

**Outcome assessment:** Outcome will be assessed using graded homework assignments, graded lab exercises and a final course project.

**Person who prepared this description and date of preparation:**

Hadas Kress-Gazit, 11/6/2009

E. Tompkins, 4/23/15 (made changes to match Courses of Study)

**MAE 5180, Autonomous Mobile Robots**

**4 credits**

**Contact Hours:** Two 75-minute lectures each week. A total of 5 labs, each 2.5 hours long:

1. Introduction to controlling the iRobot Create

2. Localization

3. Mapping

4. Potential field motion planning

5. Sampling-based motion planning

**Instructor:** Hadas Kress-Gazit

**Textbook(s) and/or other required material:**

S. Thrun, W. Burgard, and D. Fox, *Probabilistic Robotics*, MIT Press, 2005.

H. Choset, K. M. Lynch, S. Hutchinson, G. Kantor, W. Burgard, L. E. Kavraki and S. Thrun,

*Principles of Robot Motion: Theory, Algorithms, and Implementations*, MIT Press, Boston,

2005.

**Course (catalog) description:** Spring. 4 credits.

Creating robots capable of performing complex tasks autonomously requires one to address a variety of different challenges such as sensing, perception, control, planning, mechanical design, and interaction with humans. In recent years many advances have been made toward creating such systems, both in the research community (different robot challenges and competitions) and in industry (industrial, military, and domestic robots). This course gives an overview of the challenges and techniques used for creating autonomous mobile robots. Topics include sensing, localization, mapping, path planning, motion planning, obstacle and collision avoidance, and multi-robot control.

The course includes a lab portion in which students program the iRobot Create.

**Prerequisite(s):** Senior or Graduate standing. Juniors need permission of instructor. Good

knowledge of programming (MATLAB) is essential for the homework and labs.

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Course Learning Outcomes:**

On completion of the course, students should:

1. Understand and implement localization and mapping algorithms using different sensor modalities. (ABET outcomes a, c and j)

2. Be able to generate a path and the motion for a robot moving around an area with obstacles. (ABET outcomes a and c)

3. Understand the concepts of different approaches for motion planning such as roadmaps, feedback control and sampling based methods. (ABET outcomes a and j)

4. Be able to apply the tools learned in the class to physical robots (ABET outcomes a and k)

**Topics covered:**

* Introduction and motivation
* Robots :
* Reference frames
* Sensors
* Actuators
* Kinematic models
* Locomotion
* Sensing and perception :
* Localization (beacons, range measurements, vision)
* Intro to Kalman Filter
* Particle Filter
* Mapping
* Simultaneous Localization and Mapping (SLAM)
* Planning and control :
* Path and motion planning
* Roadmaps, Voronoi decomposition
* Bug algorithms
* Navigation functions
* Sampling based methods
* Multi-robot:
* Centralized Vs decentralized
* Collision avoidance
* Swarms

**Contribution of course to meeting the requirements of Criterion 5 (curriculum):**

This course can be used to partially fulfill the requirement to complete two upper-level, Major Approved Elective courses or it can be used to fulfill the Technical Elective requirement. It contributes to engineering design and to the realization of physical systems in the mechanical systems area.

**Outcome assessment:** Outcome will be assessed using graded homework assignments, graded lab exercises and a final course project which requires the students to program the robot to complete a mission in a physical environment.

**Relationship to MAE 4180/CS 3758**: This course includes two more labs, larger homework sets

and a final project with the physical system (not simulation).

**Person who prepared this description and date of preparation:**

Hadas Kress-Gazit 10/6/12
E. Tompkins, 4/23/15 (made changes to match Courses of Study)

**MAE 4230/4231/5230: Intermediate Fluid Dynamics**

**4230: 3 cr.; 4231: 4 cr.; 5230: 4 cr**

**Contact Hours**: Three 50-minute lectures each week. One 50-minute section for students enrolled in 5230.

**Instructor:** Olivier Desjardins

**Textbook(s) and/or other material:**

MAE4230/5230 Intermediate Fluid Dynamics course pack, B.J. Kirby

*Elementary Fluid Dynamics*, D. J. Acheson, or similar texts.

**Course (catalog) description:** Spring. 3 credits (4230) or 4 credits (5230).

This course builds on the foundation of MAE 3230. Emphasis is placed on both the fundamental principles and numerical calculation of real flows using a computational fluid dynamics package. Topics covered include inviscid and viscous flows at different regimes of Reynolds number. The examples will be related to engineering and environmental applications.

**Prerequisite(s):**

MAE 3230 (Introductory Fluid Mechanics) or CEE 3310/BEE 3310 or CHEME 3230 or permission of instructor.

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Course learning outcomes:**

Upon completion of this course, students should:

1. understand the derivation and physical meaning of the conservation equations (ABET outcome a);
2. be able to derive analytical solutions to simplified problems (ABET outcome a and e);
3. understand the underlying models in ANSYS/FLUENT (ABET outcome i and k);
4. be able to apply ANSYS/FLUENT to solve a range of problems (ABET outcome e and k);
5. understand numerical errors and the limitations of CFD (ABET outcome i and k).
6. demonstrate the ability to design a component using CFD analysis in ANSYS/FLUENT (ABET outcome c).

**Topics covered (asterisk indicates optional topics):**

* Mathematical Preliminaries
* Navier-Stokes equation and Conservation laws
* Flows in Nature and in Engineering systems
* Analytical Solutions of Flows in Special cases, e.g., Pipe flow, Boundary layer, Potential flow
* Introduction to Computational Fluid Dynamics
* Introduction to ANSYS/FLUENT
* Solving Engineering Flow problems using ANSYS/FLUENT
* Introduction to Turbulence

**Contribution of course to meeting MAE/ABET curriculum requirements:**

This course can be used to partially fulfill the Major Approved Elective or to fulfill Technical Elective requirement. The Senior Design version of this course, MAE 4161, can fulfill the Senior Design Elective.

**Outcome Assessment:**

12 homeworks, two preliminary exams, one final exam, weekly quiz; Student surveys (conducted at the beginning and in the middle of the semester); Standard course evaluation at end of semester (electronic); FLUENT-based design project (5230 only).

**Person(s) who prepared this description and date of preparation:**

Lance R. Collins, 2004

Updated by Brian J. Kirby, 29 Oct 2009

Updated by Z. Jane Wang, 9 Dec 2010

Updated by Olivier Desjardins, 3 June 2015

**MAE 4250: FSAE Automotive Design Project**

**2, 3, or 4 credits**

**Contact Hours:** Flexible and variable; typically 10-20 hours per week.

**Instructor:** Al George

**Textbook(s) and/or other required material:**

None, but a full paper and electronic library of books, papers, and reports kept in the FSAE class office. Extensive reading and study of these resources required.

**Course (catalog) description:** Fall, spring. Usually 3 credits: 3 for team members or 4 for team leaders. Counts as “Senior Design Elective” if M.E. seniors enroll in corresponding section of MAE 4291.

Project course to research, design, build, develop, and compete with a Formula SAE car for intercollegiate competition. Students work in interdisciplinary teams using concurrent engineering and systems engineering principles applied to complex mechanical, electromechanical, and electronic systems.

**Prerequisite(s):** Engineering juniors and seniors or permission of instructor

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Course learning outcomes:**

On completion of the course, students should:

1. Have learned and be able to apply mathematical, engineering, and communication skills and tools. Be able to solve problems, and function in a professional environment. Be able to learn how to learn information not covered in formal courses one has taken (ABET outcomes a, e, g, i and k).
2. Be able to design vehicles that will win the Formula SAE competition. This requires an engineering systems view: consider the customers, requirements, functions, structure and implementation. To learn how to maximize the points the team will win in the competition: trading off cost, time, technology, training, etc. (ABET outcomes b, c, f and h).
3. Developed an enjoyment of engineering and the team (ABET outcome d), and;
4. Have created conditions for future teams to be able to win via learning how to utilize engineering research and knowledge engineering (ABET outcomes f and h).

**Topics covered:**

* Automotive Engineering, Systems Engineering
* Design Problems
* Obtaining Sponsorship, Budget Planning and Administration
* Manpower and Project Planning and Re-planning
* Skills Training: Analysis, CAD, CAM, Design, Machining, Welding, Driving, Data Acquisition, etc.
* Preliminary Design and Review
* Mockup and Concept Testing
* Secondary Design and Review
* Final Design and Review
* Manufacturing Planning and Review
* Manufacturing
* Test and Development
* Operational Planning
* Competition Readiness
* Operational Organization and Training
* Competition
* Report Writing

**Contribution of course to meeting MAE/ABET curriculum requirements:** This course partially fulfills the requirement to complete two upper level MAE courses as a Major Approved Elective. It can be used to fulfill the Technical Elective requirement.

**Outcome Assessment:** Evaluation of required technical and required personal reflection papers written at end of term, evaluation of performance and documentation in required design reviews and meetings, evaluation of performance and outcomes in assigned project and development work as judged by faculty and by team’s student leaders, and on-line course improvement surveys.

**Person(s) who prepared this description and date of preparation:**

Al George 2/15/04

Updated 4/6/2010

Updated 6/1/2015

**MAE 4272: Fluids/Heat Transfer Laboratory**

**3 credits**

**Contact Hours:** One 75-minute lecture every other week. One laboratory or recitation for 2.5 hours each week.

**Instructors:** Charles Williamson and Max Zhang

**Textbook(s) and/or other required material:**

MAE 4272 Laboratory Manual, C.H.K. Williamson and M. Zhang (2015)

**Course (catalog) description:** Fall. 3 credits. Fulfills the technical communication requirement.

Laboratory exercises in fluid mechanics and the thermal sciences. Measurements of flame temperature, pressure, heat transfer, viscosity, lift and drag, fluid-flow rate, effects of turbulence, airfoil stall, flow visualization, and spark ignition engine performance. Instrumentation, techniques, and analysis and interpretation of results. Biweekly written assignments with extensive feedback.

**Prerequisite(s):** M&AE 3230 (Introductory Fluid Mechanics), 3240 (Heat Transfer).

**Designation as a ‘Required’ or ‘Elective’ course:** Required

**Course learning outcomes:**

On completion of the course, students should:

1. Have had experience in performing diverse experiments in fluid mechanics and the thermal sciences; extensive analysis of data (ABET outcome b);
2. Be familiar with instrumentation for fluids and thermal science experiments (ABET outcomes b and k);
3. Have had experience in applying concepts from junior-year fluid mechanics and heat transfer classes (ABET outcome a);
4. Be able to analyze experimental results and their uncertainties, and interpret them; and also to communicate these interpretations effectively (ABET outcomes b and g);
5. Be able to use graphics and words to present and discuss experimental results effectively (ABET outcome g);
6. Have had practice and feedback on Engineering Communication (ABET outcome g);
7. Have had experience working on a team to collect experimental data (ABET outcome d).

**Topics covered:**

* Engine Performance
* Forced Convection
* Flame Temperature
* Measurement of viscosity, and transition to turbulence.
* Wake Interference and Drag Reduction
* Airfoil Stall

**Contribution of course to meeting MAE/ABET curriculum requirements:** This course satisfies the Common Curriculum Engineering Communication requirement and partially fulfills the fluids and thermal science track of the ME major.

**Outcome Assessment:**

Three methods are used to evaluate how well course objectives are met: (1) The course structure and content of assignments are reviewed in the 4272 assessment report to guarantee that goals 1, 3, 6, and 7 have been met; (2) Grades on individual parts of assignments are tracked during the semester and reported in the 4272 assessment report in order to evaluate the success of the course for the other goals; (3) End-of-semester student evaluations provide further information.

**Person(s) who prepared this description and date of preparation:**

Charles Williamson, 3/16/2015

**MAE 4300: Professional Practice in Mechanical Engineering**

**2 credits**

**Contact Hours:** One lecture per week, 1.5 hours; lectures by both instructor and guest speakers.

**Instructor:** John Callister

**Textbook(s) and/or other required material**:

Course pack

**Course (catalog) description**: Fall. 2 credits. letter grades only.

Professional practice and broader impacts of the mechanical engineering profession are presented through a series of lectures and invited talks, supplemented by assignments and projects. Topics include: professional ethics, product liability, intellectual property, career/educational paths, contemporary issues facing mechanical engineers, and engineering successes and failures, along with the global, societal, environmental and/or economic aspects and impact of engineering.

**Prerequisite(s)**: Senior standing in M&AE or permission of instructor.

**Designation as a ‘Required’ or ‘Elective’ course**: Required

**Course learning outcomes:**

On completion of the course, students should:

1. be aware of diverse career/educational paths open to mechanical engineers (ABET outcome i).

2. be able to analyze the ethical and legal responsibilities of an engineer (ABET outcome f).

3. have an appreciation of the broader (global, societal, economic, and/or environmental) aspects and impact of engineering activities (ABET outcome h and j)

4. be aware of contemporary issues facing the engineering profession (ABET outcome j)

**Topics covered**:

* ASME code of ethics
* Ethics case studies
* Product liability
* Career/educational paths
* Intellectual property
* Broader impacts case studies
* Historical engineering success/failure case studies
* Selected contemporary issues in engineering

**Contribution of course to meeting MAE/ABET Curriculum Requirements**: This course, required of all seniors in ME, helps prepare students to enter the engineering profession. Societal impact, contemporary issues, ethics, and intellectual property are discussed in this course.

**Outcome assessment:** Student performance on written assignments will be monitored to address each outcome individually.

**Person(s) who prepared this description and date of preparation:**

Elisabeth M. Fisher, revised 03/17/2008

Alan Zehnder, revised 03/11/2010

John Callister, revised 03/30/2015

**MAE/ECE 4320: MicroElectro Mechanical Systems**

**ECE program outcomes (A-M)**

TheECE program should demonstrate that their graduates have:

(A) an ability to apply knowledge of mathematics, science, and engineering

(B) an ability to design and conduct experiments, as well as to analyze and interpret data

(C) an ability to design a system, component, or process to meet desired needs

(D) an ability to function on multi-disciplinary teams

(E) an ability to identify, formulate, and solve engineering problems

(F) an understanding of professional and ethical responsibility

(G) an ability to communicate effectively

(H) the broad education necessary to understand the impact of engineering solutions in a global

and societal context

(I) a recognition of the need for, and an ability to engage in life-long learning

(J) a knowledge of contemporary issues

(K) an ability to use the techniques, skills, and modern engineering tools necessary for

engineering practice.

(L) a knowledge of probability and statistics, including applications to electrical and computer engineering

(M) a knowledge of advanced mathematics, including discrete math

**Course Outcomes and Mapping to Program Outcomes (A-M)**

1. Be able to use point fabrication procedures into practical process integration (B, C, E, G, J, K)
2. Be able to use electrical measurements for MEMS mechanical structures (B, E, K)
3. Understand sufficient beam and plate mechanics to accomplish mechanical design aspects (A, D, M)
4. Quantitatively understand the limitation of surface micromachining and bulk micromachining in terms of structure and functionality (A, E)
5. Be able to estimate the force magnitude and power consumption in various actuation schemes, such as electrostatic, thermal, piezoelectric and magnetic. (A, C, E)
6. Be able to estimate the sensitivity and signal to noise ration in various sensing schemes, such as electrostatic, piezoresitive, piezoelectric and magnetic. (A, B, E)
7. Be able to map the system specification to realizable MEMS design and understand the tradeoff among different designs. (C, D, E, G, J, K, L)
8. Know the potential market and social impacts of each MEMS applications (C, D, F, G, H, I, J)

Emphasis of POs in lectures and laboratory (0=none, 1=minor, 2=substantial, 3=major)

A-3,B-2,C-3,D-2,E-3,F-1,G-3,H-1,I-1,J-2,K-2,L-1,M-1

 **Course Outcomes Example of Evidence (Achievement rating)**

|  |  |  |
| --- | --- | --- |
| 1(B,C,E,G,J,K) | HW3, Final | 3 |
| 2(B,E,K) | Lab 1 | 3 |
| 3(A,D,M) | HW6, Class process flow, Midterm | 3 |
| 4(A,E) | HW3,6, Final | 3 |
| 5(A,C,E) | HW3-6 | 3 |
| 6(A,B,E) | HW6 | 3 |
| 7(C,D,E,G,J,K,L) | Project 1, Final | 3 |
| 8(C,D,F,G,H,I,J) | Project 2, Lab 1 | 3 |

Course outcome achievement rating scale: 1 – not achieved, 2 – partially achieved, 3 – fully achieved

**Notes on course outcomes targeted for future improvement:**

|  |
| --- |
| **Better planning for labs and class-run process flow** |
| **Streamline electrostatics lectures to reduce lecture time** |
| **Inclusion of ANSYS simulations for structures – add ANSYS labs** |
|  |
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**Notes on course outcomes previously targeted for improvement:**

|  |
| --- |
| **Actuator schemes: Comparison of piezoelectrics, magnetics, and electrostatics – This was done** |
| **More realistic MEMS experience: Class developed process flow** |
| **Literature search: Project**  |
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**MAE 4340/4341/5340: Innovative Product Design via Digital Manufacturing
4340: 3 cr.; 4341: 4 cr.; 5340: 4 cr.**

**Contact Hours:** Open laboratory schedule mixed with lecture (MWF).

**Instructors:** Robert Shepherd and Sirietta Simoncini

**Textbook(s) and/or other required material:** None.

Website: blackboard.cornell.edu. Course information and handouts are posted on the website for download.

**Course (catalog) description:** Spring. 4130: 3 credits, 4131 (senior design version): 4 credits, 5340 (graduate version): 4 credits.

Combined lecture and laboratory course on the new product development cycle: iterative design based on ethnographic fieldwork, team brainstorming, prototyping, testing, consumer feedback, and the limitations set by mass manufacturing of the final product. This course will instruct students on methods to identify product concepts based on machine designs with commercial potential. Design teams will perform market analysis and explore the IP space around their own ideas and rapidly iterate them into a final prototype via digital manufacturing (e.g., 3D CAD files manifested via robotic printing or machining); advanced instruction on these tools will be given to build prototypes, and quantitative marketing will be used as feedback from them. Early stage prototypes will progress into more sophisticated designs as the class progresses. Scale-up (cost, pricing, tooling) considerations for mass manufacturing of these products will be taken into account, as well as quantitative analysis of their machine designs for their expected utility.

Graduate students will be required to expand and/or focus on some aspects of the process/products.

**Prerequisite(s):** Limited to M.E. Seniors and other M. Eng./Graduate Students. Prerequisite for Distance Learning M.Eng SYSEN students: SYSEN 5940).

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Course learning outcomes:**

On completion of the course, students should:

* + - 1. Experience the major impact of a human-centered design approach and understand the logic of the product development cycle in the context of a startup company and an established firm and communicate effectively in teams. (ABET outcomes a, c, d, f, h, j, g)
			2. Describe the limitations of early stage prototypes and the importance of staged development into more realistic prototypes. (ABET outcomes b, c, d, e, g, h, k)
			3. Identify product platforms for mechanical design with commercial potential (ABET outcomes c, d, e, f, h, j).
			4. Appreciation of Intellectual Property in terms of design and utility (ABET outcomes f, h, j).
			5. be familiar with basic tools of design and manufacturing such as CAD and digital manufacturing tools (ABET outcomes a, c, d, e, k);

**Topics covered:**

* + Ethnographic fieldwork (Human Centered Design approach)
	+ Mechanical design and prototyping
	+ Testing of designs
	+ Quantitative market analysis
	+ How to contact companies w/packet of interest/basic coverage of patent protection/incorporation strategies. Basics of raising money.

**Contribution of course to meeting MAE/ABET curriculum requirements:** This course partially fulfills the engineering design track of the ME major. This course can be used to partially fulfill the Major Approved Elective or to fulfill the Technical Elective requirement. The Senior Design version of this course, MAE 4341, can fulfill the Senior Design Elective.

**Outcome Assessment:** Outcomes are assessed through graded projects and exercises; student presentations; written and oral surveys.

MAE 4341 students will be required to complete an extra iteration on the product.

MAE 5340 students will be required to expand and/or focus on some aspects of the process/products.

**Person(s) who prepared this description and date of preparation:**

Robert F Shepherd

Sirietta Simoncini

07/07/2015

Robert F Shepherd, 4/21/16

**MAE 4351: Interdisciplinary Design Concepts**

(also MSE 4071, CHEME 5730)

**4 credits**

**Contact Hours:** Two 120-minute lectures per week.

**Instructors:** John Callister and Marty Murtagh

**Textbook(s) and/or other required material:**

1. Pfeifer M. *Materials Enabled Designs - The Materials Engineering Perspective to Product Design and Manufacturing*, Elsevier Inc., Burlington, MA, 2009.

2. Hauser J. R. and Clausing D.,*The House of Quality*, Harvard Business Review, 1988

3. Sayre R. J., *Understanding Patents and Managing Patent-Procurement Cost*, Am. Cer. Soc. Bull. Vol. 90, No. 3, pg. 24-29, 2009

4. Hankle W., *Business, Licensing and Intellectual Property Management*, Am. Cer. Soc. Bull. Vol. 90, No. 3, pg. 30-34, 2009

5. Ashby M. F., *Materials and the Environment: Eco-Informed Material Choice*, , Elsevier Science, Burlington, MA, 2009

6. Cooper R. G., *Winning at New Products – Accelerating the Process from Idea to Launch*, 3rd edition, 1993

7. Dieter G., *Engineering Design: A Materials and Processing Approach*, 2nd edition, McGraw-Hill College, 1991

**Course (catalog) description:** Spring. 4 credits.

This course emphasizes entrepreneurial driven technology designs (forward engineering) by integrating mechanical, chemical, and materials engineering through the understanding of early stage product development complexities. These complexities include staging invention and innovation via the critical selection of materials, assessing product mechanics and processes for final product function, performance, reliability, cost and technical and commercial marketability.

Students will attend lectures, participate in establishing a Tech Startup integrated into the Johnson School MBA mentoring program, attend startup design reviews, give a series of individual/group presentations, and write a startup issue paper.

M.E. students may not count both this class and MAE 4340 or 4341 towards B.S. graduation requirements in Mechanical Engineering.

**Prerequisites:** Senior standing.

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Course learning outcomes:**

On completion of this course, students should:

1. be able to describe and follow a structured product design process on a multi- disciplinary team (ABET outcomes c, d, k).

2. be able to provide written and oral communications in a business setting (ABET outcome g).

3. understand intellectual property and how IP leads to business opportunities (ABET outcome j).

4. understand how to design a product to meet the product requirements, and learn how the product requirements relate to the voice of the customer (ABET outcome c)

5. be able to apply advanced mechanical engineering coursework to a complex, open-ended engineering design problem (MAE/ABET outcomes a, and c)

**Topics covered:**

* Innovation staging
* House of Quality
* TRIZ: Theory of inventive problem solving
* Design Essentials: Introduction to product design
* Intellectual Property
* Design Essentials: External appearance, function, and use
* Design Essentials: Robust design (I and II)
* Design Essentials: Mechanical drawing
* Design Essentials: Cradle to grave considerations
* Design Essentials: Manufacturing, assembly, and fasteners
* Reliability
* Case Studies (each team)
* Design Reviews (each team, multiple sessions)

**Contribution of course to meeting MAE/ABET curriculum requirements:** This course complements the technical content of the curriculum and is consistent with the program and institution objectives. This course satisfies the Mechanical Writing engineering senior design requirement. Note that students may not count both this class and MAE

4340 or 4341 towards B.S. graduation requirements in Mechanical Engineering.

**Outcome Assessment:** The outcomes will be assessed using individual graded homework sets, an individual midterm examination, a group case study presentation, a group final presentation, a group final written issue paper, and a group design notebook.

**Person(s) who prepared this description and date of preparation:**

John Callister, 3/17/2015

**MAE 4510/5510: Aerospace Propulsion**

**4510: 3cr.; 5510: 4 cr.**

**Contact Hours:** Two 75-minute lectures or three 50-minute lectures each week.

**Instructor:** Elizabeth Fisher

**Textbook(s) and/or other required material:**

*Course Reading Packet,* available at Cornell Campus Store, or equivalent.

**Course (catalog) description:** Spring. 3 credits.

Introduction to propulsion, stationary power production with gas turbine engines, and reciprocating engines. Air-breathing propulsion is emphasized, with a brief treatment of rocket propulsion. Application of thermodynamic and fluid-mechanical principles to analysis of performance and design.

**Prerequisites:** required: ENGRD 2210 (Thermodynamics, also MAE 2210) and MAE 3230 (Introductory Fluid Mechanics) or equivalents; recommended: MAE 3050 (Introduction to Aeronautics)

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Course learning outcomes:**

Upon completion of this course, students should be able to:

* 1. Describe and interpret the types, characteristics, and performance measures of combustion engines used in propulsion, power generation, and road vehicles. (ABET outcome a);
	2. Understand the thermodynamic and fluid mechanical principles underlying their performance (ABET outcomes a and e);
	3. Predict how their performance depends on design parameters and operating conditions (ABET outcomes a and e);
	4. Describe the role of environmental and fuel considerations in their design. (ABET outcome h).

**Topics covered:**

* + Reciprocating engines
		- Engine types, terminology, operation
		- Performance measures
* Rocket engines and gas turbine aeroengines
	+ - Engine types, terminology, operation
		- Performance measures: aeroengines vs stationary power production
* Stationary gas turbines for power generation
	+ - Terminology, operation
		- Performance measures
* Thermodynamics topics
* Compressible flow: nozzles, one-dimensional shock waves
* Chemical equilibrium, adiabatic flame temperature
* Engine components/processes and thermodynamic cycles
* Review of basic ideal cycles: Otto, Diesel, Brayton
* Variations, e.g. Atkinson, Combined Rankine+Brayton, intercooling, afterburner
* Effects of real component/process efficiencies and real gas properties
* Parametric cycle analysis of ideal aeroengines
	+ - Fuels, combustion, and air pollution
		- Case studies and comparisons

**Contribution of course to meeting MAE/ABET curriculum requirements:** This course can be used to partially fulfill the Major Approved Elective or to fulfill Technical Elective requirement. It also can be used in the M.Eng. program.

**Outcome Assessment:** Grades on individual parts of assignments and exams are tracked during the semester and reported in order to evaluate how well course objectives are met.

**Person(s) who prepared this description and date of preparation:**

Elizabeth Fisher, 3/30/14.

**MAE/BEE 4530: Computer-Aided Engineering Applications to Biomedical Processes**

**3 credits**

**Contact Hours:** Two 50-minute lectures and one 50-minute lab each week (averaged over the semester).

**Instructor:** Ashim Datta

**Textbook(s) and/or other required material:**

*An Introduction to Modeling of Transport Processes: Applications to Biomedical Systems*

Datta, A. K. and V. Rakesh. 2010. Cambridge University Press, Cambridge, UK.

**Course (catalog) description:** Spring. 3 credits.

Introduction to simulation-based design as an alternative to prototype-based design; analysis and optimization of complex real-life processes for design and research, using industry-standard physics-based computational software. Emphasis is on problem formulation, starting from a real process and developing its computer model. Covers biomedical processes in thermal therapy and drug delivery that involve heat transfer, mass transfer, and fluid flow. Computational topics introduce the finite-element method, pre- and post-processing, and pitfalls of using computational software. Students choose their own semester-long biomedical project, which is the major part of the course (no final exam).

**Prerequisite(s):** Heat and Mass Transfer [BEE 350 (Biological and Environmental Transport Processes), ChemE 3240 (Heat and Mass Transfer), MAE 3240 (Heat Transfer) or equivalent].

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Course learning outcomes:**

Upon completion of this course, students should:

1. be able to identify and formulate engineering problems in heat and mass transfer in terms of a computer model using available software (ABET outcomes a, e and k);

2. be able to think of computer simulation as an important practical tool in design and research projects in the industry as well as academia (ABET outcomes a, e and k);

3. know the essential details of the components of a typical computer prototyping software (ABET outcome k);

4. have realistic ideas about the advantages and pitfalls of such a software (ABET outcome k).

5. know about the physical aspects of some biomedical processes in the area of thermal therapy (ABET outcomes a and e);

6. be comfortable in using such a tool to solve less complex problems (in heat and mass transfer) and in working with a group of experts in solving problems of increasing complexity (ABET outcomes e and k).

**Topics covered:**

* Problem formulation (starting from real physical processes, simplifying and developing the appropriate geometry, governing equation and boundary conditions)
* Pre-processing, processing and post-processing in a computational software
* Use of the software COMSOL to achieve the needs in modeling
* Model validation, sensitivity analysis and optimization
* Derivation of governing equations for flow, species mass balance and energy; Boundary conditions
* Heat and mass source terms--Introduction to microwave, radio frequency, laser and ultrasonic heating in biomedical context; measure of thermal damage
* Material property and other input parameters
* Numerical methods--1D Finite element method, solving the linear set of equations, errors in numerical solutions, convergence, accuracy in transient calculations
* Steps in biomedical design and its relationship to computing
* Report writing

**Contribution of course to meeting MAE/ABET curriculum requirements:** This course partially fulfills the requirement to complete two upper level MAE courses as a Major Approved Elective. It can be used to fulfill the Technical Elective requirement. It contributes engineering science and engineering design topics to the curriculum and contributes to the realization of physical systems in thermo-fluids systems area.

**Outcome Assessment:** In the two written exams, questions test understanding in 1) Ability to formulate a mathematical problem from a physical one; 2) Organization of a typical computer-aided engineering software; and 3) Subject matter (biomedical process modeling, numerical methods). Group projects (worth about 50% of course grade) are assessed through formal presentation and a final report.

**Person(s) who prepared this description and date of preparation:**

Ashim K. Datta 03/15/10

**MAE 4560/5560: Bioastronautics and Human Performance**

**4560: 3 cr.; 5560: 4 cr.**

**Contact Hours:** Two 75-minutes lectures each week.

**Instructor:** Ana Diaz Artiles

**Textbook(s) and/or other required material:**

Buckey, J., *Space Physiology*, Oxford University, 2006

**Optional material:**

Larson WJ & Pranke LK (1999), *Human Spaceflight: Mission Analysis and Design*, Space Technology Series, McGraw-Hill Companies.

Guyton. *Textbook of Medical Physiology*. Edited by W. B. Saunders. Philadelphia. (1991-2016)

Proctor, R. W., & Van Zandt, T. (2008), *Human Factors in Simple and Complex Systems*, 2nd Ed, Boca Raton: CRC Press. (PV)

Bluman, A.G., (2013), *Elementary Statistics, A Step-by-Step Approach,* 9th Ed, McGraw-Hill Education, New York (or equivalent)

**Course (catalog) description:** Fall or spring. 3-4 credits.

The goal of this course is to introduce students to human spaceflight, and current physiological and psychological aspects affecting human performance during space missions using a quantitative approach and engineering methods. Topics include engineering principles of human spaceflight technologies such as extra-vehicular activity (EVA) or life support systems (LSS), and quantitative modeling of several physiological systems and their changes in partial gravity environments, including bone loss, muscle atrophy, biomechanical changes, sensory-motor deconditioning, and cardiovascular adaptation. In addition, a number of aerospace human factors, including psychological issues, fatigue, lack of training, and overreliance on automation, will also be addressed. MAE 4050 students (3 credits) engage in a 2-4 person final project. MAE 5050 students (4 credits) also conduct an in-depth study of a human spaceflight problem to be integrated with the final project.

**Prerequisite(s):** ENGRD/MAE 2020 (Statics & Mech. of Solids), MAE 2030 (Dynamics), and MAE 3260 (System Dynamics), or permission of instructor.

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Course Learning Outcomes:**

By the end of this course, students will:

1. Understand the basic fundamentals and requirements of human spaceflight missions and technologies, including aerospace humans factors considerations, major human risks, and countermeasures in place (ABET outcome a)
2. Use analytical techniques and state of the art tools to model human physiological systems and understand their changes in space using a mathematical approach (ABET outcomes a, e and k)
3. Be able to use basic statistics and design of experiments focused on human research (ABET outcomes b and e).

**Topics Covered:**

* Human Spaceflight: current and future flight systems, technologies, and architectures
* Physiological Aspects of Isolated Confined Environments (ICE)
* Extravehicular Activity & Life Support Systems
* Design of Experiments and Statistical Methods in Human Research
* Bone Mechanics & Muscle Mechanics
* Biomechanics: Musculoskeletal Locomotion and Motor Control
* Cardiovascular System: Quantitative Approach using Lumped-Parameter Models
* Neurovestibular System
* Human Factors

**Contribution of course to meeting MAE/ABET curriculum requirements:** This course partially fulfills the requirement to complete two upper level MAE courses as a Major Approved Elective. It can be used to fulfill the Technical Elective requirement.

**Outcome Assessment:**

Outcome will be assessed using graded homework assignments throughout the semester, in-class reading and journal discussions, two in-class quizzes, and a term project (in-class presentation + final report).

**Person(s) who prepared this description and date of preparation:**

Ana Diaz Artiles, 4/26/2016 *(New course for Fall 2016)*

**MAE 4580: Introduction to Nuclear Science and Engineering**

(also AEP/CHEME/ECE/NSE 4130)

**3 credits**

**Contact Hours:** Three 50-minute lectures each week.

**Instructor:** David A. Hammer

**Textbook(s) and/or other required material:**

J.R. Lamarsh and A.J. Baratta, *Introduction to Nuclear Engineering*, 3rd ed, 2001.

**Course (catalog) description:** Fall. 3 credits.

For undergraduates and M.Eng. students interested in nuclear energy. Topics are presented at the level of the course text: Lamarsh and Baratta, Introduction to Nuclear Engineering, 3rd ed. and includes the fundamentals of nuclear science and engineering: nuclear structure, radioactivity, and reactions; interaction of radiation with matter; radiation protection and shielding; the neutron chain reaction and its control; light water reactors, isotope separation, fuel reprocessing, and waste disposal; heat transfer, accidents, atmospheric dispersion, and reactor licensing and safety.

**Prerequisite(s):** PHYS 2214 and MATH 2940

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Course learning outcomes:**

On completion of the course, students should:

1. Be able to synthesize multiple technical disciplines to develop a conceptual design of a nuclear power plant.(ABET outcomes a, c, e, g, j, k).

**Topics covered:**

* + - Interaction of radiation with matter
		- The neutron chain reaction
		- Time dependent nuclear reactor operations
		- Radiation protection and shielding
		- Reactor licensing, safety, and accidents

**Contribution of course to meeting MAE/ABET curriculum requirements:** This course partially fulfills the requirement to complete two upper level MAE courses as a Major Approved Elective. It can be used to fulfill the technical elective requirement. It contributes engineering sciences and engineering design topics to the curriculum and contributes to the realization of physical systems in the mechanical systems area.

**Outcome Assessment:** Outcomes will be assessed using graded homework assignments, two prelim exams, a final examination, and class participation.

**Person(s) who prepared this description and date of preparation:**

Bing Cady and Alan Zehnder

David Hammer 4/19/16

**MAE 4610: Entrepreneurship for Engineers**

(also ENGRG 4610, ORIE 4152)

**3 credits**

**Contact Hours:** Two 75-minute lectures per week.

**Instructor:** John Callister

**Textbook(s) and/or other required material:**

1. Required Book:

*The Entrepreneurial Engineer*, by Michael B. Timmons, Rhett L. Weiss, Daniel P. Loucks, John R. Callister, and James E. Timmons. ISBN 9781107607408 (2013).

2. Course Packet of business cases and articles, updated each year.

**Course (catalog) description:** Fall. 3 credits.

This course develops skills necessary to identify, evaluate, and begin new business ventures. Topics include intellectual property, competition, strategy, business plans, technology forecasting, finance and accounting, and sources of capital. A rigorous, quantitative approach is stressed throughout, and students create financial documents and plans, analyze human resource models, and work with sophisticated valuation methods, complicated equity structures, and legal and business documents. As such, this course represents the "red meat" of entrepreneurship, and the soft skills are left for other courses. Course work consists of discussions, assignments, and the preparation and presentation of a complete business plan.

**Prerequisites:** Junior or senior students in the College of Engineering, or permission of instructor.

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Course learning outcomes:**

On completion of this course, students should:

1. be able to read and understand private equity term sheets and analyze businesses from financial and strategic perspectives (ABET outcome h).

2. be able to provide written and oral communications in a business setting and work on a team (ABET outcome d, g).

3. understand market forces, pricing, competition, the nature of the process of entrepreneurship, and operational aspects of starting new technology-based businesses (ABET outcome h).

4. be familiar with the common forms of intellectual property protection (ABET outcome h).

5. appreciate the ethical issues that are found in entrepreneurial activities (ABET outcome f).

**Topics covered:**

Business Models

Financial Basics

Customer and Functional Narratives

Cash Budgeting

Venture Capital Finance and Term Sheets

Intellectual Property

Marketing and Selling

The Business Model Canvas

The Abbreviated Business Plan

**Contribution of course to meeting MAE/ABET curriculum requirements:** This course complements the technical content of the curriculum and is consistent with the program and institution objectives.

**Outcome Assessment:** The outcomes will be assessed using graded homework sets, a midterm presentation, final presentation, and a final written business plan.

**Person(s) who prepared this description and date of preparation:**

John Callister, 11/11/2009

Revised 03/31/2015

**MAE 4640/4641/5640: Orthopaedic Tissue Mechanics**

**4640: 3cr.; 4641: 4 cr.; 5640: 3 cr.**

(last taught Spring 2014)

**Contact Hours:** Two 1-hour 15-minute lectures each week.

**Instructor:** Marjolein van der Meulen

**Textbook(s) and/or other required material:**

*Basic Biomechanics of the Musculoskeletal System,* M Nordin and VH Frankel, 3e, Lippincott, Williams & Wilkins, 2001.

**Course (catalog) description:** Spring. 3 credits.

Application of mechanics and materials principles to orthopaedic tissues. Physiology of bone, cartilage, ligament, and tendon and the relationship to their mechanical function. Mechanical behavior of skeletal tissues. Functional adaptation of these tissues to their mechanical environment. Tissue engineering of replacement structures.

**Prerequisite(s):** ENGRD 2020 (Statics and Mechanics of Solids), MAE 2120 (Mechanical Properties and Selectin of Engineering Materials), and MAE 3250 (Mechanical Design and Analysis) or permission of instructor.

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Course learning outcomes:**

Upon completion of this course, students should be able to:

1. Know and understand the function and physiology of bone, cartilage, tendon and ligament as organs and tissues (ABET outcome a);
2. Apply strength of materials concepts to the mechanical behavior of musculoskeletal tissues and organs (ABET outcomes a);
3. Understand the unique adaptive capacity of musculoskeletal tissues to their mechanical environment (ABET outcome e);
4. Integrate and interpret biological data and mechanical engineering concepts (ABET outcomes b and k).

**Topics covered:**

• Forces in joints, free body diagrams and simple static analyses

• Skeletal anatomy and physiology

• Bone mechanical properties and adaptation

• Articular cartilage anatomy and physiology

• Articular cartilage mechanical properties and adaptation

• Fracture healing and regeneration

• Tendon/ligament anatomy and physiology

• Tendon/ligament mechanical properties and adaptation

• Tissue engineering

• Advanced topics

**Contribution of course to meeting MAE/ABET curriculum requirements:** This course partially fulfills the requirement to complete two upper level MAE Major Approved Elective courses. It can also be used to fulfill the Technical Elective requirement. The Senior Design version of this course, MAE 4641, can be used to fulfill the Senior Design Elective. This course contributes engineering science topics to the curriculum and contributes to the physical systems in the mechanical systems area.

**Outcome Assessment:** The assessment of the course objectives will be through both individual assessments (homework and exams) and class evaluation (anonymous minute papers). Homework will be assigned weekly. Two in class exams and a cumulative final examination will be administered. Minute papers will be used to assess fundamental concepts upon the completion of lecture topics.

**Person(s) who prepared this description and date of preparation:**

Marjolein van der Meulen

29 February 2004

Updated by Marjolein van der Meulen

20 March 2010

Revised on 3/23/11 to include design option, E. Fisher

Revised on 3/29/11 to reflect new textbook, M. van der Meulen

**MAE 4650/4651/5650, Biofluid Mechanics**

**4650: 3 cr.; 4651: 4 cr.; 5650: 4 cr.**

**Contact Hours:** Two 75-minute lectures each week.

**Instructor:** Ankur Singh

**Textbook(s) and/or other required material:**

*Biofluid Mechanics, The Human Circulation,* KB Chandran, SE Rittgers, and AP Yoganathan. CRC Press. 2nd edition

**Course (catalog) description**: Spring. 4650: 3 credits, 4651 (senior design version): 4 credits, 5650: 4 credits

The transport of energy, mass, and momentum is essential to the function of living systems. Changes in these processes often underlie pathological conditions. This course covers the understanding and analysis of micro-macroscopic fluid flow phenomena within the human body and the relation between fluid flow and physiological processes. The topics covered in this course span from cellular level to organs under healthy and diseased conditions.

**Prerequisite(s):** Students are expected to have completed MAE 3230 (Introductory Fluid Dynamics) or equivalent and ENGRD 2020 (Statics and Mechanics of Solids).

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Course learning outcomes:**

On completion of the course, students should:

1. Introduce and practice the use of the fundamental engineering principles and mathematical basis of fluid mechanics in human body. (MAE/ABET outcomes a and j)
2. Enable the students to identify the fluid flow and transport in human body, and to formulate the governing conservation equations, and solve basic engineering biofluidic problems. (MAE/ABET outcomes a, c, e, and j)
3. Understand and correctly identify modeling assumptions used to solve various biofluidic problems (MAE/ABET outcomes a, e, and j)
4. Enable the students to analyze if Biofluid mechanics a cause or an outcome of a disease and where the analysis might involve approximations and empirical approaches; for example, arterial flows and boundary layer flows. (MAE/ABET outcomes a, and b)
5. Encourage students to formulate an ordered approach to problem solving towards designing an alternative system to circumvent disease. (MAE/ABET outcomes a and e)
6. Integrate and interpret biological data and mechanical engineering concepts (MAE/ABET outcomes b and k).

**Topics covered:**

* Physiological Transport Systems Introduction
* Cellular Transport/Cardiovascular System/Respiratory System/Bone-Joints/Kidney/Lymphatics
* Fluid Statics
* Fluid Shear Stress Effects On Cellular Function
* Cardiovascular Physiology and Heart Failure
* Mechanics Of Blood Flow
* Vascular Mechanics
* Statics and Steady flow models of human circulation
* Flow through curved arteries and bifurcations
* Computational Fluid Dynamics Analysis of Human Circulation
* Wall shear stress and its effect on cells
* Native Heart Valves Mechanics and Fluid dynamics
* Dimensional Analysis & Similitude
* Role of Fluids in human disease initiation and progression

**Contribution of course to meeting the requirements of Criterion 5 (curriculum):**

This course partially fulfills the requirement to complete two upper level MAE Major Approved Elective courses. It can also be used to fulfill the Technical Elective requirement or, as MAE 4651, the major design experience requirement. This course contributes engineering science topics to the curriculum and contributes to the realization of physical systems in the mechanical systems area.

**Outcome Assessment:** Outcomes will be assessed using weekly homework assignments, a prelim and a final examination. MAE 4651 and MAE 5650 students will also complete a design project.

**Person(s) who prepared this description and date of preparation:**

Ankur Singh

September 15, 2014

**MAE 4660/BME 4010:**

 **Biomedical Engineering Analysis of Metabolic and Structural Systems**

**Prerequisite(s):** ENGRD 2020 (Mechanics of Solids) and previous coursework in biology or permission of instructor.

Quantitative biology of the renal, respiratory, cardiovascular, and musculoskeletal systems. Biophysics and biomedical engineering of bone. Tissue engineering and biomechanics of soft tissue.

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Textbook(s) and/or other required material:** *Modeling and Simulation in Medicine and the Life Sciences,* F.C. Hoppensteadt and C.S. Peskin, Springer-Verlag, New York, Second Edition, 2002.

**Course learning outcomes:**

On completion of this course, students should:

1. Understand anatomic and structural components of cardiovascular, respiratory, musculoskeletal, and renal systems (ABET h);
2. Be able to analyze the heart and blood vessels as compliance and resistance vessels (ABET a, k);
3. Understand gas flow and oxygen transport in the lung (ABET a, k);
4. Be able to apply models of elasticity and viscoelasticity to musculoskeletal tissues (ABET a);
5. Understand osmotic and electrostatic contributions to properties of soft tissues (ABET a);
6. Understand water and ion transport in the kidney (ABET a);
7. Be able to measure and analyze data obtained from physiologic systems (ABET b, d).

**Topics covered:**

* Cardiovascular System
* Cardiac Mechanics
* Blood Vessels
* Resistance of Microfabricated Vascular Networks
* Respiratory System
* Tracheal Compliance
* Musculoskeletal System
* Bone
* Cartilage
* Tendon and Ligament
* Macromolecular Transport in Cartilage
* Renal System

**Class/laboratory schedule, i.e., number of sessions each week and duration of each session:** Three 50-minute lectures per week. Labs meet only three times during the semester for 2 hours and 30 minutes each.

**Contribution of course to meeting MAE/ABET curriculum requirements:** This course partially fulfills the requirement to complete two upper level MAE Major Approved Elective courses. It can also be used to fulfill the Technical Elective requirement.

**Relationship of course to program outcomes:** This course meets ABET Outcomes a, b, d, h, and k.

**Outcome Assessment:** The following assessment tools were used to determine the success of the course in meeting the objectives. Two mid-term examinations and a final examination will determine the extent to which students can independently apply knowledge related to the understanding of anatomy, structure, and quantitative mathematical models of the cardiovascular, respiratory, musculoskeletal, and renal systems. Five homework assignments will determine the extent to which individual and groups of students can apply knowledge related to the understanding of anatomy, structure, and quantitative mathematical models of the cardiovascular, respiratory, musculoskeletal, and renal systems. Three laboratory reports will assess the extent to which teams of students can measure and analyze data from physiologic systems, compare this data to known behavior of physiologic systems, and communicate their findings in written format.

**Person(s) who prepared this description and date of preparation:**

Lawrence J. Bonassar

May 11, 2010

**MAE 4700/4701/5700: Finite Element Analysis for Mechanical and Aerospace Design**

**4700: 3 cr.; 4701: 4 cr.; 5700: 4 cr.**

**Contact Hours:** Two 75-minute or three 50-minute lectures each week. Computer laboratory meets every week for 1 hour.

**Instructor:** Hadas Ritz

**Textbook(s) and/or other required material:**

Recommended introductory linear finite elements textbook, such as *A First Course in finite Elements* by J. Fish and T. Belytschko, or equivalent. Some course notes from the instructor will also be made available on the course website.

**Course (catalog) description:** Fall. 3 credits (4700), or 4 credits (4701 or 5700).

Introduction to linear finite element static analysis for discrete and distributed mechanical and aerospace structures. Prediction of load, deflection, stress, strain, and temperature distributions. Major emphasis on underlying mechanics and mathematical formulation. Introduction to computational aspects via educational and commercial software (such as MATLAB and ANSYS). Selected mechanical and aerospace applications in the areas of trusses, beams, frames, heat transfer, and elasticity. A selection of advanced topics such as dynamic modal analysis, transient heat transfer, or design optimization techniques may also be covered, time permitting.

**Prerequisite(s):** Senior standing, or Master of Engineering student or permission of instructor.

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Course learning outcomes:**

On completion of the course, students should:

1. understand the mathematical and physical principles underlying the FEM as applied to solid mechanics, thermal analysis and select aspects of fluid mechanics (ABET Outcome a);
2. be able to create her/his own FEM computer programs, for mathematically simple but physically challenging problems, in MATLAB (ABET Outcome k);
3. be able to compare FEM results obtained with MATLAB with those obtained from ANSYS. Analyze more complex problems (in solid mechanics or thermal analysis) using the commercial FEM code ANSYS (ABET Outcome e and h);
4. demonstrate the ability to design a component using FEM analysis (both MATLAB AND ANSYS) (ABET Outcome c);
5. make clear and effective technical presentations, both in terms of form as well as content, of her/his work and write clear technical reports describing her/his work (ABET Outcome g).

**Topics covered:**

* Introduction to the finite element method.
* Structural analysis: Trusses, beams and frames (combining truss and beam analysis)
* FEM solution of 1D problems: weak forms, interpolation, numerical integration, boundary conditions, element calculations, assembly, solution, error analysis, postprocessing.
* FEM for 2D scalar field problems: element calculations, isoparametric transformation, quadrature rules, assembly, etc.
* Applications to steady-state heat conduction, torsion, irrotational flow, etc.
* 2D solid mechanics, linear elasticity, plane stress and plane strain. 3D stress analysis
* Selected topics such as:
	+ Transient heat conduction.
	+ Introduction to elasto-dynamics - natural frequencies, modal analysis, transient response.
	+ Optimization and design, sensitivity analysis, integration of FEM with optimization.
	+ Finite element modeling of incompressible flows.

**Contribution of course to meeting MAE/ABET curriculum requirements:** This course may be used to satisfy the requirement for Major Approved Elective, or to satisfy the technical elective requirement.

1. **Outcome Assessment:**
* Each student’s knowledge and understanding of fundamental principles, related to the FEM, is assessed by all homework assignments, two prelims and the project.
* Each student’s competence in FEM programming using MATLAB is assessed by all homework assignments and the final project (if applicable).
* Each student’s competence in critical review of the result of numerical simulations is assessed in every homework (e.g. comparison of ANSYS, MATLAB and analytical solutions) as well as through the final project.
* More complex problem identification, formulation and solutions and the student’s ability to design an engineering component are assessed through the final project for the 4 credit versions of the course.
* Each student’s written communication skills are assessed by her/his homework and project reports.

**Person(s) who prepared this description and date of preparation:**

Nicholas Zabaras, 3/25/2010

Updated by Hadas Ritz 4/3/2015

**MAE 4730/5730 Intermediate Dynamics and Vibrations**

**3 credits**

**Contact Hours:** Two 75 minute lectures per week.

**Instructor:** Andy Ruina

**Textbook(s) and/or other required material:**

The dynamics part of this course could use *Classical Mechanics,* by John R. Taylor, 2005 (used in 5700, Fall 2011), or *Principles of Dynamics,* by Donald T. Greenwood (used in 5700 many times), or *Dynamics of Particles and Rigid Bodies: A Systematic Approach,* by Anil Rao, or equivalent. The vibrations portion could use *Principles of Vibration,* by Benson H. Tongue or *Engineering Vibrations,* by Dan Inman, or equivalent.

**Course (catalog) description:** Fall. 3 credits.

The course emphasizes the dynamics and vibrations of multi-degree-of-freedom systems including particles, rigid-objects and structures in 2 dimensions using three approaches: Newton-Euler, Lagrangian approach, both using minimal co- ordinates, and also a ‘maximal coordinate’ approach using differential algebraic equations (DAEs). The course emphasizes finding equations of motion, solving them analytically (if possible) and numerically; and graphical presentation of solutions. Vibrations topics include modal analysis of discrete systems, including analysis of damped systems using the matrix exponential. Special topics, such as vibration absorbers and vibration control, are introduced.

**Prerequisite(s):** MATH 2940, MAE 3260 or equivalents, or permission of the instructor.

**4730 (undergrad version) vs 5730 (grad version):**

The lectures and readings will be the same. Students enrolled in 5730 will have some more advanced homeworks and projects.

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Course learning outcomes:**

On completion of this course, students should:

1. Given a description in sketches and/or simple words, for a variety of dynamical mechanical systems consisting of particles and rigid objects interacting with various standard connections (e.g., strings, springs, hinges, rolling, surface sliding) and forces (e.g., gravity, friction), the student should be able to find the governing differential equations, solve the simple cases by hand, solve the more complex cases with numerical integration (MATLAB), graphically represent the results, including animations, and check the reasonableness of the results using extreme cases and conservations laws (momentum, angular momentum and energy) (ABET outcomes a, e, k).

2. Students will be proficient at writing Lagrange equations for simple conservative systems (ABET outcomes a, e).

3. Students will understand and be able to do analysis associated with vibrations of multi-degree-of-freedom and continuous systems (ABET outcomes a, e, k).

4. Students will understand means of controlling vibrations using absorbers and elementary feedback approaches (ABET outcomes a, e, k).

**Topics covered:**

1. Newton-Euler equations, constraint kinematics (hinges, rolling, sliding, skate) and constraint forces.

2. Introduction to 2D multi-object systems.

3. Lagrange equations (but not their derivation).

4. Assembly of differential algebraic equations of motion

5. Conservation laws.

6. Numerical solution of ODEs in MATLAB. Simple animations in MATLAB.

7. Review of free and forced vibrations of single degree of freedom (SDOF) systems.

8. Multiple degree of freedom systems: eigenvalues and eigenvectors; modal analysis; free and forced response.

9. Vibration absorbers and an intro to feedback control for structural damping.

**Contribution of course to meeting MAE/ABET curriculum requirements:**

This course partially fulfills the requirement to complete three upper level MAE courses as a Major Approved Elective or it can be used to fulfill the Technical Elective requirement.

**Outcome Assessment:** A review of prelims and the final exam will determine whether students mastered the subject. In addition, a questionnaire will be used to assess student views as to what learning mechanisms were most useful and on student perception of the educational impact of the course.

**Person(s) who prepared this description and date of preparation:**

Andy Ruina and Ephrahim Garcia 4/6/2012, 4/26/2012

Andy Ruina and Ephrahim Garcia 4/6/2012, 4/26/2012

Andy Ruina 3/20/15

MAE 4750/MAE 5750: Robotic Manipulation

(CS 4752/CS 5752)

**4 credits**

**Contact Hours:** Three 50-minute lectures each week.

**Instructor:** Ross Knepper

**Textbook(s) and/or other required material:**

Mark W. Spong, Seth Hutchinson, and M. Vidyasagar, *Robot Modeling and Control*, Wiley,

2006.

This course will give an overview of the challenges faced and techniques used for programming robot manipulator arms.

**Course (catalog) description:** Fall. Offered every year. 4 credits.

Introduction to the theory and algorithms used to program autonomous robot manipulator arms. Topics include forward and inverse kinematics, dynamics of a kinematic chain, path and trajectory planning, position control, velocity control, force control, and Lyapunov stability. The course includes a lab portion in which students program the Rethink Robotics Baxter.

**Prerequisite(s):** Senior or Graduate standing. Juniors need permission of instructor. MATH 2210 or equivalent course in Linear Algebra. A dynamics course, such as MAE 2030 or MAE 3260, may be helpful but is not required. Good knowledge of programming (e.g. Python) is essential for the homework and labs. C++ and Matlab are also acceptable languages.

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Course Learning Outcomes:**

On completion of the course, students should:

1. Understand and implement algorithms for pick and place manipulation by composing primitive building blocks. (ABET outcomes a, e and k)
2. Be able to generate a path and the motion for a robot coming into contact with objects. (ABET outcomes a and e)
3. Understand the concepts of different approaches for motion planning such as roadmaps, feedback control and sampling based methods. Includes cutting-edge techniques. (ABET outcomes a, j, and k)
4. Be able to use simulation to implement and test algorithms before running on the physical robot (ABET outcomes a, e, and k)
5. Be able to apply the tools learned in the class to a complex, open-ended engineering design problem using physical robots (ABET outcomes a, c, e, j, and k)

**Topics covered:**

1. Introduction and motivation
2. Robots :
	* Reference frames
	* Actuators
	* Compliance
3. Kinematic Chains :
	* Forward kinematics
	* Inverse kinematics
	* Dynamics
	* Jacobians
4. Control :
	* PID control
	* Position control
	* Velocity control
	* Stability
5. Planning :
	* Path and motion planning
	* Roadmaps, Voronoi decomposition
	* Potential fields
	* Sampling based methods

**Contribution of course to meeting the requirements of Criterion 5 (curriculum):**

This course can be used to partially fulfill the requirement to complete two upper-level, Major Approved Elective courses or it can be used to fulfill the Technical Elective requirement. It contributes to engineering design and to the realization of physical systems in the mechanical systems area.

**Outcome assessment:** Outcome will be assessed using graded homework assignments and a final course design project which requires the students to program the robot to solve a challenge problem.

**Person who prepared this description and date of preparation:**

Ross Knepper

**MAE 4780/5780: Feedback Control Systems**

**4 credits**

**Contact Hours:** Two 75-minute lectures each week and one 3-hour lab every four weeks.

**Instructor:** Douglas MacMartin

**Textbook(s) and/or other required material:**

*Feedback Systems: An Introduction for Scientists and Engineers,* Karl J. Åström and Richard M. Murray, Princeton University Press, First Edition, 2008.

**Course (catalog) description:** Spring. 4 credits.

This course covers the analysis and design of linear systems in both the frequency and time domains. The course includes a laboratory that examines modeling and control of representative dynamic processes. The frequency domain aspects are analyzed via Laplace transforms, transfer functions, root locus, and frequency response methods. The time domain aspects are analyzed via state space models, stability, controllability, observability, state feedback, and observers.

**Prerequisite(s):** One of the following: CHEME 3720 (Introduction to Process Dynamics and Control), MAE 3260 (System Dynamics), or permission of instructor.

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Course learning outcomes:**

On completion of this course, students should:

* 1. Be able to obtain the linearization of a non-linear system about an operating point (ABET outcome a);
	2. Construct a transfer function representation of a linear dynamical system (ABET outcome a);
	3. Manipulate block diagrams and transfer functions (ABET outcome a);
	4. Understand the relationship between a linear system and its frequency response, and know how to construct a Bode plot (ABET outcome a);
	5. Know how to design traditional controllers such as Proportional, Integral, Derivate (PID), and lead lag (ABET outcome c);
	6. Understand the concepts of stability, including gain and phase margins and Nyquist stability condition (ABET outcome a);
	7. Design control systems in the frequency domain using Bode plots and the Nyquist stability condition (ABET outcome c);
	8. Analyze control systems using Root Locus techniques (ABET outcome c);
	9. Be able to apply the tools learned in the class to physical problems (ABET outcomes b, d and k).

**Topics covered:**

* + Introduction and Brief History of Automatic Control
	+ Summary of Dynamical Models for Mechanical, Electrical, Liquid, and Thermal Systems
	+ Transport Lags
	+ Linearization of Nonlinear Ordinary Differential Equations
	+ Time domain linear systems (state-space), including stability and convolution equation for both continuous-time and discrete-time formulations
	+ Review Laplace Transforms, including Transport Lags
	+ Transfer Functions
	+ Block Diagrams
	+ Transient and Frequency Response of Simple Systems, including Transport Lags
	+ Bode Diagrams
	+ Empirical Determination of Transfer Functions.
	+ Introduction to Feedback Control; Sensitivity; Basic Control Actions
	+ Integral and Derivative Control
	+ Steady-state Errors
	+ PID Controllers and Tuning Rules
	+ Nyquist Stability Criterion
	+ Stability Analysis
	+ Gain and Phase Margin
	+ Control Design: Lead, Lag, and Lead-lag Compensation
	+ Root-locus Plots
	+ Introduction to state space control concepts, including reachability and observability

**Contribution of course to meeting MAE/ABET curriculum requirements:** This course may be used to satisfy the requirement for a Major Approved Elective, or to satisfy the technical elective requirement. It contributes engineering sciences and engineering design topics to the curriculum and contributes to the realization of physical systems in the mechanical systems area.

**Outcome Assessment:**

* + Knowledge of fundamental principles is assessed by quiz and examination questions.
	+ Competence in problem identification and formulation is assessed by open-ended exam questions, and by short design problems assigned as group homework assignments.
	+ Competence in application of the tools is assessed by group laboratory assignments.
	+ Instructor feedback is based on informal solicitation of candid feedback from various students known to the instructor (typically 10 to 20 percent of the class), and formal questionnaires.
	+ Instructor’s ability to present the knowledge for learning is assessed using year-end evaluations.

**Person(s) who prepared this description and date of preparation:**

Original: Raff D’Andrea, 12/13/02

Revised: Mark Campbell, 1/9/04, Revised: Mark Campbell, 12/21/09

E. Tompkins, 3/19/15 (updated to match COS description)

D. MacMartin 4/19/16

**ECE 4840: Introduction to Controlled Fusion: Principles and Technology**(also AEP/NSE 4840, **MAE 4590**)

**Catalog description:** ECE4840,Introduction to Controlled Fusion: Principles and TechnologySpring. 3 credits. [Cross-listed with AEP4840, NSE4840, MAE4590]

**Prerequisite(s):** PHYS 1112, 2213 and 2214, or equivalent background in electricity and magnetism and mechanics.

**Course Description from *Courses of Study*:** Introduction to the physical principles and various engineering aspects underlying power generation by controlled fusion. Topics include: fuels and conditions required for fusion power; basic fusion-reactor concepts; fundamental aspects of plasma physics relevant to fusion plasmas; basic engineering problems for a fusion reactor; and an engineering analysis of proposed magnetic and/or inertial confinement fusion reactor designs.

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Textbook(s) and/or other required material:**

*Principles of Fusion Energy*, by A.A. Harms, K.F. Schoepf, G.H. Miley and D.R. Kingdon,

 World Scientific, New Jersey, 2000.

*Introduction to Plasma Physics and Controlled Fusion Research*, Vol. 1, 2nd Ed., by F. F.

 Chen, Springer, New York, 1984.

**Course objectives:**

On completion of the course, students with a variety of different backgrounds all should

1. Understand the scientific basis for controlled fusion by both magnetic confinement and inertial confinement approaches, as well as the technological requirements for practical electric power generation by the controlled fusion process. (ABET outcomes a, e and k).
2. Be able determine the energy release of any nuclear reaction or reaction chain using the mass-energy relationship, and be able to solve well-posed engineering problems in plasma physics as applied to controlled fusion using Maxwell’s equations and the equations of motion of charged particles in electric and magnetic fields. (ABET outcomes a, e, k).
3. Be able to solve well-posed engineering problems in energy generation by controlled fusion having to do with the properties of materials in the presence of neutron irradiation and other relevant processes. (ABET outcomes a, e, k).
4. Understand the fundamental role played by energy in our society and in the developing world, the potential role fusion can play, and the reasons that it is potentially more attractive than fission-based electric power generation. (ABET outcome h, j).
5. Be able to determine the state-of-the-art of different aspects of fusion reactor design by independent study using books, journals, conference proceedings, reports on the web and personal communication with experts. (ABET outcome e, h, i, j, k).
6. Be able to work with a group to prepare a final report and oral presentation on a specific fusion reactor design to be determined by the group. (ABET outcome d, e, g, h, k).

**Topics covered:**

* + - Matter and Energy; fusion fuels and reactions; particle distribution functions.
		- Fusion reactions versus particle scattering
		- Confinement, diffusion and burn (using up) of fusion fuel
		- Particle motion in electric and magnetic fields; particle drift motion
		- Fusion reaction chains
		- Reactor energetics
		- Magnetic and inertial confinement fusion configurations and energy sources
		- Advanced reactor concepts
		- Reactor walls, structure and other materials needs
		- Production, handling and characteristics of tritium as a fusion fuel

**Class/laboratory schedule, i.e., number of sessions each week and duration of each session:** Three 50-minute lectures each week. Student groups, each of which undertakes a different specific reactor design, must set up meetings outside of class time once per week for at least one hour in order to divide up the reactor design tasks for the course project and to plan and develop their reactor design.

**Contribution of course to meeting the requirements of Criterion 5:** This course is an elective in the Electromagnetics area of ECE. It contributes to (b) engineering science and design (about 50%) and to (c) general education in science and engineering (about 50%).

**Course Outcomes and their relationship to program outcomes:** This course addresses ABET program outcomes a, d, e, g, h, i, j, and k.

**Outcome Assessment:** Outcomes will be assessed using graded homework assignments, midterm and final examinations, and a reactor design project.

**Person(s) who prepared this description and date of preparation:**

David Hammer

May 8, 2010

**MAE 4860/4861/5860: Automotive Engineering**

**4860: 3 cr.; 4861: 4 cr.; 5860: 3 cr.**

**Contact Hours:** Two 75-minute lectures each week.

**Instructor:** John Callister

**Textbook(s) and/or other required material:**

None. The course is lecture/handout based.

**Course (catalog) description:** Spring. 3 credits.

Selected topics in the analysis and design of vehicle components and vehicle systems. Emphasis on automobiles. Engines, transmissions, suspension, brakes, and aerodynamics will be discussed. The course uses first principles and applies them to specific systems. The course is highly quantitative, using empirical and analytical approaches.

**Prerequisite(s):** ENGRD 2020 (Statics and Mechanics of Solids) or permission of instructor.

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Course learning outcomes:**

Upon completion of this course, students should:

1. Perform basic calculations for internal combustion spark ignition engines, including turbochargers and superchargers (MAE/ABET outcomes a, e, and k);

2. Calculate the power and torque required to operate a vehicle under various loads (MAE/ABET outcomes a, e, and k);

3. Calculate braking and acceleration performance (MAE/ABET outcomes a, e and k);

4. Calculate the dynamic stability of vehicles (MAE/ABET outcomes a, e and k);

5. Calculate steering and suspension performance (MAE/ABET outcomes a, e and k)

**Topics covered:**

* + - * Free body diagrams and forces acting upon bodies
* Power and torque in rotating systems
* Loads on vehicles
* Gearboxes and clutches
* Brakes and braking performance
* Fundamentals of IC engines
* Turbochargers and superchargers
* Valves and engine breathing
* Anti-lift/anti-dive fundamentals
* Roll steer
* Suspension linkage analysis
* Roll center and suspension kinematics
* Camber and tire forces
* Steering
* Roll and weight transfer during cornering
* Vehicle stability
* Ride, pitch, and bounce
* Springs and damping

**Contribution of course to meeting MAE/ABET curriculum requirements:** This course may be used to satisfy the requirement for two major approved electives, or to satisfy the technical elective requirement.The Senior Design version of this course, MAE 4701, can be used to fulfill the Senior Design Elective.

**Outcome Assessment:** Outcomes will be assessed using graded **w**eekly homework assignments, two in-class quizzes, and a final exam. MAE 5860 students will also complete a design project.

**Person(s) who prepared this description and date of preparation:**

John Callister

November 11, 2009

Revised on 3/23/11 to include 5000-level option, E. Fisher

Revised on 3/25/11 to include the extra work required for 5000-level option, J. Callister

**MAE 5010: Future Energy Systems**

**3 credits**

**Contact Hours:** Two 75-minute lectures each week.

**Instructor:** Max Zhang

**Textbook(s) and/or other required material:**

*Energy Systems Engineering: Evaluation and Implementation*, Francis Vanek and Louis Albright, McGraw-Hill Professional, First edition, 2008

**Course (catalog) description:** Spring. 3 credits.

Critically examines the technology of energy systems that will be acceptable in a world faced with global climate change, local pollution, and declining supplies of oil. The focus is on renewable energy sources (wind, solar, biomass), but other non-carbon-emitting sources (nuclear) and lowered-carbon sources (co-generative gas turbine plants, fuel cells) also are studied. Both the devices as well as the overall systems are analyzed.

**Prerequisite(s):** ENGRD 2210 (Thermodynamics) or equivalent. Recommended: MAE 3230 (Introductory Fluid Mechanics), MAE 3240 (Heat Transfer), or equivalents. Open to graduate and upper class students or with approval from instructor.

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Course learning outcomes:**

Upon completion of this course, students will be:

1. Proficient in engineering calculations of the performance and rudimentary design of various energy conversion systems (ABET outcomes a and c);
2. Familiar with the physics of the environmental issues, including the greenhouse effect and global climate change (ABET outcomes a, h and j);
3. Adept in the comparative analysis of various energy conversion systems. The comparisons will include cost, social acceptability as well as environmental consequences (ABET outcomes e and h).

**Topics covered:**

* Motivation for Studying Future Energy Systems
* Modeling of Global Climate
* Estimation of the Effect of Increased Greenhouse Gases on Global Climate
* Overview of Fossil Fuel Combustion and Plants
* Comparison of Fuels
* Thermodynamics Cycle Analysis: Brayton cycle, Rankine cycle, Regeneration, Combined Cycles, Cogeneration
* Efficiency and Conservation: Overall System Efficiency Starting from Well/Mine; Demand-side management
* Emerging Sequestration Technologies: Biomass, Oceanic, Mineral Deposition
* Solar Power: Solar Ponds, Solar Towers, Economics of Solar Power; P-n Junctions, Materials, Photovoltaic Cells
* Wind Power: Formation and Availability; Wind Turbine Theory; Operating Conditions; Land Requirements; Economics of Wind Energy
* Nuclear Power: Current Reactor Designs, Breeder Reactors, Nuclear Fusion, and Waste Disposal
* Transportation: Role of Energy Industry and Renewable Energy Sources; Advances in ICE Technology; Hybrid Technology and Fuel Cells; Hydrogen Supplies from Renewable Sources; Infrastructure Requirements; Battery-powered Vehicles; Distributed Electric Generation from Vehicles; Issues in Energy for Freight Transportation
* Political and Social Dimensions: the Legislative Process; Interest Groups
* Social Acceptability of New Technologies
* Comparison of Environmental Effects from Fossil Fuel, Wind, Solar, and Nuclear

**Contribution of course to meeting MAE/ABET curriculum requirements:** This course may be used to satisfy the requirement for two Major Approved Electives, or to satisfy the technical elective requirement. It contributes engineering sciences and engineering design topics to the curriculum and contributes to the realization of physical systems in the mechanical systems area.

**Outcome Assessment:** Outcomes are assessed by considering grades on specific questions in homework, prelims and final projects, and by analyzing the student end-of-semester survey.

**Person(s) who prepared this description and date of preparation:**

Francis Vanek, 2/23/2004

Updated by Max Zhang 3/14/2010

**MAE 5060: Aerospace Propulsion Systems**

**3 credits**

(last taught Spring 2010)

**Contact Hours:** Two 75-minute lectures each week.

**Instructor:** None currently

**Textbook(s) and/or other required material:**

*Elements of Propulsion; Gas Turbines and Rockets,* Jack D. Mattingly, American Institute of Aeronautics and Astronautics, 2006.

**Course (catalog) description:** Fall. 3 credits. Offered alternate years, including 2009-10.

Application of thermodynamic and fluid-mechanical principles to design and performance analysis of aerospace propulsion systems. Jet propulsion principles, including gas turbine engines and rockets. Electric propulsion. Future possibilities for improved performance of aerospace propulsion systems.

**Prerequisite(s):** MAE 3230 (Introductory Fluid Mechanics) and MAE 3050 (Introduction to Aeronautics) or permission of instructor.

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Course learning outcomes:**

On completion of the course, students should:

1. Understand the generation of propulsive forces acting on flight vehicles (ABET a and e);
2. Understand the basic thermodynamic and fluid mechanical principles of aerospace propulsion systems (ABET a and e);
3. Understand the role of parametric analysis of engine cycles (ABET a and e);
4. Understand the significance of specific impulse for space propulsion systems (ABET a and e);
5. Understand the fundamental trade-offs required for aerospace propulsion system design (ABET c and e);
6. Be able to carry out parametric analyses of ideal and real gas turbine engine cycles (ABET a and e);
7. Be able to carry out systems analyses for space missions (ABET a and e);
8. Understand the principal constraints imposed on aerospace vehicle design by propulsion system requirements and performance (ABET e).

**Topics covered:**

* + Introduction and history
		- Overview of engine types
		- Generation of thrust and performance measures

Thermodynamic review

* + Basic laws for systems and control volumes
* Review of compressible flow
	+ Nozzle flows (including shock waves)
	+ Heat addition and friction
* The aircraft gas turbine engine components and basic cycle
* Parametric cycle analysis of ideal engines
	+ Turbojet and turbofan
* Component performance
	+ Diffuser, compressor and turbine efficiencies
	+ Real gas effects
* Turbomachinery
	+ Euler turbine/pump equation
	+ Axial flow compressors
		- Parametric cycle analysis of real engines: turbojet
		- Space propulsion

Rocket engines

Orbital mechanics and mission analysis

Topics in electric propulsion

**Contribution of course to meeting MAE/ABET Curriculum Requirements:** This course partially fulfills the requirement to complete two upper level MAE courses as a Major Approved Elective. It can also be used to fulfill the Technical Elective requirement.

**Outcome Assessment:** Each student's knowledge of fundamental principles is assessed by performance on mid-term and final examinations, and on homework exercises. Each student's competence in problem identification and formulation is assessed by performance on assigned homework exercises and on mid-term and final examination questions. Student's suggestions for improvements in the course, obtained from comments on Course Evaluation Forms, also will be considered.

**Person(s) who prepared this description and date of preparation:**

D. A. Caughey

11/12/09

**MAE 5070: Dynamics of Flight Vehicles**

**3 credits**

**Contact Hours:** Two 75-minute lectures each week.

**Instructor:** Andy Ruina

**Textbook(s) and/or other required material:**

A book such as *Flight Stability and Automatic Control,* Robert C. Nelson, McGraw-Hill, Second Edition, 1998.

**Course (catalog) description:** Spring. 3 credits. Offered alternate years.

Introduction to stability and control of atmospheric-flight vehicles. Review of aerodynamic forces and methods for analysis of linear systems. Static stability and control. Small disturbance equations of unsteady motion. Dynamic stability of longitudinal and lateral-directional motions; Simulation of large motions of aircraft (large rotations) Approximately at the level of Flight Stability and Automatic Control by Nelson.

**Prerequisite(s):** MAE 3050 (Introduction to Aeronautics), MAE 3230 (Introductory Fluid Mechanics) and MAE 3260 (System Dynamics) concurrently or permission of instructor.

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Course learning outcomes:**

Upon completion of this course, students should be able to:

* 1. Understand the nature of aerodynamic forces and moments (aerodynamic stability derivatives) in determining the motions of a flight vehicle (MAE/ABET outcomes a, c, and e);
	2. Understand the various terms in the equations of motion and the simplifications arising from assumptions of small disturbances from equilibrium flight and from the bi-lateral symmetry of most aircraft (MAE/ABET outcomes a);
	3. Be able to identify, formulate and solve engineering problems in aircraft flight dynamics (MAE/ABET outcomes a, e and k);
	4. Understand the principal constraints imposed on aircraft design by stability and con-trollability requirements (MAE/ABET outcomes c, e and j).

**Topics covered:**

* + Definitions, Coordinate Systems, Dimensions and Units.
	+ Aerodynamic Background
	+ Static Stability and Control
	+ Equations of Motion
	+ Dynamical Systems Background
	+ Longitudinal Dynamics
	+ Lateral/Directional Dynamics
	+ Euler angles and Nonlinear Dynamics

**Contribution of course to meeting MAE/ABET curriculum requirements:** This course partially fulfills the requirement to complete two upper level MAE courses as a Major Approved Elective. It can be used to fulfill the Technical Elective requirement.

**Outcome Assessment:** Each student's knowledge of fundamental principles is assessed by performance on homework, Matlab simulations, a final simulation project and a final examinations. Each student's competence in problem identification and formulation is assessed by performance on assigned homework exercises and on mid-term and final examination questions. Student's suggestions for improvements in the course, obtained from comments on Course Evaluation Forms, also will be considered.

**Person(s) who prepared this description and date of preparation:**

D. A. Caughey 11/12/09

Andy Ruina 3/22/2016

**MAE 5200: Dimensional Tolerancing in Mechanical Design**

**2 credits**

**Contact Hours:** Two 75-miute, or three 50-minute, lectures per week for seven weeks.

**Instructor:** Herb Voelcker

**Textbook(s) and/or other required material:**

*Geometric Dimensioning and Tolerancing: A Pocket Guide,* A. Neumann, Technical Consultants Inc., 2009.

**Course (catalog) description:** Fall or spring. 2 credits (a seven-week half-course)

Designers use dimensional tolerances to limit spatial variations in mechanical parts and assemblies; the primary goals are interchangeability in assembly, performance, and cost. This course covers traditional limit tolerances briefly, but focuses mainly on modern geometric tolerances and their role in assembly control. Students learn how to represent assemblies in terms of mating and relational constraints and how to design tolerances and inspection procedures from part and assembly specifications.

**Prerequisite(s):** MAE 2250 or an equivalent CAD-based design course, plus 2.5 years of engineering mathematics through probability and statistics.

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Course learning outcomes:**

Upon completion of this course, students should:

1. Assembly Analysis: understand the principles used to determine, in mechanical assemblies, the critical part-mating and intra-part feature constraints whose variations must be controlled with tolerances. (MAE/ABET outcomes a, e, k)

2. Tolerancing Principles: understand the containment-zone principles used in geometric tolerancing, and the principles used in tolerance design to preserve functionality while insuring part interchangeability. (MAE/ABET outcomes a, e, k)

3. Standards & Conformance: understand the distinctive characteristics of the Y14.5 American tolerancing standard and some of the methods used to test parts for conformance to Y14.5 tolerance specifications. (MAE/ABET outcomes a, b, e, k)

4. Assembly Design: be able to specify the assembly part-mating constraints and the intra-part feature constraints needed in moderately complex assemblies to attain specified performance goals (MAE/ABET outcomes a, c, d, e, g, k)

5. Tolerance Design: be able to design Y14.5-compliant tolerances for parts in moderately complex assemblies that will preserve the assemblies' functionality while guaranteeing part inter-changeability. (MAE/ABET outcomes a, c, d, e, g, k)

6. Conformance Assessment: be able to interpret Y14.5-compliant tolerances on industrial parts of moderate complexity, and to design gages or recommend measurement procedures for testing conformance to many Y14.5 tolerances. (MAE/ABET outcomes a, b, c, e, g, k)

**Topics Covered:**

* + Introduction: goals, context, history
	+ Parametric tolerances
	+ Selective review of math and mechanics
	+ Mechanical assemblies
	+ Geometric dimensioning and tolerancing (GD&T)
	+ Current practice: the American Y14.5 Standard
	+ Conformance technology
	+ Future directions

**Contribution of course to meeting MAE/ABET curriculum requirements:** This course partially fulfills the requirement to complete two upper level MAE courses as a Major Approved Elective, as long as total credit hour requirements for Major Approved MAE courses are met. It can also be used to fulfill the Technical Elective requirement, as long as total credit hour requirements for technical electives are met.

**Outcome Assessment:**

|  |  |
| --- | --- |
|  | **ASSESSMENT MECHANISMS** |
| **OUTCOME** | **Homework Problems** | **Small Design Projects** | **Exam Questions** |
| 1 |  |  |  |
| 2 |  |  |  |
| 3 |  |  |  |
| 4 |  |  |  |
| 5 |  |  |  |
| 6 |  |   |  |

**Person(s) who prepared this description and date of preparation:**

Herbert B. Voelcker

21-Nov-09

**MAE 5430: Combustion Processes**

**3 credits**

**Contact Hours:** Three 50-minute lectures each week.

**Instructor:** Michel Louge

**Textbook(s) and/or other required material:**

*An Introduction to Combustion,* Stephen R. Turns, McGraw-Hill, Second Edition, 2000, or equivalent.

**Course (catalog) description:** Fall. 3 credits.

An introduction to combustion and flame processes, with emphasis on fundamental fluid dynamics, heat and mass transport, and reaction-kinetic processes that govern combustion rates. Topics covered include thermochemistry, kinetics, vessel explosions, laminar premixed and diffusion flames, and droplet combustion. Optional topics may include complex combustion systems, turbulent flames, fuel cells or combustion of solids.

**Prerequisite(s):** Graduate standing or permission of instructor.

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Course learning outcomes:**

Upon completion of the course, students should have the ability to:

1. Use tabulated enthalpy or internal energies to calculate an adiabatic flame temperature, and to use tables or software to calculate equilibrium mixtures of perfect gases (ABET outcomes a and k);
2. Calculate concentration time-histories in elementary kinetic mechanisms such as the formation of NO, the combustion of CO, or the combustion of hydrogen (ABET outcomes a and k);
3. Calculate the stability and performance of elementary combustion systems such as the one-dimensional detonation wave, the well-stirred reactor, and the Bunsen burner (ABET outcome a);
4. Understand balance laws for mass, momentum, energy and species conservation and their application to diffusion-limited combustion such as in the gas phase, around spherical droplets or on solid spheres (ABET outcome a);
5. Appreciate the complexity of real combustion systems and the importance of this field in society (ABET outcome h).

**Topics covered:**

* Thermochemistry
* Kinetics
* Reactors
* Premixed flames
* Laminar diffusion flames
* Droplet combustion

**Contribution of course to meeting MAE/ABET curriculum requirements:** This course partially fulfills the requirement to complete two upper level MAE courses as a Major Approved Elective. It can be used to fulfill the Technical Elective requirement.

**Outcome Assessment:** Outcomes 1 through 4 are assessed by recording grades assigned to specific homework and exams, and by conducting a specific student survey at semester's end. Outcome 5 is assessed by survey.

**Person(s) who prepared this description and date of preparation:**

Michel Louge 1/16/04 Revised: 11/4/04

Fred Gouldin 4/6/2010

MAE 5690: Clinical Biomechanics of Musculoskeletal Tissues
(also BME 5690)

3 credits

**Contact Hours:** Two 75-minute lectures each week.

**Instructor:** Yingxin Gao

**Textbook(s) and/or other required material:**

None. Handout and journal papers will be used

**Course (catalog) description:** Spring. 3 credits.

Review of physiology and biomechanics of musculoskeletal tissues, focusing on skeletal muscle, ligament, and tendon and the relationship between the structure and mechanical function.  Apply mechanics of materials to evaluate and solve clinical problems of musculoskeletal tissues. Determine how the tissues adapt to injury and degenerative changes.

**Prerequisite(s):** Prerequisites: ENGRD 2020: Mechanics of Solids, MAE 2120: Mechanical Properties and Selection of Engineering Materials, and MAE 3250: Analysis of Mechanical and Aerospace Structures, or permission of instructor

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Course learning outcomes:**

On completion of the course, students should:

1. Understand physiology and biomechanics of musculoskeletal tissues (ABET outcome a and e)
2. Be able to apply mechanical engineering principles to analyze a mechanically relevant medical problem (ABET outcome a and e)
3. Be able to develop a research proposal about some specific clinical problems of musculoskeletal tissues, and present it in written and oral forms (ABET outcome b, e, g and k)
4. Read research papers and discuss their content with others (ABET outcome g)

**Topics covered:**

* General review of the musculoskeletal system and joint structures, including the knee, hips, ankle, shoulder, elbow and wrist.
* Introduction of each tissue, including the skeletal muscle, ligament/tendon, bone and cartilage
* Physiology and mechanical behavior of each tissue, and the structure-function relationships
* Experimental methods to determine the mechanical properties of skeletal muscle, ligament and tendon
* Types and mechanisms of injury, and the mechanical and structural adaptations to injuries
* Repairing and healing process, and the role of mechanical forces on the tissues
* Structural and functional changes associated with aging and degeneration, and role of the mechanical loading and exercises on regeneration and the aging process

**Contribution of course to meeting MAE/ABET curriculum requirements:** This course partially fulfills the requirement to complete two upper level MAE courses as a Major Approved Elective. It can be used to fulfill the Technical Elective requirement.

**Outcome Assessment:** Outcome will be assessed using discussion of research papers, midterm and final presentation, and project report.

**Person(s) who prepared this description and date of preparation:**

Yingxin Gao

08/19/08

Updated January 2010

E. Tompkins 3/19/15 (updated description to match COS)

**MAE 5910: Applied Systems Engineering**

**(also CEE 5240, CIS 5040, ECE 5120, ORIE 5140, SYSEN 5100)**

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Course (catalog) description:** Fall. 3 credits.

Fundamental ideas of systems engineering, and their application to design and development of various types of engineered systems. Defining system requirements, creating effective project teams, mathematical tools for system analysis and control, testing and evaluation, economic considerations, and the system life cycle. Students majoring in Systems Engineering enroll in SYSEN 5100. Students taking the minor in Systems Engineering enroll in CEE/CIS 5040, ECE/ORIE 5120, or MAE 5910. Students in distance-learning programs enroll in SYSEN 5110. Course is identical for all versions.

**Prerequisite(s):** Senior or graduate standing in an engineering field; concurrent or recent (past two years) enrollment in group-based project with strong system design component approved by course instructor.

**Textbook(s) and/or other required material:**

*Engineering Complex Systems with Models and Objects,* D.W. Oliver, T.P. Kelliher and J.G. Keegan, Jr., McGraw-Hill, 1997.

*The Readings Packet,* available from the Cornell Campus Store.

**Course learning outcomes:**

Upon completion of this course, students should be able to:

1. understand how to design and carry out a complete systems engineering process for complex systems (MAE/ABET c, e, f, h, and k);
2. organize and manage systems engineering tasks in a team environment (MAE/ABET c, d, e, g, i and k);
3. ascertain customer input and translate into technical requirements and allocate them to subsystems, etc. (MAE/ABET c, e and k);
4. carry out and evaluate alternative functional and structural architectures and designs and carry out simple evaluations and simulations (MAE/ABET a, c, e, i and k);
5. optimize systems and subsystems and evaluate risk and reliability for systems (MAE/ABET a, e, i and k);
6. apply simple decision-making tools to system alternatives and trade-offs (MAE/ABET i and k).

**Topics covered:**

* Overview: Systems Engineering Process
* Overview: Case Studies: Formula SAE and Boeing 777
* Overview: Systems Engineering Management and Technical Processes
* People & Teams: Organizing the Systems Engineering Effort
* People & Teams: Team Dynamics
* The Customer: Contextual Inquiry, Gathering Data
* The Customer: Eliciting Customer Preferences
* Documenting the Client’s Domain: Context, Process, Culture
* Requirements: Requirements Allocation, Taxonomy and Traceability, Quality Function Deployment (QFD)
* Requirements: Design for X: Overview, Usability, Manufacturability, Maintainability, Safety, Life Cycle
* Requirements: Why Systems Fail, Risk and Reliability
* Requirements: Design for Affordability
* Design: Design Overview, Functional Design
* Design: Structural Design
* Design: A Case Study in Creative Design
* Performance: Dynamic Systems: Tradeoffs, Modeling, Prototyping, Simulation
* Performance: Dynamic Systems: Control and Dynamics, Working Model
* Performance: Simulation via Activity Diagrams, Optimization
* Design: Software Systems: Principles of Computer Systems Design
* Design: Software Systems: Principles of Computer Systems Design
* Performance: Multi-Attribute Decision Making
* Implementation: Change Control, Organization, Documentation, Metrics, Verification and
* Validation, Testing
* Case Study: Boeing 777

**Class/laboratory schedule, i.e., number of sessions each week and duration of each session:**

Two 75-minute lectures each week.

**Contribution of course to meeting MAE/ABET curriculum requirements:** This course partially fulfills the requirement to complete two upper level MAE courses as a Major Approved Elective. It can be used to fulfill the Technical Elective requirement.

**Relationship of course to program outcomes:** This course meets MAE/ABET Outcomes a, c, d, e, f, g, h, i, and k.

**Outcome Assessment:** Weekly pre-works based on readings, homework based on lectures and readings, two prelims, one final team project, class participation. On-line course assessment surveys.

**Person(s) who prepared this description and date of preparation:**

Albert R. George 2/14/04

Updated Mason Peck 4/2/2010

**MAE 5950 Theory and Practice of Systems Architecture**

(Cross list of SYSEN 5400)

**3 credits**

**Contact Hours:** Two 75-minute lectures and one 50-minute recitation per week.

**Instructor:** Daniel Selva

**Textbook(s) and other required material:**

* Maier, M. and Rechtin, E., The Art of Systems Architecting, 3rd edition, CRC Press, 2009
* Buede, D.,The Engineering Design of Systems: Models and Methods, 2nd edition, McGraw-Hill, 2009.
* Crawley, E. F., Cameron, B. G., and Selva, D., System Architecture, 1st edition, Pearson, 2015.
* Lecture notes provided by staff.

**Course (catalog) description:** Fall. 3 credits.

Every system has an architecture (its essence, or DNA), i.e., a high-level abstraction of its design that provides a unifying concept for detailed design and commits most of the system’s performance and lifecycle cost. This course presents the frameworks, methods, and tools required to analyze and synthesize system architectures. The course has a theory part that emphasizes synergies between humans and computers in the architecture process, and a practical part based on a team-based semester-long project and guest lectures by real system architects. The theory part covers topics such as architecture views, layers and projections, stakeholder networks, dealing with fuzziness, automatic concept generation, architecture space exploration, patterns and styles, heuristics, and knowledge engineering. The practice part focuses on lessons learned by real system architects and special topics such as commonality, platforming, reuse, upstream and downstream influences, and software architecture. Examples of mechanical engineering related systems used in class and in students’ projects include aerospace systems (e.g. constellations of satellites), defense systems (e.g. marine surveillance system), robotic and autonomous systems (e.g., space robots), automotive systems (e.g., car product platforms), biomechanical systems (e.g., artificial pancreas) and IT systems (e.g., communication networks) among others.

**Prerequisite(s):** Basic probability and statistics at the level of ENGRD 2700, familiarity with Matlab, Python or Java, and co-registration in SYSEN 5100 (Introduction to Systems Engineering) or permission of instructor.

**Designation as a ‘Required’ or ‘Elective’ course:** Elective.

**Course learning outcomes:**

Upon completion of the course, students should be able to:

1. Describe and communicate a system architecture using SysML, including its functional architecture, physical architecture, and allocated architecture (ABET Outcomes c, d, g, k).
2. Be familiar with the major architectural frameworks (e.g. DODAF, TOGAF) (ABET Outcomes c, k)
3. Characterize and prioritize stakeholders and their needs using stakeholder value networks and transform stakeholder needs into a set of goals for the system (ABET Outcomes h, k)
4. Use both formal brainstorming methods and computational tools to synthesize large spaces of concepts and architectures (ABET Outcomes a, c, k)
5. Develop functions that assess the relative value of system architectures across all important metrics including performance, cost, schedule, risk, and others. (ABET Outcomes a, c, k)
6. Use design of experiments and multi-objective evolutionary algorithms to fully or partially explore the architectural trade space and find a set of “good” architectures (ABET Outcomes a, b, c, k)
7. Use simple statistics and clustering algorithms to discover the structure of the tradespace (ABET Outcomes a, c, k)
8. Use sensitivity analysis to identify the set of driving decisions and parameters (ABET Outcomes a, c, k)
9. Analyze and quantify the flexibility, modularity, robustness, and scalability of system architectures (ABET Outcomes a, c, k)
10. Critique an architecture, identifying its strengths and weaknesses (ABET Outcomes g, h, j)

**Topics covered:**

* Introduction to Systems Thinking: Form, Function, Concept, Architecture
* Stakeholder Analysis and Stakeholder Value Networks
* Concept generation and selection
* Functional architecture
* Physical and allocated architecture
* Architecture Frameworks (e.g. DODAF)
* Architecture enumeration
	+ Brute-force algorithms for full factorial enumeration
	+ Production (rule-based) systems
	+ Random sampling
	+ Orthogonal arrays
* Architecture evaluation
	+ Engineering economics: Cost Modeling, Net Present Value
	+ Operational risk: reliability analysis
	+ Programmatic risk: quantification of schedule slippage and cost overrun
	+ Multi-Attribute Utility Theory
	+ Uncertainty: Interval Analysis and Monte Carlo simulation
	+ Ambiguity: fuzzy sets
* Architecture tradespace analysis
	+ Pareto analysis
	+ Sensitivity analysis
	+ Clustering algorithms
	+ Surrogate models
* Architecture tradespace search and optimization
	+ Evolutionary algorithms
	+ Incorporating domain-specific knowledge
* Quantifying lifecycle properties
	+ Flexibility and robustness: real options analysis
	+ Reactive and proactive commonality

**Contribution of course to meeting ABET curriculum requirements:** This coursecontributes to meeting the design curriculum requirement (Outcome c) and related outcomes including the ability to function in multi-disciplinary teams (semester-long team projects) and communicate effectively (final presentations).

**Outcome Assessment:** In addition to analyzing student surveys administered by the College, the instructor will assess the outcomes of the course by considering student results on specific questions on homeworks, exams, and final report and presentations.

**Person(s) who prepared this description and date of preparation:**

Daniel Selva, March 10 2015 (updated April 9, 2015)

**MAE 6630 Immuno-engineering**

**Department, number, and title of course:** Mechanical & Aerospace Engineering, 6630, **Immuno-engineering**

**Designation as a ‘Required’ or ‘Elective’ course:** Elective

**Course (catalog) description**: Fall. 3 credits. Offered alternate years.

Emphasizes the application of engineering principles and tools to quantitatively study the immune system in health and disease development. This course will establish concepts necessary for developing new engineered therapies or improve existing therapies by controlling immune cells. The topics covered span from biophysical mechanics of immune cells, fluid transport, interplay of soft/hard tissue mechanics with the immune system, host responses to bio-prosthetic and mechanical implants, smart material design to program immune system or evade immune response, and developing micro-nanoscale technologies for detection and/or manipulation of the immune system. The application area embraces a comprehensive list of diseases including infections, autoimmune disorders, cancer, allergies, implants, musculoskeletal disorders etc.

**Prerequisite(s):** Graduate standing or permission from instructor

**Recommended Textbook(s) and/or other material for reference:** Material from existing literature.

**Topics covered:**

1. Basic immunology: Immune organs; B cells, T cells, Dendritic Cell, Macrophages, etc.
2. Innate immunity and adaptive immunity
3. Physics and mechanics of immune cell development
4. Engineering methods to study mechanical regulation of molecular interactions, conformational changes, and proteolysis: Atomic force microscopy, spinning disk, Bio-membrane force probe, molecular dynamics simulations
5. Engineering single immune cells at multiple length scales using micro and nanotechnologies – microfabrication, microfluidics, nanofluidics
6. Biomaterials based immuno-engineering
7. Effect of lymphatic fluid on immune cells
8. Engineering new technologies to exploit lymphatic fluids transport to treat diseases
9. Tissue degeneration mediated inflammation
10. Mechanical and bioprosthetic implant associated inflammation
11. Autoimmunity and transplantation: basics and rejection
12. Aging and immunity
13. Brain and immunity
14. Cancer, inflammation, and immunity
15. Lymphangiogenesis, mechanobiology, and cancer
16. Engineer tumor microenvironment to enhance immune response
17. Protein engineering tools in immunology
18. Engineering micro-nanoscale diagnostic tools for detecting immunological changes
19. Immunology: A cause or outcome of disease development and progression

**Class schedule, i.e., number of sessions each week and duration of each session:**Two 75-minute lectures each week.

**Outcome Assessment:** Outcomes will be 40% Exam, 20% Class team project, and 40% HW. For class project each student is required to submit a report which requires the students to apply engineering knowledge to solve an immune system related problem.

**Person(s) who prepared this description and date of preparation:** Ankur Singh (May 06, 2015)