Russ College of Engineering and Technology

Stocker Center

Dennis Irwin
Dean

Angelia Bukley
Associate Dean

http://www.ent.ohiou.edu/

Programs leading to master's degrees are available in chemical, civil, computer science, electrical, industrial and systems, and mechanical engineering. In addition, the Ph.D. is offered in chemical engineering, electrical engineering, and a cross-disciplinary program in integrated engineering with specialties in civil engineering, industrial engineering, and mechanical engineering.

Facilities

Graduate programs in engineering are enhanced by an endowment provided by a distinguished alumnus, the late Dr. C. Paul Stocker, and his wife, Beth. Income from this endowment, the net value of which is more than $37 million, supports advanced research and graduate education through equipment purchases, scholarships, faculty enrichment, and two faculty chairs that bring some of the world's leading engineering talent to the campus for visiting professorships.

The college is housed in the Stocker Engineering and Technology Center. Interdisciplinary research is conducted through the college's centers and institutes: the Avionics Engineering Center, the Center for Advanced Materials Processing, the Center for Automatic Identification Education and Research, the Institute for Corrosion and Multiphase Technology, the Ohio Coal Research Center, the Center for Advanced Software Systems Integration, the Center for Intelligent, Distributed, Dependable Systems, and the Ohio Research Institute for Transportation and the Environment. Students and faculty cooperate across departments to perform research in these centers on multidisciplinary projects.

Graduate Programs

Graduate programs can be formulated with a major in chemical, civil, computer science, electrical, industrial and manufacturing systems, or mechanical engineering. The M.S. is offered in all the engineering departments, and the Ph.D. can be earned in chemical engineering, electrical engineering, and integrated engineering with specialty areas in civil engineering, industrial engineering, and mechanical engineering.

The standard four-year course in engineering or its equivalent, as offered in institutions approved by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology Inc., is a general prerequisite for graduate study. For computer science, the prerequisite for graduate study is the standard four-year course offered by institutions approved by the Computer Science Accreditation Commission of the Computer Science Accreditation Board. Graduates in science and other fields of engineering whose programs included sufficient courses in mathematics, physics, chemistry, the humanities, and the social sciences may be accepted as graduate students, although undergraduate basic engineering courses may be required as preparatory. The Graduate Record Examination is required for applicants to all graduate programs except in extenuating circumstances. See program listings for specific application and admissions information.

Private endowments provide fellowships and assistantships ranging from $12,000 to $18,000 plus tuition (excluding the general and recreational facilities fees). Other teaching and research assistantships also are available. See program listings for details.

Programs leading to the M.S. and Ph.D. in chemical engineering are offered with particular research emphasis in the areas of air quality and atmospheric chemistry, biomedical and biochemical engineering, batteries and fuel cells, corrosion and flow in multiphase systems, electronic and advanced carbon materials, and energy and pollution control. Interdisciplinary collaborations are maintained with civil and mechanical engineering, biology, chemistry, physics, and medicine.

The M.S. in civil engineering may be focused in geotechnical engineering, environmental engineering,

geoenvironmental engineering, structures, water resources, solid mechanics, or transportation. Research areas include treatment of water and wastewater, landfill components, pavement analysis and modeling, accelerated pavement load testing, noise abatement, structural reliability, reinforcement and prestressed concrete, soil structure interaction, centrifugal modeling, cone penetrometer technologies, constitutive relations for soils and rocks, nondestructive testing, computational methods in structural mechanics, computer-aided structural engineering, long-term water resources forecasting, and stochastic flood and drought analyses.

Programs leading to the M.S. in computer science and the M.S. and Ph.D. in electrical engineering are offered. Areas of interest include avionics, artificial intelligence, computers, applied and theoretical computer science, communications, controls, information theory, solid-state electronics, energy conversion, power electronics, power systems, electromagnetics, signal processing, manufacturing, VLSI design, computer vision, robotics, electronic circuits, and opto-electronics.

One of the most distinctive features of the School of Electrical Engineering and Computer Science is its Avionics Engineering Center. Initiated in 1963, the center provides educational opportunities for graduate students who have an interest in electronics and systems related to aircraft safety in takeoffs, landings, and navigation. The center participates in NASA's Tri-University Program with Princeton University and the Massachusetts Institute of Technology. Research projects at the center include instrument landing technologies (ILS, MLS, and GPS), airborne data collection, communications, and navigation system analysis. A special twelve-month, non-thesis option in Electronic Navigation Systems is available.

The Department of Industrial and Manufacturing Systems Engineering offers an M.S. in industrial engineering with specialized study concentrations in engineering management, manufacturing systems, and manufacturing information systems. Each area has a set of core courses and recommended electives. Research leading to an M.S. in mechanical engineering can be formulated with specialization in a number of areas. An M.S. with a manufacturing option is also offered. Areas of interest include computer-aided design and manufacturing, microcomputer control and data acquisition systems, automated manufacturing systems, finite-element analysis, materials processing, robotics, combustion, energy engineering and management, thermal stress analysis, thermofluid systems, air pollution, heat transfer, fluid mechanics, and mechanical design.

The Ph.D. in integrated engineering combines studies from at least two departments to focus on research areas in civil engineering, industrial engineering, and mechanical engineering. Students and faculty work across disciplinary lines on important problems in these areas.

Computer Science Courses (CS)—see Electrical Engineering and Computer Science.

All students completing a thesis or dissertation must abide by the Russ College of Engineering and Technology's strict policy on plagiarism. The student must sign a Statement of Originality before final approval is granted to any thesis or dissertation. To obtain copies of the plagiarism policy and Statement of Originality, please see the department or Dean's office graduate student representative.

Biomedical Engineering

Please note: The Master of Science degree in Biomedical Engineering is tentatively scheduled to commence operations by the fall of 2006. This is a research-oriented degree program with concentrations offered in cellular and molecular engineering, biomechanics and biomedical information processing.

The basic requirement for admission to the M.S. program is a B.S. degree in engineering. The Test of English as a Foreign Language (TOEFL) is required of students whose native language is not English, and the Graduate Record Exam (GRE) is required of any student seeking financial aid. Special programs of study leading to the M.S. in Biomedical Engineering are possible for exceptionally well-qualified students who have received Bachelor's Degrees in other scientific fields. Inquiries are welcome.

For further information and for the latest news regarding the status of this program, please visit the Russ College of Engineering and Technology Web site at http://www.ohio.edu/engineering/

Chemical Engineering

http:/www.ent.ohiou.edu/che/

Programs leading to M.S. and Ph.D. degrees are offered with research emphasis in the areas of electronic and advanced carbon materials, corrosion and flow in multiphase systems, batteries and fuel cells, energy and pollution control, air quality and atmospheric chemistry, and biomedical and biochemical engineering. Active collaborations exist with biology, chemistry, physics, medicine, and civil and mechanical engineering.

The basic requirement for admission to the M.S. program is a B.S. in chemical engineering. The Test of English as a Foreign Language (TOEFL) is required of international students, and the Graduate Record Exam (GRE) is required of any student seeking financial aid. Special programs of study leading to the M.S. in chemical engineering are possible for students who have received a bachelor's degree in another scientific or engineering field. These special programs require completion of some portion of undergraduate chemical engineering courses and are generally available only to exceptionally well-qualified students. Inquiries are invited.

An M.S. in chemical engineering or an appropriate related area is required for candidacy in the Ph.D. program in most cases.

If you are working toward the M.S., you are expected to take a minimum of 30 credit hours of graded coursework. The following courses must be included in the chemical engineering area: 600, 601, 604, and 642. You also must complete a thesis requiring a minimum of 30 credit hours of work. All graduate students

must maintain a minimum g.p.a. of 3.0 overall and in departmental courses.

A nonthesis option is available for students having proven research competence. This program requires a minimum of 45 credit hours of graded coursework. A special topic investigation extending over two or more quarters is required of all nonthesis participants. The special project requires a minimum of 15 credit hours of work.

You are encouraged to take coursework outside the department in other engineering disciplines and in related areas such as mathematics, chemistry, and physics. All graduate students are expected to participate in departmental graduate seminars when offered.

If you are working toward a Ph.D., you will take courses and appropriate work as required to fulfill a program of study determined by you and your advisory committee and acceptable to the departmental graduate committee. A minimum of three 700-level courses are required. The Ph.D. qualifying examination, normally given twice a year, is a prerequisite for unconditional admission to the doctoral program. No student will be allowed to attempt the exam more than twice. After you have completed your coursework, you will be required to take a comprehensive examination consisting of the oral and written presentation of a research proposal in an area unrelated to your dissertation topic.

Chemical Engineering Courses (CHE)

520 Coal Conversion Technologies (3)
Coal characterization. Introduction to fixed bed, fluid bed, and entrained bed operations. Equilibrium and kinetic predictions. Coal gasification and liquefaction processes.

530 Advanced Metallic Corrosion (3)
Review of basic principles and current theories of stress corrosion and embrittlement, corrosion fatigue, and transgranular and intergranular corrosion. Some laboratory work using recent techniques and apparatus. 4 lec.

531 Advanced Topics in Materials Science and Engineering (3)
Structure, processing, and applications of cermaics, polymers, and composites. Corrosion and degradation of materials. Electrical, thermal, optical, and magnetic properties of materials. Materials selection and design.

540 Process Modeling and Control (3)
Digital computer control in chemical engineering. State space concepts and their application in process control.

550 Fundamentals of Material Analysis (3)
An overview of both classical and modern techniques of materials analysis. Topics covered range from classical optical spectroscopies (IR, FTIR, Raman, UV/VIS) to such modern surface techniques as AES, XPS, (ESCA), and RBS.

555 Analysis of Electrochemical Systems (3)
Application of thermodynamics, transport phenomena, and reaction engineering to the design and understanding of electrochemical processes. Emphasis on industrial electrochemical processes such as electrolysis, batteries, and fuel cells. Special topics include: lithium ion batteries, plating and electrode characterization, fuel cells and the hydrogen economy. Includes the design, construction, and testing of a bench-scale electrochemical process.

560 Atmospheric Pollution Control (4)
Sources of air pollution from major industries, internal combustion engines, and other sources. Techniques available for measuring particulates and gaseous pollutants in atmosphere and at their sources. Techniques available for control and future possibilities for control of air pollution. Bases for air pollution legislation.

563 Atmospheric Chemistry (3)
Homogeneous chemistry of the lower and middle atmosphere, emphasizing processes by which human activity influences the environment.

577 Polymer Synthesis and Properties (3)
Polymer classifications and nomenclature, reaction mechanisms, reaction kinetics, characterization techniques, reactor design and modeling, manu-facturing processes, and polymer processing techniques.

581 Biochemical Engineering (3)
Study of processes in chemical engineering that depend on biological systems. An overview of biological basics, enzyme kinetics, major metabolic pathways, cell growth characteristics, essentials of recombinant DNA technology, bioreactor design and control, and an introduction of purification methods.

582 Topics in Bioseparations (3)
Basic techniques such as cell disruption, centrifugation, precipitation, micro- and ultrafiltration, and various forms of chromatography for the separations of biomolecules, especially proteins, are introduced. Some emphasis on preparative and large-scale applications.

583 Biomedical Engineering (3)
Biomedical engineering with an emphasis on cell and tissue engineering.

600 Applied Chemical Engineering Calculations (5)
Linear and nonlinear algebra, ordinary and partial differential equations, optimization, and regression. Extensive treatment of numerical techniques for nonlinear problems. Computer modeling.

601 Advanced Chemical Engineering Thermodynamics (5)
Chemical engineering processes, pure materials, and mixtures. Criteria of equilibrium for homogeneous and heterogeneous systems. Correlation and estimation of properties; thermodynamic consistency tests.

604 Chemical Reaction Engineering (5)
Homogeneous and heterogeneous kinetics, isothermal and non-isothermal reactor design, non-ideal flow, axial dispersion, mass transfer and reaction, catalysis, multiphase systems.

620 Manufacturing Materials (4)
Examines interrelationship among chemical and physical structure, properties, and processability of materials. Emphasis on the effect of this interrelationship on the final properties of manufactured products.

632 Modern Composite Materials (4)
Survey of the different types of composite matrix and reinforcement materials. Also covered are mechanical and thermal properties and properties of strength and fracture in composites.

642 Transport Phenomena (5)
Theoretical basis of development of heat, mass, and momentum transfer. Boundary layer theory and comparison with other theoretical and semitheoretical approaches.

645 Separation Processes (4)
The description, selection, and modeling of separation processes including crystallization, leaching, extraction, distillation, absorption, filtration, membrane and diffusional processes, and fixed bed sorption. Similarities of separation processes based on models of operation are emphasized.

647 Computer-Aided Process Design and Simulation (4)
Use of ASPEN process flowsheet simulator to solve chemical process design problems. Nonideal vapor-liquid equilibrium. Multicomponent separations. Processes with recycle streams.

690 Special Topics in Chemical Engineering (1–6)
Advanced study in a particular field of chemical engineering.

691 Seminar (1)
Special presentations by internal and external speakers.

695 Thesis (1–15)

700 Advanced Chemical Engineering Mathematics (3)
Prereq: 600. Advanced study in applied mathematics in chemical engineering. Restricted to small groups with extensive student participa-tion required.

702 Perturbation Methods (3)
Prereq: 600. Application of perturbation methods to fluid mechanics and heat transfer. Basic solutions using potential flow, conformal mapping, and separation of variables. Asymptotic solutions using regular and singular perturbation methods.

709 Advanced Chemical Reaction Engineering (3)
Prereq: 604. Advanced study in chemical engineering reactor kinetics and design. Extensive student participation required.

730 Advanced Corrosion (3)
Prereq: 530. Advanced study in corrosion. Restricted to small groups with extensive student participation required.

740 Process Dynamics (3)
Prereq: 540. Advanced study in chemical engineering process dynamics. Restricted to small groups with extensive student participation required.

741 Advanced Process Control (3)
Prereq: 540. Advanced study in analog, hybrid, and digital computer control theory. Restricted to small groups with extensive student participation required.

742 Advanced Chemical Engineering Momentum Transfer (3)
Prereq: 642. An analysis of the flow of fluids and the transport of momentum and mechanical energy. The differential equations of fluid flow, potential flow, flow in porous media, flow in fixed and fluidized beds, laminar boundary layer theory, and non-Newtonian fluids.

744 Advanced Chemical Engineering

Mass Transfer (3)
Prereq: 642. Topics covered include theory of diffusion, interphase mass transfer theory, turbulent transport, mass transfer in porous media, mass transfer with chemical reaction, simultaneous mass and heat transfer, multicomponent microscopic balances.

776 Advanced Topics in Materials Processing (3)
Prereq: 620 or ME 563. Examines current issues in materials processing for different applications. Tailored to student interests and needs.

777 Turbulence and Advanced Topics and Fluid Flow (3)
Prereq: 642. Introduces theoretical and practical aspects of turbulence in chemical engineering. Topics include introduction to turbulence and its measurement, time and space correlations, two equation models, and other specialized topics based on student interest.

890 Special Topics in Chemical Engineering (1-3)
Ph.D.-level study in a particular field of chemical engineering.

895 Dissertation (1–15)

Civil Engineering

http://www.ent.ohiou.edu/ce/

In civil engineering, programs for the Master of Science are offered in geotechnical, environmental, geoenvironmental, structures, solid mechanics, construction, water resources, and transportation areas. A program leading to the Ph.D. in integrated engineering with a specialty in the geotechnical and environmental areas is also offered (see "Integrated Engineering").

A B.S. in civil engineering is a basic requirement for entrance to the M.S. program. An undergraduate g.p.a. of 3.0 or better is required for unconditional admittance.

Applications are invited from engineering and science graduates. Collateral work to remedy deficiencies of those without civil engineering degrees may be carried out in conjunction with the M.S. program. Collateral requirements will depend upon preparation in the applicant's major field of study.

Students may choose either the thesis or the nonthesis plan (at least 33 credits of graduate coursework plus 12 credits of thesis, or 45 credits of graduate coursework including three to five credits of a special investigation, respectively). Students who are supported by research funds are normally required to follow the thesis option.

Students must pass an oral examination before a recommendation for the degree is made.

The Department of Civil Engineering recommends that students begin in the fall quarter. There is no deadline for financial aid application; most awards, however, are made during spring quarter for fall entrance.

Civil Engineering Courses (CE)

500N Preparation for Graduate Studies (1–10)
Course designation to be used by graduate students needing preparation for civil engineering courses. Not for graduate credit for civil engineering majors.

515 Geodetic Surveying (3)
Prereq: 210. Equipment and methods used in aerial photography and land measurement. 2 lec, 2 lab. *W; Y.*

518 Construction Administration (3)
Project funding; contractor cash disbursements; contract provisions; borrowing practices; concepts and explanations of financial documents and cost reports; overview of book-keeping fundamentals; construction marketing practices. *W.*

520 Finite Element Methods in Engineering (3)
Background theory, formulation, and application to one- and two-dimensional problems and techniques for analysis. Structures, consolidation, and wave propagation. *F; Y.*

523 Continuum Mechanics (4)
Matrix methods in mechanics and structures; law of dynamics; mechanical properties of solids and fluids; basic theories of continuum mechanics. 4 lec. *W; D.*

524 Strength of Materials II (3)
Theories of failure, unsymmetrical bending, shear center, and other topics not covered thoroughly in undergraduate course. For nonmajors in civil engineering. 3 lec. *F; Y.*

525 Advanced Strength of Materials (4)
Advanced treatment of theories of failure, stresses, and strains at a point, cross shear, unsymmetrical bending, curved beams, torsion, thick-walled cylinders, energy methods. 4 lec. *F; D.*

526 Theory of Stability (3)
Buckling of columns, beam columns, plates, and rings. 3 lec. *F; D.*

527 Experimental Stress Analysis (3)
Prereq: 524 or 525. Elasticity theory; theory and use of mechanical, electrical, and other strain-measuring devices including photo-elastic equipment. 2 lec, 3 lab. *Sp; Y.*

528 Theory of Elasticity and Applications (3)
Equations of equilibrium and compatibility; stresses and strains in beams, curved members, thick cylinders, torsion, and structural members. *W; D.*

531 Experimental Methods in Structural Dynamics (3)
Modal analysis of structural models to identify their vibration characteristics. Frequency response functions using dual-channel signal analyzers. Mobility measurement techniques. Modal parameter extraction techniques. Computer-aided structural dynamics. *W; D.*

533 Advanced Structural Theory I (3)
Analysis of indeterminate structures by both classical and modern methods. Energy theorems; method of finite differences; column analogy.

534 Advanced Structural Design (4)
Modern design concepts and principles as applied to various construction materials. *Sp; D.*

535 Advanced Steel Design (3)
Design of steel structures, including plate girders, other built-up members, trusses, frames, composite beams, and connections. 3 lec.

536 Advanced Reinforced Concrete Design (3)
Advanced design of reinforced concrete structural members. *D.*

537 Timber Design (3)
Prereq: 330. Material properties and behavior of structural timber. Analysis and design of sawed timber and laminated timber members. Timber connection analysis and design. *D.*

538 Prestressed Concrete Design (3)
Theory of prestressing, design and analysis of prestressed concrete beams, slabs, box girders, and bridge girders by elastic and ultimate strength methods. *D.*

539 Computer-Aided Structural Design (3)
Analysis and design of complete structural systems by computer. Reinforced concrete, structural steel, and other applicable materials. Design reports and cost estimation of projects. *F; Y.*

540 Deterministic Approaches in Water Resources (3)
Prereq: 343. Flood routing and overland-flow theory. Parametric hydrology, linear and nonlinear analysis of rainfall-runoff systems, unit and instantaneous unit hydrograph. Conceptual models for hydrologic watershed. *W; D.*

541 Stochastic Hydrology (3)
Prereq: 343. Probability distributions applicable to hydrologic events; analysis of extremes, floods, and droughts; statistical associations between hydrologic variables. Analysis of hydrologic time series. Spectral and parametric formulation of stochastic models of precipitation, runoff, precipitation-runoff transfer. *Sp; D.*

542 Applied Hydraulics (3)
For nonmajors in civil engineering. Flow and pressure distribution in multi-loop networks, dynamics of flow in pumps and turbines. Uniform and nonuniform flow in open channels, culvert hydraulics, hydraulic transients. 2 lec, 2 lab. *Sp; Y.*

543 Open Channel Hydraulics (3)
Prereq: 342. Principles of uniform and varied flow. Channel design for uniform flow, gradually varied flow profiles, channel transitions, hydraulic jumps, flow in prismatic and non-prismatic channels. 3 lec. *F; Y.*

545 Design of Hydraulic Structures (3)
Prereq: 342. Design flood peaks, flood hydrograph, spillway, penstock, and river channel regulation. *Sp; Y.*

553 Solid/Hazardous Waste Management (3)
An introductory course to identify, classify, and study methods of handling, treating, and managing solid/hazardous waste. *F; Y.*

554 Green Engineering (3)
Waste management hierarchy, industrial ecology, life-cycle assessments, waste audits, emission inventories, pollution prevention for process unit operations, flowsheet analysis, fugitive and secondary emissions, and green design. 3 lec. *W; A.*

555 Advanced Water Treatment (4)
Prereq: 450, 452. Advanced study of theory. Design of physical/chemical treatment units. Practice in control methods. 3 lec, 3 lab. *W; Y.*

556 Advanced Waste Water Treatment (4)
Prereq: 451, 452. Advanced study of theory. Design of biological treatment units. Practice in control methods. 3 lec, 3 lab. *Sp; Y.*

558 Water Quality Engineering (3)
Natural and man-made characteristics of water quality, changes in quality resulting from use, criteria for control of stream pollution, methods of improving water quality, legal and economic aspects. *Sp; D.*

559 Surface Water Quality Modeling (3)
Prereq: 450, 451. An advanced course on the fundamentals and principles that underlie the mathematical modeling techniques used to analyze the quality of surface waters. *F or Sp.*

561 Environmental Analysis of Transportation Systems (3)
Prereq: perm. The process and methods of environmental assessment in transportation planning and project development is addressed. *F; D.*

562 Traffic Engineering (3)
Prereq: perm. Traffic data collection, capacity analysis of freeways for design, signilized intersection design. *W; Y.*

563 Traffic Parameters (4)
Fundamental and derived traffic parameters, their uses, and methods of detection and measurement. *Sp; D.*

564 Transportation Planning (4)
Introduction to traffic survey methods, data collection, evaluation. Topics include origin-destination, speed, parking, accident, and future development studies. *W; D.*

565 Traffic Regulations and Controls (4)
Prereq: 563. Typical traffic ordinances and regulations and their use in controlling traffic through use of signs, markings, control devices, and traffic signals, including their use as single units or as a progressive series. *Sp; D.*

566 Transportation Design (3)
Prereq: perm. Design of highways, interchanges, intersections, and facilities for air, rail, and public transportation. *F; D.*

567 Traffic Studies I (3)
Traffic data collection and analysis; traffic flow theory; traffic controls with emphasis on traffic signal design; traffic capacity and analysis. *S; D.*

568 Traffic Studies II (1–4)
Prereq: 565. Practical problems relating to vehicular characteristics and traffic movements. *W; D.*

570 Soil Engineering (4)
For non–civil engineering majors. Soil composition, physical and chemical properties, and classifications. Water movement and seepage problems; stress distribution, settlement, and shear strength. Applications to earth structures, retaining walls, foundations, and slope stability. 4 lec. W.

572 Soil Mechanics I (3)
Water movement through soil; construction and interpretation of flow nets. Stress distribution, compressibility and settlement of cohesive and noncohesive soil; consolidation theory. 2 lec, 2 lab. *F; Y.*

573 Soil Mechanics II (3)
Prereq: 572. Shearing strength. Lateral soil pressures, stability of footings (bearing capacity), retaining walls, and slopes. 2 lec, 2 lab. *W; D.*

574 Advanced Soil Mechanics Laboratory (1)
Prereq: 572, 573. Advanced techniques for measurement of soil engineering properties. 3 lab. *Sp; D.*

575 Advanced Foundation Engineering (3)
Prereq: 471. Design of shallow and deep foundations for complex or unusual soil conditions; design of earth retaining structures including retaining walls, cofferdams, and sheet pile bulkheads; site improvement; performance evaluation and instrumentation. *Sp; D.*

576 Soil Stabilization (4)
Engineering, geological, and pedological soil classification systems. Mineralogy of clay minerals and claywater systems; requirements for and factors affecting soil stability. Methods and mechanisms of soil stabilization; designing and testing stabilized soils. 3 lec, 3 lab. *F; D.*

582 Paving Materials and Mixtures (3)
Types, constituents, chemical behavior, tests, specifications, and uses of bituminous materials. Portland cements and aggregates in pavements. Design and manufacture of paving mixtures and construction of pavements. 2 lec, 3 lab. *W; D.*

583 Principles of Pavement Design (3)
Fundamentals of wheel loads and stresses in pavements. Properties in pavement components and design tests. Design methods and evaluation. 3 lec. *Sp; D.*

684 Constitutive Equations (3)
Stress; strain; linear and nonlinear theories of elastic media; stress path; introduction to plasticity. *Sp; A.*

585 Soil-Structure Interaction (3)
Beams and plates on elastic foundations, axially and laterally loaded piles; retaining walls; interface elements; construction sequences. *W; D.*

586 Theory of Plates and Shells (3)
Bending of rectangular and circular plates, small and large deflection theory, membrane and bending shell theory. *F; D.*

588 Soil Dynamics (3)
Vibration of elementary system, wave propagation, behavior of dynamically loaded soil, analysis and design of foundations for vertical vibration-rocking vibration. *F; D.*

590 Special Investigations (1–5)
Special investigations or problems not covered by formal courses and not requiring thesis. *F, W, Sp, Su; Y.*

616 Construction Project Control Systems (3)
Contractual and delivery systems for construction management; safety and risk; techniques for project control, software applications; construction materials management processes. *Sp.*

617 Construction Productivity (3)
Methods used to measure productivity in civil engineering projects; line of balance (LOB); modeling of construction operations using simulation software; relationship between construction productivity and safety; construction automation. *F.*

625 Finite Element Methods in Mechanics (3)
Development of elements from variational principles. Application of finite element methods in static and dynamic continuum problems; computational techniques; interpretation of results. *D.*

630 Active Structures (3)
Prereq: Perm. Advanced analysis, design, and control for active structures. Multi-criteria design optimization for modular active structures. Dual listed as ME 630.

632 Structural Dynamics (3)
Prereq: ME 591. Dynamic analysis of structures with multi-degree of freedom. Free and forced vibration analysis of elastic beams, frames, grids, and trusses. Earthquake and wind-induced vibration of high-rise buildings and bridges. Classical and computer methods. *D.*

633 Earthquake Engineering (3)
Prereq: 632. Characteristics and causes of earthquakes and their effects on soils, structures, and the interaction between them. Seismology and seismicity, earthquake wave propogation, measurement of earthquake ground motions and use of groung motion records, structural dynamics, structural analysis, and design for lateral forces, influence of foundation medium in earthquake response, response of linear elastic and inelastic systems to earthquake excitations, principles of earthquake resistant design. 3 lec.

635 Advanced Steel Design II (3)
Prereq: 535. Advanced topic in steel design such as: connections, member and frame stability, fatigue, fracture, and plastic mechanisms. 3 lec.

636 Advanced Concrete Design II (3)
Prereq: 536. Design of connections and composite sections. Truss analogy, yield line theory and high performance concrete. 3 lec.

650 Chemical Fate and Transport in the Environment (3)
Physical processes controlling the fate and transport of pollutants in surface water soils. Processes studied include advection, diffusion, sorption, Henry's Law, and abiotic transformations. Govering mathematical equations will be derived and several modeling packages utilized. 3 lec. *F; A.*

652 Biodegration and Bioremediation (3)
Prereq: 650. The major biochemical pathways that are significant in the microbial conversion of xenobiotic compounds to common metabolic intermediates. Interpretation of quantification of biodegration reactions and investigation of various physicochemical and environmental factors that impact biodegradation reactions. 3 lec. *F; A.*

653 Environmental Geotechnology I (4)
Prereq: 370 or 450 or 451. Presents the theoretical basis and in-situ/laboratory practices of geo-environmental methods. 3 lec. 3 lab. *W; Y.*

670 Computational Methods in Geomechanics (3)
Prereq: 520. Application of numerical techniques such as finite difference, finite element, and discrete element methods in solving geotechnical engineering problems related to seepage, diffusion, theory of consolidation, slope stability, retaining structures and substructures, fracture and dynamic motion of geomaterials, andthe use of existing computer programs in geotechnical design. 3 lec.

691 Civil Engineering Seminar (1)
Presentation on research topics by students. Typically take in final year of graduate study. *Sp.*

694 Research (1–6)
For thesis.

695 Thesis (1–15)

710 Energy and Variational Principles (3)
Prereq: 592. Provides a solid foundation in variational calculus and energy methods as applied to solid mechanics. Approximate techniques are formulated for geotechnical problems. *Sp; D.*

723 Continuum Mechanics II (4)
Prereq: 523. Tensor notation and application. Global behavior of solids, liquids, or gases under the influence of external disturbances. Basic laws of physical phenomena. *Sp; D.*

729 Mathematical Theory of Elasticity (3)
Prereq: 528. Foundations of solid mechanics, stress function, displacement potentials, finite element applications, and propagation of waves in elastic solid media. 3 lec.

730 Finite Element Methods II (3)
Formulation and application to two- and three-dimensional problems and techniques for analysis in fluid mechanics, elastostatics, elastodynamics, and heat conduction. *F; D.*

731 Structural Reliability (3)
Prereq: 533. First-order, second-moment reliability method, Monte Carlo simulation, load and resistance factors, reliability index and code checking. 3 lec.

734 Bridge Design (3)
Prereq: 535 or 536. Analysis and design of bridges using various materials in accordance with ASSHTO specifications. 3 lec.

738 Advanced Prestressed Concrete Design (3)
Prereq: 536. Prestress, losses, deflections, compression members, and connections in prestressed concrete. 3 lec.

743 Stochastic Modeling (3)
Prereq: MATH 550A or ISE 504. Review of probability theory, stochastic analysis, geostatistics, analysis of random processes, and applications of stochastic modeling in engineering. *F; D.*

750 Design of Water Treatment Facilities (3)
Prereq: 555 and 491B. Selection of processes/operation and design of water treatment facilities. *G. Mitchell; W; D.*

751 Sludge Treatment Processes (3)
Prereq: 555 and 556. Characterization of waste sludges from primary, chemical, and biological treatment; design of sludge treatment processes. *G. Mitchell; F; D.*

752 Industrial Waste Treatment (3)
Prereq: 555 and 556. Classification, characterization, and study of industrial wastes by industrial category. Selection and combination of unit processes/operations for treatment. *Sp; D.*

757 Subsurface Remediation (3)
Engineering design of systems to clean up contaminated soil and water above and below the water table. Physical, biological, and chemical methods. Emphasis on state-of-the-art technologies and most appropriate technology for a given site. *F; D.*

771 Engineering Behavior of Soils (3)
Prereq: 573. Microstructural aspects of geotechnical behavior of clays and sands; clay-water electrolyte systems; soil fabric and its measurements; soil composition; influence of structure, fabric, and compositional variables on geotechnical properties of soils; intergranular stresses; conduction phenomena; volume change behavior; drained and undrained strength and deformation behavior. 3 lec.

774 Experimental Soil Mechanics (3)
Prereq: 572 and 573. Experimental studies of advanced aspects of soil property measurements to evaluate the engineering behavior of soil for applications to analysis and design. 2 lec, 2 lab.

790 Special Topics in Civil Engineering (1–5)
Special topics or problems not covered by formal courses.

853 Environmental Geotechnology II (3)
Prereq: 653. Addresses the technical and practical engineering issues of containment of wastes and restoration of contaminated and/or disturbed portions of the geoenvironment. *Sp; Y.*

861 Traffic Flow Theory (3)
Prereq: 563. Fundamentals of traffic flow, definitions, concepts, and calibrating relationships. Consideration is given to the applicability of the Greenshields, Underwood, Greenberg, and Edie models. The development of flow-speed and flow-density relationships for existing highways is examined. 3 lec. *D.*

863 Traffic Detection and Control (3)
Prereq: 563. The underlying principles for traffic detection stategies are considered. The characteristics, suitability, accuracy, and current vehicle detection strategies are considered for rural application. Requirements for system integration of traffic detection and traffic control are identified. 3 lec. *D.*

866 Transportation Design II (3)
Prereq: 566. The results of current geometric design research are reviewed. The challenges to the design of roadside features, drainage systems, and horizontal and vertical alignment of roadways are investigated for computer integrated surveying, design, and construction applications. 3 lec. *D.*

885 Soil-Structure Interaction (4)
Prereq 520 and 572. Beams and plates on elastic foundation; axially and laterally loaded piles; retaining walls; interface elements; construction sequences.

Electrical Engineering and Computer Science

http://www.ent.ohiou.edu/eecs/

Programs leading to the Master of Science degree in computer science and the Master of Science and Doctor of Philosophy degrees in electrical engineering are available. Major areas of study include avionics, computers, artificial intelligence, applied and theoretical computer science, communications, controls, solid-state electronics, energy conversion, power electronics, power systems, electromagnetics, signal processing, manufacturing, VLSI design, computer vision, robotics, electronic circuits, and opto-electronics.

Graduate Record Examination (GRE) scores are required for all applicants. However, if you have a B.S. in electrical engineering from an accredited (ABET) electrical engineering program, or a B.S. in computer science from an accredited (CSAB) computer science program, an exemption may be requested from this requirement. The Test of English as a Foreign Language (TOEFL) is required for non-native speakers of English. International students are strongly encouraged to sit for the TWE before applying for admission.

To be considered for entrance into the Doctor of Philosophy degree program, an applicant must have a Master of Science degree in electrical engineering, computer science, or a related field of engineering or the physical sciences.

Typically, Ph.D. students complete two to three academic quarters of formal coursework in their chosen area of specialization and either mathematics or physics. This is followed by a three-part comprehensive exam that includes a written part, an oral part, and a defense of the dissertation research proposal. A dissertation must be submitted and defended that is the equivalent of two years of full-time independent research.

The average duration of the Ph.D. program is four years. Ohio University regulations require that candidates for the Doctor of Philosophy degree be in residence for a minimum of three academic quarters. Recipients of the Doctor of Philosophy degree are prepared for research careers in the private, public, and academic sectors.

To be considered for entrance into the Master of Science in electrical engineering degree program, an applicant must have a B.S. degree in electrical engineering, computer engineering, or a closely related field. To be considered for entrance into the Master of Science computer science degree program, an applicant must have a B.S. degree in computer science, computer engineering, or a closely related field. Deficiencies must be made up by self-study or by auditing (or taking without graduate credit) appropriate undergraduate courses.

The typical Master of Science degree program consists of one year of formal coursework followed by thesis research, preparation of the thesis, and a combined oral examination and thesis defense. Details of the individual masters programs are available on the school's Web site.

Students are encouraged to enter the program in the fall quarter; however, students are accepted in other quarters.

All financial aid is awarded competitively based on standardized test scores and academic performance. In some cases, supplemental aid is available for highly qualified U.S. citizens.

Financial aid consists of Recruitment stipend/scholarships, teaching assistantships, research assistantships, and Stocker research assistantships. Teaching and research assistants are required to work in the school approximately 20 hours a week. Stocker research assistantships are awarded to students who show

exceptional promise for research. As a consequence, students who receive these awards are required to perform research duties over the duration of the award. Teaching assistantships are awarded to students judged to be the most qualified for positions supporting the teaching activities within the school. Other research assistants support various sponsored research projects within the school; as a consequence, an individual faculty member responsible for a particular research project makes his or her own selections for these positions.

For more information regarding financial aid, including current stipends and the number of awards made annually, visit the school's Web site.

Computer Science Courses (CS)

500N Introduction to Discrete Structures (4)
Review of set algebra including mappings and relations. Algebraic structures including semigroups and groups. Elements of theory of directed and undirected graphs. Boolean algebra and propositional logic. Applications of these structures to various areas of computer science.

504 Design and Analysis of Algorithms (4)
Prereq: MSCS major or 561N. (fall, winter) Correctness of algorithms. Analysis of efficiency of algorithms—recurrence relations, worst-case and best-case behavior, average-case behavior. Design of algorithms: divide-and-conquer and balancing, greedy method, graph searching, dynamic programming, backtracking, branch-and-bound and preprocessing techniques.

506 Computation Theory (4)
Prereq: MSCS major or 500N. (fall, spring) Algorithms, recursive functions, Turing machines, decidability.

509N C++ for Non-majors (4)
This course is designed to teach the C++ language to technically able students with previous programming experience who are not majoring in Computer Science. This course deals with various topics including the syntax and semantics of C++, modular design of programs, functions, iterative structures, selection structures, classes, arrays, abstract data types (ADTs), and the separate compilation of modules. The course also includes a brief introduction to the string class and template classes.

510 Formal Languages and Syntactic Analysis (4)
Prereq: MSCS major or 500N and 561N. (winter) Definition of formal grammars: arithmetic expressions and precedence grammars, context-free and finite-state grammars. Algorithms for syntactic analysis: recognizers, backtracking, operator precedence techniques. Semantics of grammatical constructs: reductive grammars, Floyd productions, simple syntactical compilation. Relationship between formal languages and automata.

520N Organization of Programming Languages (4)
Formal definition of programming languages including specification of syntax and semantics. The imperative, object-oriented, functional and logic programming language paradigms are discussed. Names, bindings, storage allocation, type checking and scopes in the major programming languages. Programming language design issues including data types, expressions, assignment statements, control structures and subprograms. Runtime representation of program and data structures.

529 Topics in Computer Science for Elementary and Secondary Teachers (1–5)
Selected topics in computer science of interest to teachers in grades K-12. (May be repeated for credit.)

542 Operating Systems and Computer Architecture I (4)
Prereq: MSCS major or 561N. (winter) In-depth coverage of computer operating systems and related computer architecture issues. Coverage of physical devices, interrupts, and communication between the computer and external hardware. Interfaces between user programs and the operating system, system calls, software interrupts, and protection issues. Context switching, process address spaces, and process scheduling. Process synchronization, interprocess communications, critical sections, and deadlock detection and recovery. Memory mapping, swapping, paging, and virtual memory.

544 Computer Networking (4)
Prereq: 542. In-depth coverage of computer-to-computer and program-to-program communication over modern computer networks focusing on the TCP/IP protocol family. Review of data communication issues, physical address binding, bridging, Ethernet, and Token Ring. Internetwork protocols, routing, domains, networks, and subnetworks. Transport protocols, reliability, flow control, retransmission, and acknowledgment. Distributed systems, server and client issues including verification, and authentication. High-level protocols and applications including electronic mail, network news, remote terminal interaction, and the World Wide Web.

556 Software Engineering (4)
Prereq: MSCS major or 561N. (fall, spring) All phases of the software engineering lifecycle, including system engineering, requirements analysis, design, implementation, and testing. Communication skills that are relevant to working in software engineering teams and interacting with customers. Teams of students perform all software engineering phases in response to the needs of a customer.

558 Operating Systems and Computer Architecture II (4)
Prereq: 542. Continuation of 542. (spring) Detailed discussion of virtual memory and backing stores. File system interfaces, implementation, and protection mechanisms. Process scheduling issues, policies, and mechanisms. Interprocess communication between programs on different computers. Distributed systems issues, examples, and implementation.

561N Data Structures (4)
Prereq: 500N. Basic concepts of data. Linear lists, strings, arrays, and orthogonal lists. Representation of trees and graphs. Storage systems and structures, and storage allocation and collection. Multilinked structures. Symbol tables and searching techniques. Formal specification of data structures, data structures in programming languages, generalized data management systems.

562 Database Systems I (4)
Prereq: MSCS major or 561N. (winter, spring) This course introduces fundamental concepts in data modeling and relational database systems. It begins with the entity-relationship (ER) modeling technique as a tool for conceptual database design. The relational data model and relational algebra are introduced next, followed by the SQL query language for relational databases. Functional dependencies, normalization and relational database design algorithms are then discussed.

575 Internet Engineering (4)
Prereq: not COMT 575. Understanding of internet protocols; network cabling, hubs, and switches; configuring network routers; configuring Unix and Windows workstations; measuring and analyzing network performance; and troubleshooting.

580 Artificial Intelligence (4)
Prereq: MSCS major or 500N. (fall) This course covers the fundamental underpinnings of Artifical Intelligence (AI), including knowledge representation and search. Predicate calculus, state speace graphs, and heuristic search algorithms are presented. The AI programming languages, LISP and Prolog, are introduced. Current applications and research thrutsts in AI are discussed.

590 Special Problems in Computer Science (1-15)
Special project in one of various subfields of computer science or application area studied, investigated, and/or solved by individual student or small group working in close relationship with instructor. Suitable problems might include construction of compiler for special purpose artificial language, perfection of computer code to solve some significant problem, or study of coherent subfield or computer science. May be repeated for credit.

599 Elementary Topics in Computer Science (1–15)
Special topics omitted in student's undergraduate preparation for graduate study. May be repeated for credit.

604 Advanced Algorithms (4)
Prereq: 504 or 506. Advanced topics in the design and analysis of algorithms are explored. These topics include the theory of NP-completeness, NP-hard optimization problems, polynomial-time approximation algorithms, approximation schemes, approximability and non-approximability results, randomized algorithms, and parallel algorithms. *Juedes.*

605 Parallel Computation Theory (4)
Prereq: 504 or 506. Topics in the theory of parallel computation are explored. These topics include the PRAM model, the Boolean circuit model, uniform circuit families, parallel complexity classes, reducibility, P-completeness, and the approximation of P-complete problems. *Juedes.*

606 Computational Complexity (4)
Prereq: 506. The complexity of computational problems is explored with respect to a variety of complexity measures. Topics of study include deterministic time complexity, nondeterministic time complexity, the polynomial-time hierarchy, average-case time complexity, space-bounded complexity, circuit complexity, reductions, relativizations, and parallel models of computation. *Juedes.*

612 Real Time Systems (4)
Prereq: 556, 558. Discusses real-time systems and their design principles. Studies the particular characteristics of these systems and some real-time programming technologies. *Welch.*

620 Compiler Construction (4)
Prereq: 510. Fundamental and advanced topics in compiler design are explored. These topics include lexical analysis and scanner generation, syntax analysis and parser generation, semantics analysis and attribute grammars, code generation, and code optimization.

621 Parallel Compilers (4)
Prereq: 620. Fundamental and advanced topics in parallelizing compilation techniques for parallel systems are explored. These topics include data dependence, scalar analysis, loop restructuring, optimization for locality, and concurrency analysis.

641 Medical Image Analysis (4)
Prereq: EE664. Fundamentals of medical image processing and analysis. Image data acquisition from CT, MR, PET, SPECT, and ultrasound devices. Image segmentation, registration, and visualization.

644 Advanced Topics in Computer Networking (4)
Prereq: 544. High-speed networking, experimental protocols, congestion control, reliability, security, distributed systems. *Ostermann*.

645 Cryptography and Computer Security (4)
This course will introduce students to the basics of cryptography and how it is used to provide security for various tasks performed by computers. Foundation topics that will be covered include: symmetric-key cryptosystems, asymmetric-key cryptosystems, digital signature algorithms, one-way hash functions, and zero-knowledge proofs. Security systems that will be covered include: kerberos, kryptoknight, and PGP.

657A Software Specification (4)
Prereq: 556. The theme is how software specifications are expressed and used. The emphasis is on formal specifications and the use of formal specifications in software verification and validation. Important formal specification models, including algebraic and axiomatic models, state/transition-based models, and temporal logic models, along with their related analysis techniques are explored.

657B Software Design (4)
Prereq: 657A. Advanced object oriented modeling is studied. Specifically, students learn how to employ the Unified Modeling Language (UML) for advanced structural modeling, advanced behavioral modeling, and architectural modeling of software systems. Advanced structural modeling involves software components and their relationships. Concepts taught in advanced behavioral modeling pertain to hierarchical representations of external environment dependencies and interactions as well as concurrency. The course also covers architectural modeling, including design patterns, collaborations, and deployment diagrams.

657C Software Implementation (4)
Prereq: 657B. This course provides students with the skill necessary for successful management of software engineering projects. Students learn technical management techniques as well as interpersonal communication concepts. The principles taught in the course are applied to a software engineering program.

680 Advanced Topics in Artificial Intelligence (4)
Prereq: 580. Advanced topics in artificial intelligence (AI) are studied. The concepts of heuristic search and knowledge representation are studied in detail to provide a firm grounding in AI. Then an advanced topic will be studied, such as machine learning, natural language understanding, computer vision, and/or reasoning under uncertainty. The emphasis is to illustrate that representation and search are fundamental issues in all aspects of artificial intelligence. *Chelberg*.

681 Research in Computer Science (1-6)
F, W, Sp, Su; Y.

682 Artificial Intelligence: Case-Based Reasoning (3)
Prereq: 580. Case-Based reasoning (CBR) is an artificial intelligence (AI) paradigm, in which new problems are solved by reusing the solutions to previously encountered problems. This course will enable students familiar with other AI problem solving techniques to explore CBR in depth. Featured will be: an overview of fundamentals; discussion of research projects; CBR system implementation; and student presentations.

690 Selected Topics (1-4)
Selected topics of current interest in computer science. *F, W, Sp; Y.*

695 Thesis (1-9)
Thesis research in computer science. *F, W, Sp, Su; Y.*

698 Graduate Research Seminar (1)
Research seminar for graduate students in computer science. *F, W, Sp, Su; Y*.

Electrical Engineering Courses (EE)

505 Physical Electronics (3)
Simplified one-dimensional band theory of solids. Valence and conduction band occupancy from Fermi-Dirac statistics. Hole conduction and doping. Derivation of PN junction volt-amp- temperature characteristic. DC and AC characteristics of junction transistors derived from fundamentals. *Curtis; F; D.*

506 Advanced Analog Circuits (3)
Advanced analog circuitry. Operational amplifiers, characteristics, limitations. Linear and nonlinear applications. Feedback, stability criteria compensation, time and frequency response. Waveform generation and shaping, timing, comparison, arithmetic operations. *Curtis; S; Y.*

507 Advanced Digital Circuits (3)
Advanced digital circuitry. Basic logic operations, digital device families and characteristics. Arithmetic, counting, memory, other MSI and LSI functions. Numeric display devices. Analog/digital conversion. *Curtis; W; Y.*

510 Semiconductor Principles I (3)
Prereq: 505. Continuation of 505. (spring, on demand) Application of semiconductor theory to solid state devices; diodes, transistors, FETs, and Gunn effect devices. Charge control analysis. Ebers-Moll equations. Electro-optical effects. *Curtis; Sp; D.*

511 Analog Filters I (3)
Principles of filter synthesis, positive-real functions, synthesis of one-port networks, synthesis of two-port networks, approximation, frequency transformations, and filter design. *F; Y.*

512 Analog Filters II (3)
Prereq: 511. Principles of active filter synthesis, active filter elements, realization of active two-port networks, multiple feedback filters, explicit formulas and practical filter design. Sensitivity and non-ideal filter elements. Switched capacitor filters. *W; Y.*

513 Digital Filter Design (3)
Prereq: 511 and 512. Principles of digital filter design, z-transform, discrete Fourier transform, representations of digital filters, digital filter hardware implementations, and computer-aided design of digital filters. *Sp; A.*

514 VHDL Design (4)
Application of very high speed hardware description languages (VHDL) for digital design, simulation, verification, and specification. Structural design concepts, design tools. VHDL lnaguage, data types, objects, operators, control statements, concurrent statements, functions, and procedures. VHDL modeling techniques, algorithmic, RTL, and gate level designs. Design synthesis. 3 lec, 2 lab. *Starzyk; F; A.*

515 VLSI Design I (4)
Prereq: 505 or equivalent. Introduction to very large scale integration (VLSI) technology and design of CMOS integrated circuits. VLSI fabrication process; design rules; logic design; performance estimation; chip engineering; computer aids to VLSI design. 3 lec, 2 lab. *Starzyk; W; Y.*

516 VLSI Design II (4)
Prereq: 515. Sequential system design, clock generation and clocking disciplines, design validation, sequential testing, standard cell layout, adders, ALUs, multipliers, high density memory, PLA design, floorplanning, I/O architecture, register transfer design, datapath control, high-level synthesis. 3 lec, 2 lab. *Starzyk; Sp; A.*

525 Control Theory I (3)
Formulation of models for lumped parameter systems, fundamental principles of closed-loop control, signal flow graphs, stability, Routh-Hurwitz criterion, root locus construction, specifications, and design via root locus. *Lawrence, Irwin; W.*

526 Control Theory II (3)
Simulation, Bode plots, frequency response performance specifications and relationship to time doman specifications, Nyquist criterion, relative stability measures, closed-loop frequency response, analytical desgin of lead, lag, lag-lead, and PID compensators. *Lawrence; Sp.*

527 Control Theory III (3)
Sampling and data reconstruction, discrete-time systems, z-transforms, sampled data systems, frequency response, Nyquist criterion, root locus, bilinear transformation, analytical design of lead, lag, lag-lead, and PID compensators.

528 State Variable Methods in Control (3)
Basic state variable concepts, writing state equations, time-domain solution of the state equation and the matrix exponential, relations to transfer functions, controllability and observability, stability, state variable methods of design including state feedback and state estimation. *F; A.*

529 Mechanics and Control of Robotic Manipulators (4)
(spring) Classification and applications for mechanical manipulator systems. Manipulator motion description, forward kinematics transformations, solution of inverse kinematics equations. Velocity kinematics and manipulator dynamics equations. Trajectory generation and control schemes including sensory feedback. Laboratory exercises to augment lecture material. Co-listed with ME 529. *Williams; Sp; Y.*

531 Optoelectronics and Photonics I (3)
(fall) Introduction to the important modern optical devices, lasers, and their applications. Emphasizes the basic physical theory needed to understand lasers, their construction, and their applications. A detailed discussion of various types of lasers and their characterization. *Lozykowski; W; Y.*

532 Optoelectronics and Photonics II (3)
Prereq: 531. (winter) Continuation of 531. Additional theoretical material discussed begins with Maxwell's equations. Examines electromagnetic issues that play a major role in laser oscillations—amplification and feedback. Characterization of lasers and continuing discussion of laser types and their applications. *Lozykowski; Sp; Y.*

533 Optoelectronic Materials and Devices (3)
Introduction to modern optical materials and devices using semiconductors technology, the optical integration of these devices, and their application in diverse fields. Both fundamentals of devices and materials are emphasized. *Lozykowski; D.*

540 Microwave Theory and Devices (3)
(offered every other year) Wave propagation, transmission lines, Smith chart, impedance matching, waveguides, and survey of devices (microwave generators, semiconductor devices, etc.). *Radcliff.*

541 Antennas (3)
(winter) Fundamental concepts and definitions, radiation integrals and potentials functions, linear wire antennas, loops, arrays, matching techniques, antenna measurements, laboratory demonstrations. *Radcliff.*

543 Electromagnetics I (3)
(offered every other year) Mathematical review of vector operations in Cartesian and curvilinear coodinates. Solution of wave equation in Cartesian coordinates and application to wave reflection from interfaces between general media. Decomposition of wave solutions into TE, TM, and TEM waves, with application to waveguides and transmission lines; solution of wave equation in cylindrical coordinates, with application to circular waveguide, radiation from line sources, and scattering from cylindrical objects. *W.*

554 Power Electronics (3)
(winter) Introduces the graduate student to power electronics. Covers most uses of semiconductor devices for the conversion and control of electric power: AC to DC, AC to AC, DC to DC, and DC to AC conversions; DC and AC motor drives. Semiconductor device characteristics (particularly those parameters not stressed in most undergraduate electronics courses) and device protection. *Sp; Y.*

555 Introduction to Electric Power System Engineering and Analysis (3)
(fall) Includes power system representation, computer methods, symmetrical components, protection methods, and stability. *Manhire; F; Y.*

556 Introduction to Electric Power System Engineering and Analysis II (3)
Prereq: 555. (winter) Continuation of 555. See 555 for description. *Manhire; W; Y.*

557 Introduction to Electric Power System Engineering and Analysis III (3)
Prereq: 556. (spring) Continuation of 555, 556. See 555 for description. *Manhire; Sp; Y.*

561 Digital Systems I (3)
Postulates and fundamental theorems of Boolean algebra; algebraic and map methods for design of combinational logic and simple sequential circuits; logic minimization methods; introduction to system design using shift registers, counters, etc. *Celenk; F; Y.*

562 Digital Systems II (3)
Prereq: 561. Basic concepts from theory of finite-state machines; analysis and synthesis of sequential circuits; study of state assignment; synchronous and asynchronous machines; system design using integrated circuits. *Celenk; W; Y.*

563 Digital Systems III (3)
Prereq: 562. Synthesis of sequential circuits using ROMs and RAMs for control logic. Introduction to computer organization and design including selection of instruction set, register and bus organization, and implementation of control logic with micro-programmed control. *Celenk; Sp.*

564 Engineering Applications of Expert Systems (3)
Knowledge representation. The process of knowledge engineering. Areas in engineering for expert systems applications. Implementing engineering projects that involve a decision-making process, by using VP-Expert, a PC-based expert systems tool. *Vassiliadis; W; Y.*

567 Microcomputers I (3)
Organization of several mini- and microcomputer systems. Theory and application of assemblers, loaders, etc. Numerous control and data acquisition problems programmed in assembly language on existing computers. Applications in wide range of areas studied. *F; Y.*

568 Microcomputers II (3)
Prereq: 567W. Continuation of 567W. *Klock; W; Y.*

570 Communication Engineering (3)
Unified approach to communications stressing principles common to all transmission systems. Review of Fourier series. Fourier integral and complex frequency techniques with emphasis on communication networks, time response and convolution, measurement of information, amplitude modulation (double and single sideband techniques), frequency modulation, sampling theory, pulse modulation systems, with emphasis on modern digital signaling techniques including PCM, DPCM, PAM, PDM, PPM, and DELTA modulation; fundamentals of random signal theory and its application to communication systems; noise figure, noise suppression techniques, and other related topics. *Essman; F; Y.*

571 Stochastic Processes in Electrical Engineering (3)
(winter) Brief review of probability concepts, including densities, moments, etc. Random process fundamentals (ensembles and realizations), stationarity concepts, 2nd-order statistics, Gaussian processes, random signal through linear systems, Markov chains.

572 Introduction to Digital Communications (3)
(spring) Review of deterministic and stochastic signal and system characterizations, sampling, quantization. Baseband pulse signaling, the matched filter, and intersymbol interference. Introduction to signal spaces and distance concepts. Bandpass modulations and their performance in AWGN. Link budget analysis, communication system tradeoffs.

575 Internet Engineering (4)
Prereq: not COMT 575. Understanding of internet protocols; network cabling, hubs, and switches; configuring network routers; configuring Unix and Windows workstations; measuring and analyzing network performance; and troubleshooting.

585 Electronic Navigation Systems I (3)
(winter) Principles and theory of operation of electronic navigation systems with emphasis on avionics; aircraft instrumentation, VOR DME, Inertial, Omega, LORAN, ILS, MLS, TRANSIT, GPS, air traffic control, and radar. *van Graas; F; Y.*

586 Electronic Navigation Systems II (3)
Prereq: 585. (spring)Continuation of 585 focused on current and future avionics systems and aircraft electronics. Design and signal processing in navigation receivers. *van Graas; W; Y.*

587 Electronic Navigation Systems III (3)
Prereq: 586. Continuation of 585 and 586 with emphasis on mathematical modeling of navigation and landing systems, fault tolerant avionics system design and architecture, night testing, and current developments. *van Graas; Sp; D.*

590 Special Topics (1–6)
Selected topics of current interest in electrical engineering. *Y.*

601 Electromagnetic Wave Propagation in Electronic Navigation Systems (3)
Electromagnetic principles and propagation of radio waves over the earth surface and through the atmosphere. Topics include groundwaves, skywaves, tropospheric and ionospheric effects, Total Electron Content, group and phase velocity, incident fields, reflection coefficients, Brewster angle, diffraction, scattering, Fresnel Zone. *Bartone.*

602 Radar Systems (3)
Theory of operation of radar systems. Topics include the radar equation, radar cross-sections, radar altimeter, Air Traffic Control radar, Doppler radar, weather radar, synthetic aperature radar, Mode A/C/S. *Bartone.*

603 Inertial Navigation Systems I (3)
Principles of operation of inertial navigation systems. Topics include rigid body kinematics, observation equations, attitude update, earth rate and transport rate, position and velocity updates, initialization, orientation, sensor technology. *Braasch.*

604 Inertial Navigation Systems II (3)
Continuation of Inertial Navigation Systems I. Emphasis on error sources and propagation/ simulation of errors, including gravity, Schuler period, vertical damping, scale factors, biases, drift, temperature, noise, alignment, initialization, cross-coupling, g-sensitive errors, magnetic field-sensitive erros. *Braasch.*

605 Satellite-Based Navigation Systems (3)
Theoretical development of spread spectrum ranging and positioning with space-based transmitters; ephemerides, broadcast signal structure; ranging observables; absolute and relative positioning methodologies; error source characterization and mitigation. *Braasch.*

606 Integrated Navigation Systems (3)
Theoretical development of positioning and navigation with multiple sensors; optimal navigation solutions; the Kalman Filter as an integration tool; fault detection and isolation. *Braasch.*

607 Navigation Receiver Design (3)
Theoretical development of receiver design with emphasis on spread spectrum ranging; low-noise amplifiers; radio frequency processsing; down conversion and intervmediate frequency processing; In-phase and quadrature components; analog-to-digital conversion; signal acquisition and tracking. *Braasch.*

608 Aviation Standards, Software Design and Certification (3)
Overview of aviation standards including Federal Aviation Regulations, Technical Standard Orders, Advisory Circulars, RTCA documents and ARINC standards. Software design using military and civilian standards, IEEE software standards, software life cycle processes, program design language, documentation, testing, independednt test verification, case studies. *van Graas.*

610 Aerospace Controls (3)
Theory of controls for aerospace applications. Topics include: state-space models, coordinate systems and transformations, Euler angles, quaternions, continuous and discrete feedback systems, Bode plots, aircraft control, aerodynamics, flight path reconstruction, update rate, latency, stability. *van Graas.*

611 Circuit Analysis and Design (3)
Review of network analysis and matrix methods. Passivity and positive real functions. Introductory graph concepts and topological network analysis. Indefinite admittance matrix and active two-ports. Amplifier design and stability. High frequency circuits. Time domain versus frequency domain analysis. Nonlinear circuits. Introduction to numerical methods. *F; Y.*

612 Multipath in Navigation Satellite Systems (3)
Characterization and mitigation of multipath errors in satellite-based navigation systems. The multipath problem and its impact will be covered along with multipath modeling, measurement and characterization, and means to reduce effect. *Braasch.*

615 VLSI Systems Design (4)
Prereq: 515. Communication and concurrency in computers; processor arrays; hierarchically organized machines. Structured design; layout

algorithms; MOS cell library. Design tools; rule checking; timing analysis; switch level simulation; placement; and routing. *Starzyk; Sp; A.*

616 Computer-Aided Analysis of Electronic Circuits (3)
Computer-aided simulation, numerical solution of nonlinear networks, tableau method, multistep numerical integration, sensitivity calculations, sparse matrix techniques, symbolic analysis, large change sensitivity, design by minimization. *Starzyk; F; Y.*

617 Fault Testable Design (4)
Prereq: 514 or perm. Basic concepts of reliability. Physical faults and testing. Test generation for combinational and sequential logic circuits, random testing, and signature analysis. Fault tolerance and circuit redundancy, self testing and fail-safe design, fault tolerant VLSI design, practical fault tolerant systems. Self testing, design for testability, built-in test, boundary scan testing, IEEE standards. 3 lec, 2 lab. *Starzyk; W; A.*

623 Nonlinear Analytical Techniques (3)
Dynamic systems-use and limitations of phase plane portraits in characterization of nonlinear components and nonlinear activation. Nonlinear phenomena and classification of singularities. Role of forcing function. Solutions found through methods of residues and variation of parameters. Selection process as means for decision making in problem solution; influence of selected criteria. Applications to networks, controlled systems, and optimal control systems. Problems and techniques of Poincaré, Lienard, and others. Systems with analytical solutions. Linearization techniques and error-tolerance determination. *D.*

632 Integrated Optics I (3)
Theory of dielectric waveguides. The waveguide fabrication techniques, materials for waveguides. Waveguide measurements. Materials for active devices: LED's, lasers, and detectors. Fundamentals of optical coupling, input and output couplers, coupling between waveguides. *Lozykowski; Sp; Y.*

633 Integrated Optics II (3)
Prereq: 632. Modulators: electro-optic modulators, acousto-optic modulators, light sources: light emitting diodes, semiconductor lasers, (homo and heterostructures). Modulation of semiconductor lasers. Detectors for integrated optics application. Application of integrated optics and recent progress in integrated optics. *Lozykowski; F; Y.*

641 Advanced Antenna Theory (3)
Theory of dielectric waveguides. The waveguides' circular apertures, parabolic and corner reflectors, lenses, continuous sources, and antenna synthesis. Overview of integral equation and optical techniques in antenna theory. *Radcliff; Sp; D.*

645 Electromagnetics II (3)
Prereq: 543. Review of dyad, antisymmetric matrix Uxl, solutions of homogeneous and inhomogeneous equations in coordinate-free form. Wave propagation in anisotropic media. Wave propagation in uniaxial media. Radiation in isotropic medium. *Chen; W; A.*

646 Electromagnetics III (3)
Prereq: 645. Wave propagation in plasmas and ferrites. Wave propagation in moving media. Radiation in uniaxial medium. Radiation in moving medium. *Chen; Sp; D.*

647 Numerical Methods in Electromagnetics (3)
Prereq: 441 or 541. A review of basic integral equation of electromagnetics and an introduction to the method of moments including many practical solution examples. Software provided for many currently used general-purpose codes such as the Numerical Electromagnetic Code (NEC) and MININEC. *Radcliff; Sp; Y.*

648 High-Frequency Techniques in Antenna Theory (3)
Prereq: 441 or 541. Geometrical optics, radar cross sections, physical optics, and the Geometrical Theory of Diffraction (GTD). Diffraction theory for both the wedge and convex curved surfaces is presented, along with computer examples. Hybrid GTD-moment method techniques. *Radcliff; D.*

652 Design and Control of Manufacturing Systems (3)
Prereq: ME 560 or ISE 640 or perm. Benefits of CIM, integrated databases, IDEF-0, IDEF-1x, flexible manufacturing systems. System design: requirements, design and implementation. Control and software design for manufacturing systems. *Judd; W; A.*

653 Advanced Topics in the Control of Manufacturing Systems (3)
Prereq: EE 571 or perm. Markov chains, Markov process, and generalized semi-Markov processes. Application of Markov models to manufacturing systems. Infinitestimal, finite, and extended perturbation analysis. Petri nets, reachability graphs, incident matrix, boundedness, safe and live nets. Using Petri nets to control manufacturing systems. Aggregate production models. Hedging point strategies. *Judd; Sp; Y.*

661 Hardware Architecture of Computers I (3)
Prereq: CS 542. Processor level design methodologies. Computer arithmetic and number systems. Fixed- and floating-point ALU design; bit-sliced ALU organization; high performance multifunction array processors. Control organization and instruction sequencing; control implementation techniques and control memory optimization. Memory organization and virtual memories; address mapping; memory allocation and replacement policies; segments, pages and files; caches and associative memories. *Celenk; F; Y.*

662 Hardware Architecture of Computers II (3)
Prereq: 661. Continuation of 661. System organization; bus control and interfacing, bus arbitration, and timing. I/O subsystems; programmed I/O; DMA and interrupts; I/O coprocessors. Introduction to operating systems and systems management. *Celenk; W; Y.*

663 Architecture of Parallel Computers (3)
Parallelism in uniprocessor systems. Parallel computer structures; pipeline computers, array processors, and multiprocessor systems. Multiplicity of instruction/data streams; SISD, SIMD, MISD, and MIMD computer organizations; parallelism versus pipelining. Virtual and cache memories; memory allocation; I/O subsystems. Principles of pipelining and vector processing. Pipeline computers and vectorization methods. Structures and algorithms for array processors. SIMD computers and performance enhancement. Multiprocessor computer architecture. Data flow computers and systolic arrays. *Celenk; Sp; Y.*

664 Digital Image Processing (3)
Image fundamentals and human visual system; image radiometry, photometry, and colorimetry. Image sensing and formation; imaging geometry, perspective transformations, camera modeling and calibration, stereoscopic imaging. Neighbors, connectivity, and distance measures. Image sampling, quantization, and representation. Linear 2-D transformation techniques; DFT, FFT, Haar, Hotelling, Walsh, Hadamard, and Hough transformations. Image filtering and noise cleaning. Image enhancement and restoration. Image detection and registration. Template matching. Image coding and transmission. Image understanding systems. *Celenk; F; Y.*

665 Computer Vision (3)
Computer vision system models. Image analysis and early processing; approaches to image segmentation (edge detection, region growing, histogramming, clustering, split and merge); thinning and contour following. Image feature extraction and texture analysis. Stereo vision and 3-D scene analysis. Geometrical and topological properties of binary images. Higher level processing; shape analysis and description, object representation, and recognition. Photometric stereo and shape from shading. Motion field and optical flow. Motion path planning and visual guidance. Visual inspection and quality control. *Celenk; W; Y.*

666 Pattern Recognition (3)
Decision-theoretic pattern recognition and classification. Supervised learning and training algorithms, perceptions, reward and punishment, potential functions, linear discriminants. Bayesian learning, parametric and nonparametric classification, Bayes and Fisher classifiers. Unsupervised learning and clustering; maximum-distance, K-means, and Isodata algorithms, graph-theoretic approach. Feature selection through clustering transformation, entropy minimization, Karhunen-Loeve expansion. Principles of syntactic pattern recognition; formal language theory, recognition grammars, learning, and geometrical inference. *Celenk; Sp; Y.*

667 Introduction to Neural Networks (3)
Prereq: 571. Fundamentals of artificial neural networks. Training algorithms. Software and hardware ANN products. Current ANN research trends. *Vassiliadis; F; Y.*

668 Knowledge-Based Systems in Engineering Design (3)
Prereq: 464/564. Advanced topics in knowledge representation. Knowledge-based expert systems for design, planning, and classification. Expert systems integration with databases, neural networks, and fuzzy logic systems. Languages for symbolic computation. *Vassiliadis; Sp; Y.*

671 Digital Signal Processing II (3)
Prereq: 312 or equiv. Discrete time signals,systems, FFT review. IIR and FIR filter design, adaptive filter theory introduction, spectrum analysis, eigenanalysis, weiner filters.

673 Advanced Topics in Signal Processing (3)
Prereq: 671 or equiv. Digital filter design methodology. Numerical problems in signal processing. Discrete random signals. Introduction to sonar signal processing. Open problems and current research trends. *W; Y.*

674 Information Theory (3)
Prereq: 571. Definition of measure of information, entropy, efficient methods for source coding, mutual information, types of communication channels and channel capacity, error correction coding bounds, continuous-time-signal information theory.

675 Introduction to Plasma Dynamics (3)
Prereq: 543. Particle orbit theory, magneto-ionic theory, waves in cold plasmas, waves in warm plasmas. *H. Chen; D.*

676 Adaptive Signal Processing (3)
Prereq: 671 or equiv. Linear prediction, Kalman filters, steepest descent and stochastic gradient algorithms, method of least squares, singular value decomposition, superresolution algorithms, recursive least squares. Current research topics.

680 Medical Ultrasonics (3)
Fundamental principles of medical ultrasonics. Wave propagation, interaction of ultrasound with tissues, beam formation, clinical instrumentation, bioeffects, and Doppler ultrasound. *Giesey; D.*

681 Research in Electrical Engineering (1–6)
F, W, Sp, Su; Y.

690 Selected Topics (1–3)
Selected topics of current interest in electrical engineering and computer science. *F, W, Sp; Y.*

694 Project Report
(1–3 as recommended by department)

695 Thesis (1–9)
F, W, Sp, Su; Y.

698 Seminar (1–4)
F, W, Sp, Su; Y.

712 Automata Theory (3)
Development of capabilities and limitations of computers and other digital systems in terms of Turing machines, push-down automata, and other organizations; relations between grammar of a computer programming language and machine which accepts the language. *Sp; D.*

715 VLSI Design of Neural Networks (4)
Prereq: 515 or perm. VLSI implementation of neural networks. Multilayered neural networks. Self organizing nets for pattern recognition. Integrated circuit synaptic connections. Active building blocks of the neural networks. Circuits for arithmetic functions. Analog multipliers and convolution circuits. Associative memory imple-mentation. Optical motion sensor. Electronic neural processors. 3 lec, 2 lab. *Starzyk; Sp; D.*

716 Linear Network Theory I (3)
Prereq: 611 or equiv. High frequency circuit analysis and design using scattering parameters. Broadband limitations on network performance. Signal flow graphs and feedback amplifier theory, stability of feedback amplifiers. Introduction to broadband matching. CAD techniques. *W; Y.*

717 Linear Network Theory II (3)
Prereq: 716 or equiv. Review of generalized s-parameters. Broad-band matching and design of equalizers. Microwave amplifier design and bias considerations. Low noise, broadband, and large signal design methods. Broadband negative resistance amplifiers. CAD techniques. *Sp; Y.*

718 Network Topology (3)
Fundamental concepts in linear graph theory, matrix representation of linear graphs, properties of incidence, circuit and cut-set matrices, graphs and vector spaces, derivation of topological formulae for linear lumped networks, application to analysis, and synthesis of communication nets. *Starzyk; W; D.*

721 Multiport Synthesis (3)
Prereq: 511, 512. Positive-real and bounded-real matrices. Synthesis of lossless n-ports. Synthesis of n-ports with prescribed immittance matrix. Scattering synthesis. *Starzyk; D.*

755 Power System Reliability (3)
Prereq: 557. Probability theory; reliability concepts; evaluation of reliability of generating, transmission, and composite systems, interconnected systems and DC transmission systems. *Manhire; F; D.*

756 Computer Methods in Power System Analysis (3)
Prereq: 755. Review of matrix algebra. Incidence and network matrices. Algorithms for formulation of network matrices. Short circuit, load flow, and stability studies. *Manhire; W; D.*

757 Probabilistic Simulation of Electric Power Systems (3)
Prereq: 756. Overview of long range generation system expansion planning problem. Load duration based simulation and cumulant method of production costing. Chronological simulation techniques. *Manhire; Sp; D.*

771 Advanced Digital Communication (3)
Prereq: 571. Review of signal/system characterization, including signaling formats and signal spaces; modulation methods and their power spectra, optimum receivers for the AWGN channel, both coherent and noncoherent, carrier and symbol synchronization introduction, intersymbol interference and introduction to signal design for bandlimited channels.

772 Modulations Systems (3)
Prereq: 771. Performance of familiar communication systems within context of statistical concepts and random noise representations, correlation and spectra analysis and narrow band noise, linear modulation, synchronous demodulation, suppressed carrier techniques, angle modulation, noise in FM, threshold effects in FM, frequency division, multiplexing, correlation detection, coherent binary signaling, coherent phase-reversal keying, differential phase-shift keying, optimum detection, and decision theory. Individual problems associated with state of art techniques. *Essman; Sp; D.*

773 Digital Detection Systems (3)
Prereq: 771. Detection of digital signals using decision theory concepts, conventional and unconventional communication systems, channel characteristics, Hilbert transforms, signal space representations, optimum detection of known signals, detection of signals with finite number of unknown parameters, estimation, estimator-correlator receivers, and suboptimum receivers. Techniques and problems from current literature. *Essman; W; D.*

774 Mobile Communications I (3)
Prereq: 472/572. Introduction to mobile communication system design and analysis. Focus is on the physical layer. General mobile system design principles for both terrestrial and satellite mobile systems. Representations for stochastic bandpass signals and systems. The mobile communication channel will be studied in depth, including both large-scale path loss and multipath fading. Effective modulation schemes for digital mobile communicaitons will be studied, including their power spectra, and performance in AWGN and flat fading channels. Statistical characterization of interference will also be covered. Examples of current and future mobile communication systems will be presented. *Matolak; W.*

775 Mobile Communications II (3)
Prereq: 472/572. Second course in the sequence of two continues study of mobile communication system design and analysis by extending study to advanced topics. Focus is on the physical and data link layers. Topics include diversity techniques, equalization and forward error correction coding with emphasis on MLSE, CDMA system principles including soft handoff and power control, multiple access scheme capacity estimation, and system control procedures including access, mobility management, and security. Future proposed mobile communication systems will be addressed. *Matolak; Sp.*

776 Advanced Plasma Dynamics I (3)
Prereq: 675. Distribution function and Boltzmann equation, transport equation, BV equation, and relaxation model. Landau damping, kinetic treatment of waves in plasmas. *H. Chen; D.*

777 Advanced Plasma Dynamics II (3)
Prereq: 675, 776. Continuation of 776. Boltzmann collision term, Chapman-Enskog expansion. BBKY equations for plasma confinement and stability. *H. Chen; D.*

778 Boundary Value Problems I (3)
Partial differential equations derived from engineering problems. Topics include linear spaces and operators, eigenvalue, and eigenfunctions. Sturm-Liouville systems and Othogonal functions, separation of variables in special coordinate systems, generalized Fourier series, and integrals. *H. Chen; W; D.*

779 Boundary Value Problems II
Techniques for solving boundary value problems, Green's functions and generalized functions, special methods making use of symmetries, images, inversion, and conformal mapping; introduction to integral equation method. *H. Chen; D.*

780 Principles of CDMA Systems (3)
Prereq: 572. Introduction to code division multiple access (CDMA) systems, primarily those using direct sequence spread spectrum (DS-SS). Focus is the physical layer. Origins of DS-SS will be covered, along with general spread spectrum/CDMA system features. Jamming and spectral overlay will be analyzed for several types of jammers. Both orthogonal and pseudo-random spreading sequences and their properties will be studied in depth. Initial code acquisition and tracking. RAKE receiver principles, satellite CDMA principles, and system-level techniques such as power control and soft handoff will be studied. An overview of several current/future systems will be provided, emphasizing open areas of research. Multi-user detection concepts will be introduced. *Matolak; W.*

790 Linear Geometric Control Theory (3)
Prereq: 796 and MATH 511. Topics include a geometric treatment of controllability and observability in terms of invariant subspaces and the concepts of controlled invariant and controllability subspaces with application to disturbance decoupling and noninteracting control problems. *Lawrence; D.*

791 Advanced Digital Control Systems (3)
Prereq: 527 or equiv. Analysis of the effects of signal sampling. Modeling A/D and D/A operations. Application of z-transform to digital control systems, stability techniques. Design of controllers for sampled data systems. *Mitchell, Irwin; W; Y.*

792 Advanced Topics in Automatic Control (3)
Prereq: 526 and 527 or equiv. Basic control system philosophy. Development of control system models. Model reduction. Generalized use of the Nyquist Criterion for determining performance. Model development from test data. Automated and manual frequency response design techniques. *Mitchell; Sp; A.*

793 Nonlinear Control Theory (3)
Prereq: 623 and 790. Introduction to analysis and design of nonlinear control systems using differential-geometric approach. Topics include distributions, nonlinear coordinate transformations, and Frobenius' Theorem with application to nonlinear controllability and observability, feedback linearization, disturbance decoupling, and noninteracting control. *Lawrence; D.*

794 Adaptive, Learning, and Self-Organizing Systems (3)
Fundamental concepts underlying adaptive, learning, and self-organizing systems. System identification, use of gradient methods, peak-holding systems, application of adaptive principle to autopilot and communication systems. Model reference adaptive control, dual control. Self-tuning control, pattern recognition, discriminant functions, training in classifiers, statistical classification, feature selection and ordering, nonparametric procedure, Bayesian learning, stochastic approximation. *Sp; A.*

795 Advanced Probability and Stochastic Processes for Communications (3)
Prereq: 571. Transformations of random variables, sequences of rvs and stochastic convergence, statistics, parameter estimation, hypothesis testing, KL-expansions, Markov chains.

796 Advanced State Variable Methods in Control (4)
Prereq: 527 and 528. Rigorous treatment of controllability and observability for LTI systems; standard state variable forms; duality; minimal

realizations; grammians; eigenvalue placement with full state feedback; full and reduced order observers; separation principle; robustness; discrete-time systems; multivariable systems. *Irwin; W; Y.*

797 Linear Optimal Control (4)
Prereq: 796. Performance functionals discrete-time systems; principle of optimality; Hamilton-Jacobi equation; finite-time solutions; steady-state solutions; asymptotic properties; design. *Irwin; F; Y.*

798 Numerical Methods in Control (4)
Prereq: 796. Basic time domain and frequency domain calculations specialized decompositions; specialized matrix equations and their solutions; calculation of minimal realizations; state space methods of transfer function matrix analysis. *Irwin; Sp; Y.*

819 Theory of Graphs I (3)
Prereq: MATH 510. Fundamental topics of graph theory, e.g., connectedness, path problems, Eulerian graphs, matroids, matching theorems, Hamiltonian directed graphs, acyclic graphs, and partial order. Depth-first search, reducibility of program graph, binary search trees, flows in transport network. *Starzyk; D.*

844 Advanced Microwave Networks (3)
Analytical study of waveguide junctions. Impedance, admittance, and scattering matrices formulations for waveguide junctions, eigenvalue problems, symmetrical devices and directional coupler, group theory and its applications to waveguide junctions. *H. Chen; D.*

845 Computer Solutions of Electromagnetic Problems (3)
General techniques of solutions suitable for digital computation and their application to electromagnetic field problems of practical interest, matrix formulation of field problems, wire antennas and scatters, generalized network parameters, Galerkins method, Rayleigh-Ritz variational method. *H. Chen; D.*

846 Special Topics in Engineering Mathematics (3)
Concentrated study of advanced mathematical techniques in analytical solution of engineering problems. Selected topics from recent and/or classical literature of applied mathematics, as integral equations, variational and perturbational methods, applications of theory of a complex variable, theory of distributions. Introduction to functional analysis. *H. Chen; D.*

881 Doctoral Research (1–9)
F, W, Sp, Su; Y.

890 Special Topics in Electrical Engineering (3)
Current developments in electrical engineering. Selected topics offered yearly. May be taken for repetitive and variable credit. *F, W, Sp, Su; Y.*

895 Dissertation (1–9)
F, W, Sp, Su; Y.

Industrial and Manufacturing Systems Engineering

http://www.ohio.edu/industrial/

The Department of Industrial and Manufacturing Systems Engineering (IMSE) offers three degree options leading to a Master of Science degree: engineering management, manufacturing systems and manufacturing information systems. Other specialized study concentrations are available in areas of faculty interest, including artificial intelligence, systems simulation, process planning, distribution systems, genetic algorithms, data mining, and location science.

The focus of graduate educational and research activities is on structuring the decision process, system analysis, and the design of complex systems that integrate technical, human, and economic resources within a variety of constraints and environments.

The engineering management option is desired for individuals holding undergraduate degrees in engineering, physics, or other technical areas. This option will help students develop appropriate skills for the management of technology-based companies. The program requires a set of courses emphasizing skills required of technology managers including coursework in quality systems, economic analysis, information technology, and manufacturing systems. This program requires the completion of the nonthesis option.

The option emphasizing manufacturing systems has been developed to meet the needs of engineers and other technical graduates who plan to perform industrial and systems engineering and management functions in manufacturing organizations. The option is designed to build upon mathematical and analytical expertise gained from a technical education and professional experience. It is heavily directed toward using the computer to solve production problems and includes courses from other departments to provide valuable interdisciplinary experiences.

The option in manufacturing information systems educates students who intend to work as industrial and systems engineers in the areas of manufacturing systems and manufacturing management. Information being the key to successful control of these complex systems, students will learn both the fundamentals of database theory and manufacturing applications. The focus of this area is computer integrated manufacturing through information integration.

A plan of study must be submitted to the IMSE Graduate Chair for approval before the end of the second quarter of study.

The department also participates in the integrated engineering Ph.D. program, emphasizing industrial engineering. For more information, see the department Web site.

Each of these options and other concentration areas may be taken with or without a thesis. The thesis option requires a minimum of 45 quarter hours including a maximum of 6 hours of thesis (ISE 695). The nonthesis option requires a minimum of 51 credit hours including a three-credit-hour scholarly project (ISE 694), a formal written report, a nonthesis committee, and formal defense. All full-time graduate students are expected to register for three successive quarters of ISE 630 beginning with their first quarter in residence. Up to six hours of independent study may be taken for degree credit in addition to hours earned in ISE 694 or 695.

A maximum of 12 credit hours of elective graduate level courses may be taken outside the department or the University, provided they are included in an approved plan of study. You are also required to complete at least one-third of your total required hours in graduate-only courses, while the other two-thirds may be in graduate courses that are cross-listed with certain undergraduate courses.

The department welcomes applications from engineering students and qualified students with a bachelor's degree in physical sciences, including mathematics and computer science. Each candidate is evaluated on previous academic record, work experience, and career goals. All applicants are required to take the Graduate Record Examination (GRE), except in extenuating circumstances. International students desiring a graduate assistantship must pass a test of clarity of speech (SPEAK test).

Industrial and Manufacturing Systems Engineering Courses (ISE)

500 Fundamentals of Industrial Engineering (6)
Review of fundamental industrial engineering concepts to provide students with non–IMSE undergraduate degrees the foundation for graduate courses. Covers material in ISE 532, 540A, 545 and 583. (Not for degree credit for M.S., IMSE.) *F.*

501 Manufacturing Systems Design (4)
Prereq: 330, 333, 440A. Introduction to current state-of-the-art and advanced manufacturing systems design concepts in a CIM environment and in a "global economic and marketing system."

Uses the "enterprise approach" in a "top down" system design approach to manufacturing system design.

502 Manufacturing Systems (4)
Applications of industrial and systems engineering techniques, principles, practices, and methodologies as they relate to the operation, analysis, management, planning, and design of manufacturing systems. *F.*

503 Material Handling Systems Engineering (4)
Provides an understanding of material handling engineering from a system design and application engineering point of view. Instruction in the engineering principles, design criteria operating parameters, performance requirements, equipment resources, and application engineering practices involved in the planning, design, and operation of materials handling systems for manufacturing, physical distribution, and government operations. A materials handling system design project is a required part of the course.

504 Applied Engineering Statistics (3)
Prereq: calculus. Introduction to efficient methods for data collection and analysis. Application of basic statistical tests, techniques, and experimental design to engineering and science data problem areas. 3 lec. (Degree credit for M.S., IMSE in engineering management option only.) *F, W; Y.*

505 Engineering Statistics I (3)
Prereq: calculus. Introduction to probability, concept of random variables, discrete and continuous probability distribution, expectation functions of random variables, and sampling distributions. (Not for degree credit for M.S., IMSE.) *F, W; Y.*

506 Engineering Statistics II (3)
Prereq: 505. Estimation theory, hypothesis testing, and statistical prediction, simple linear regression, multiple regression, transformations, analysis of variance and simple experimental design. (Not for degree credit for M.S., IMSE.) *F, Sp; Y.*

507 Intro to Designed Experiments (3)
Prereq: course in probability and statistics. Design and analysis of engineering experiments from linear statistical model point of view. Blocking designs, full and fractional factorial designs, analysis of variance, and introduction to response surface methodology. 3 lec. *F; Y.*

509 Cost Engineering (3)
Product cost estimating, product value engineering, and manufacturing performance evaluation in state-of-the-art manufacturing systems. Examines the application of industrial engineering techniques, work measurement, cost accounting, and computers to manufacturing cost measurement and process design.

510 Decision Theory I (3)
Prereq: perm. Introduction to decision theory and its applications. Modern utility theory and its application to decision making under risk is emphasized. Examples selected from inventory, bidding purchasing, maintenance and investment policies.

514 Robotics in Industrial Systems Engineering (4)
Provides an opportunity to learn and understand the application of industrial robots and their role in industrial and systems engineering. Presents the relationships among product design, process control, robots, design of experiments, and flexible automation.Emphasizes hands-on laboratory exercises.

515 Introduction to Systems Engineering (3)
Introduction to systems engineering concepts. Systems structure, open-loop and closed-loop systems, positive and negative feedback. Applications to production and inventory systems, population, and physical systems. Design project required. 3 lec. *W.*

517 Analytical Foundations of Industrial and Systems Engineering (3)
Special analytical techniques introduced for solution of complex industrial and systems engineering problems. Calculus of finite differences, Fourier analysis, and use of transform techniques in linear system analysis; probability implications of transforms, and probability modeling.

526 Microprocessor Applications in Manufacturing (3)
Comparison and contrast of micro-, mini-, and mainframe computers; comparison of RISC and CICS microprocessors; numbering and arithmetic systems; microprocessor and microcomputer hardware organizations; assembly, procedural, and object-oriented high level languages; basic input/output and interfacing concepts; industrial data acquisition; process control and computer-integrated manufacturing concepts; graphics and industrial applications data processing; and database management for office use and business application. *W; Y.*

530 Engineering Economy (3)
Economic analysis of engineering projects. Intended to provide both basic theory and practical experience in comparing alternatives for capital expenditures, alternatives for providing needed production or services, and alternatives for income generation. 3 lec. (Degree credit for M.S., IMSE in engineering management option only.) *F, W, Sp; Y.*

531 Advanced Engineering Economy (3)
Prereq: perm. Risk explicitly treated by consideration of uncertainties of cost estimates, forecasting and other economic variables. Construction and use of mathematical models for analysis of engineering alternative. 3 lec.

532 Inventory and Manufacturing Control I (3)
Design of inventory and manufacturing control systems. Forecasting, continuous and periodic review inventory systems. Relationship between production schedules and inventory. Production scheduling systems. Sequencing models, dispatching rules. 3 lec. *F; Y.*

533 Industrial Computer Simulation (3)
Prereq: basic statistics and programming. Simulation of industrial engineering systems using discrete event modeling. Process modeling approach to simulation. Coverage of basic (entities, processes, and resources), intermediate (queues, seize, and release), and advanced (entity transport) modeling concepts. Statistical analysis of simulation results. Animation of simulated model. Application of simulation in manufacturing, production, and service areas. Lab projects using state-of-the-art simulation software. 4 lec.

534 Network Analysis and Scheduling (3)
Engineering project planning using such techniques as PERT and critical path method; shortest route; maximal flow; minimal spanning tree; flow graphs; GERT; and other network models. 3 lec.

535 Quality Control and Reliability (3)
Application of statistics to control of quality and reliability in products and services. Design of acceptance sampling and process control systems, including attention to inspection and test methods. Design and implementation of quality assurance programs, including nonstatistical dimension of quality systems. 3 lec. *Sp; Y.*

536 Project Management (3)
Development and utilization of network techniques to schedule activities, develop financial budgets, allocate resources, and control progress and costs of practical projects. Students introduced to use of available computer programs that generate project schedules. 3 lec. *F; Y.*

540A Industrial Plant Design I (2)
Prereq: 333, 445A. Introduction to two-quarter program in which students design a manufacturing facility. First quarter topics include product and process analysis, plant size, layout and location, building design, estimation of produc-tion time for each operation, production scheduling, and inventory control. (Not for degree credit for M.S., IMSE.) *W; Y.*

540B Industrial Plant Design II (3)
Prereq: 540A. Continuation of 540A. (Not for degree credit for M.S., IMSE.) *Sp; Y.*

541 Introduction to Operations Research (4)
Basic methodology of operations research. Application and mathematical structure of linear, integrated, and dynamic programming; queuing theory; and other modeling techniques. *W, Sp; Y.*

542 Inventory and Manufacturing Control II (3)
Branch and bound scheduling algorithms, horizon planning, control of integrated production, inventory and workforce systems, and linear decision rules. 3 lec.

544 Applications of Mathematical Programming (3)
Linear programming theory and practice. Topics include simplex method, two-phase method, duality theory, and sensitivity analysis. 3 lec. *Sp; D.*

546 Design of Maintenance Systems (3)
Provides a working knowledge of maintenance systems and the ability to design a maintenance system.

555 Information Systems Engineering (4)
Introduction to the design and usage of typical information systems found in a manufacturing environment. Also covers IDEF0 system modeling. 4 lec.

556 Database Information Systems (4)
Methods and procedures for storing and retrieving data in large computerized databases, in support of manufacturing information. Also covers IDEF1X modeling of database systems. 4 lec.

560 Computer Integrated Manufacturing I (4)
This course will provide the students with an understanding of the fundamentals of computer integrated manufacturing. Several issues will be addressed,among them geometric modeling, tolerances, numerically controlled machines and programming, CAD/CAM integration, data communication in manufacturing, process planning, and group technology. Lab projects with advanced automated machines and commercial CAD/CAM software. 4 lec, lab.

561 Operations Research (3)
Prereq: 517. Queuing theory and its applications. Single and multiple channels with various system parameters and queue disciplines. Both steady state and transient conditions investigated. Real-world data collection required. 3 lec.

562 Operations Research II (3)
Prereq: course in probability. Theory and application of dynamic programming to discrete and continuous multistage processors. Principle of optimality; forward and backward recursion; state and decision inversion; converging and diverging branch systems; feed-forward and feedback loops; computational algorithms and programs; stochastic dynamic programming. 3 lec. *D.*

563 Operations Research III (3)
Prereq: 544. Theory and application of integer programming, convex programming, geometric programming, gradient search methods. *D.*

564 Reliability in Design (3)
Application of reliability theory to equipment or facilities design. Design of testing systems and procedures for effective reliability measurement and prediction. Analysis of overall system reliability as function of component reliability. 3 lec. *D.*

565 Information Systems Design (3)
Design and control of information flow in organizations. Information storage and retrieval by data processing equipment. Students practice design of information systems in laboratory. 3 lec.

581 Graduate Internship in ISE (1)
This course is an internship course of ISE graduate students. Students wishing to gain external experience during their studies should enroll in this course for credit when performing an internship.

583 Work Design (3)
Prereq: 505. Design of work systems and measurement of work. Topics include job methods, operation analysis, charting techniques and schematic models, stop-watch time study, work sampling, predetermined time systems, standard data, incentive wage systems, and learning curves. 3 lec, 2 lab. (Not for degree credit for M.S., IMSE.) *F; Y.*

589 Special Investigations (1–6)
F, W, Sp, Su; Y.

590 Advanced Problems in Computer Application (1–6)
Special investigations of advanced systems and industrial engineering problems involving use of digital or analog computers. *F, W, Sp, Su; Y.*

626 Artificial Neural Networks in Manufacturing (3)
Artificial neural network applications for the development of intelligent manufacturing systems. Integration issues with induction, genetic algorithms, and fuzzy logic paradigms. *Sp; Y.*

630 Seminar in Industrial and Systems Engineering (1)
Current topics and new developments in industrial and systems engineering. Required of all IMSE graduate students each quarter until three credit hours are earned. *F, W, Sp; Y.*

632 Seminar on the Control of Inventory and Manufacturing Systems (3)
Advanced inventory control, scheduling, and forecasting techniques. Critical review of current literature on inventory and manufacturing control including advanced production scheduling and forecasting techniques. Box-Jenkins Methodology. 3 lec.

640 Facilities Layout and Location (3)
Prereq: 540A. Construction and improvement algorithms for discrete layout problems. Math programming formulations for continuous layout problems; planar and network location models. Design of linear, nonlinear, quadratic, and network programming applications. Analysis of trade-offs between model realism and solvability. Design project required.

642 Warehouse and Distribution Systems Design (4)
Quantitative and operational approach to the design of the total receiving, storage, and retrieval system including packaging, palletizing, storage, material handling, order picking, shipping, facility sizing and layout, information systems, and operating policy.

650 Foundations of Engineering Management (4)
Engineering management skills and executive leadership are required to meet the demands of both global and domestic markets. Modern corporations require engineering leadership to be creative and progressive, and to produce profitable performance. This course will help engineers to broaden their understanding of management activities and their unique applications to engineering functions.

655 Supply Chain Engineering (4)
This course examines networks of manufacturers and distributors. Study of buyer-supplier relationships and the procurement of materials, including product requirements and negotiations.

660 Geometric Modeling in Manufacturing (3)
This is an advanced graduate level course in manufacturing applications of geometric modeling. Topics covered will include geometric transformations, solid modeling representations, feature recognition and feature modeling, and generative process planning. Hands-on experience in implementing geometric modeling systems as well as using commercial CAD/CAM software. 3 lec.

681 Research (1–18)
F, W, Sp, Su; Y.

689 Advanced Topics in Industrial and Systems Engineering (1–6)
Readings and lectures. *D.*

694 Nonthesis Independent Research (3)
F, W, Sp, Su; Y.

695 Thesis (1–12)
F, W, Sp, Su; Y.

708 Quality Systems (4)
Prereq: applied stats. Modern quality systems concepts of Total Quality Control (TQC), Total Quality Management (TQM), and Quality Function Deployment (QFD), etc., with an emphasis on "quality by design." Includes Taguchi Methods for robust product and process design and western experimental design methodology.

709 Intelligent Engineering Systems (4)
In-depth study of techniques available in computer technology and human-machine systems to aid in the analysis of decision-making situations using expert systems technology.

710 Genetic Algorithms in Manufacturing (3)
Genetic algorithms are search algorithms based on the mechanics of natural selection and natural genetic operators such as crossover and mutation. In this course, genetic algorithms and evolutionary computation concepts will be presented. Their application to engineering problems in manufacturing, design, and regression will be emphasized. In addition, their connections to other artificial intelligence paradigms, such as fuzzy logic and neural networks, will be introduced (i.e., soft computing). *Sp; Y.*

727 Data Integration (3)
Data integration, including object based structures, relational and hierarchical data. Focus on Express, XML.

732 Seminar in the Control of Inventory and Manufacturing Systems (3)
Prereq: 532 or equiv. Critical review of current literature on inventory manufacturing control. Presentation of selected papers, with class participation in constructive critique. Related research within department included. Representatives of industry invited to present their control systems for critique.

733 Advanced Systems Simulation (3)
Advanced discrete event simulation modeling. Modeling, design, statistical analysis, and optimization of large scale systems. Programming and comparison of simulators, simulation languages, and object-oriented simulation tools.

737 Computer Systems Seminar (1–3)
Prereq: 528. Analytic examination of selected topics in computer system planning, design, and evaluation. Presentation of selected papers or student research, with class participation in constructive discussion. Representatives from government, industry, or other educational institutions are invited to lead discussions on topics of current interest.

790 Special Topics in Industrial and Systems Engineering (1–6)
Course content and structure (lecture, lab, or combination) will be determined at the discretion of the instructor. Examples include artificial neural networks in manufacturing, artificial intelligence in manufacturing system design, advanced manufacturing database architecture, and evolutionary computation in job shop scheduling.

891 Special Investigations in Industrial and Systems Engineering (1–6)
Course content is determined at the discretion of the instructor with an emphasis on individual study.

Integrated Engineering

http://www.ent.ohiou.edu/

An interdisciplinary Ph.D. is offered with three specialty areas: civil engineering, industrial engineering, and mechanical engineering.

Admission to the program is restricted to students who wish to study in one of the three specialties. An M.S. in engineering or a related field is required for admission. Further admissions information is available from the associate dean for research and graduate studies of the Russ College of Engineering and Technology.

A plan of study is developed on an individual basis by the student and his/her advisor. All plans of study must include a set of designated core courses (a list is available in the dean's office) and an appropriate research focus. The plan must include at least 12 credit hours from each of two departments in the Russ College of Engineering and Technology or 8 credit hours from each of three departments. A minimum of 20 hours of coursework must be at the 600 level or above, including 10 hours at the 700/800 level. A minimum of 90 credit hours above the M.S. (including 45 credit hours for the dissertation) is required. The plan must be approved by each student's dissertation advisory committee, the track coordinator, and the integrated engineering steering committee.

Each student must satisfactorily complete a qualifying examination near the beginning of the program and a compre-

hensive examination near the completion of all coursework. The qualifying exam tests a student's knowledge of fundamentals needed to study advanced coursework. The comprehensive examination measures knowledge and integration of the subjects necessary to successfully complete the dissertation.

Integrated Engineering Courses (IE)

881 Doctoral Research (1–15)

895 Doctoral Dissertation (1–15)

Mechanical Engineering

http://www.ent.ohiou.edu/me/

Graduate work leading to a Master of Science in Mechanical Engineering can be formulated with specialization in mechanical systems, thermofluid sciences, CAD/CAM, manufacturing, or biomedical engineering. Areas of interest include combustion and air pollution, computer-aided design and manufacturing, mechanical design, energy engineering and management, automated manufacturing systems, finite element analysis, materials processing, robotics, controls, composites, stirling engines, heat transfer, fluid mechanics, biomechanics, biomaterials, and mechanical design.

The basic requirement for admission is a B.S. in mechanical engineering. Applicants holding degrees in other fields of engineering or from non-accredited engineering colleges may be required to make up deficiencies prescribed by the department. The Graduate Record Examination is required except in extenuating circumstances. Special programs of study leading to the M.S. in Mechanical Engineering are available for students who have earned a B.S. in science with a major in physics or mathematics. These programs are designed to make up for deficiencies and prepare you for graduate study in one to three quarters.

Both thesis and nonthesis options are available for the M.S. program. The minimum requirements for the thesis program are 35 credits of coursework and 12 credits of thesis work. For the nonthesis program, the minimum requirements are 44 credits of coursework and 6 credits of research project. The program of study must include fundamental courses in areas of design and thermofluids. ME 597, and ME 636 are required core courses, and students must register for three quarters of graduate seminar. During the first two quarters in the program, each student will develop a specific plan of study in consultation with his/her advisor.

An interdisciplinary Ph.D. is offered in Mechanical Engineering as one of the tracks in a college-wide program. Students applying to this program must have an M.S. degree in engineering or related field. After admission to the Ph.D. program, students must pass a qualifying exam in the areas of solid mechanics, fluid mechanics, controls, and thermal sciences. The program of study requires 45 credit hours of courses and 45 credit hours of dissertation. For additional information, see the Integrated Engineering listing.

Financial assistance is available in the form of graduate fellowships, research assistantships, and graduate assistantships.

The department recommends that you enter the program in the fall quarter. Contact the department for details on graduate programs.

International students whose proficiency in English is inadequate are encouraged to enroll in the Ohio Program of Intensive English (OPIE) at Ohio University in the summer quarter preceding their first quarter of study in the department.

Mechanical Engineering Courses (ME)

503 Machine Design I (4)
Prereq: 313, CHE 331. Applications of mechanics, mechanisms, materials, and mechanical processes to the design and selection of machine members and units of power transmission. *Halliday; Sp; D.*

504 Machine Design II (4)
Prereq: 403. Morphology and anatomy of engineering design. Inventiveness, engineering analysis, optimization, statistics, and decision making. Engineering design project. Graduate credit for non-mechanical engineering majors only. *W.*

506 Analysis and Design of Mechanisms (4)
Analysis and synthesis of planar and three-dimensional mechanisms using classical and modern analytical approaches. Structural synthesis of mechanisms and dimensional synthesis of linkages for function generation, path generation, and rigid-body guidance. Applications of matrix methods, optimization techniques, and computer solutions. *Williams; D.*

507 Fundamentals of Nuclear Engineering (4)
Nuclear engineering, including nuclear reactions, radiation detection and measurement, reactor control, radiation shielding, effects of radiation on materials, uses of radioactive materials. *D.*

508 Nonlinear Vibrations (3)
Qualitative and numerical study of mathematics and physics of nonlinear systems. Formulations of nonlinear engineering problems, solutions techniques, and stability analysis. *Halliday, Pasic; Sp; D.*

509 Advanced Machine Dynamics (3)
Theoretical analysis and applications of dynamical aspects and problems in machines and their components.

510 Advanced Vibrations Analysis (4)
Prereq: 592. Vibrations of multi-degree-of-freedom, lumped, parameter systems and of continuous systems such as bars, beams, and plates; numerical methods of solution; use of Rayleigh-Ritz and Galerkin procedures. *Halliday, Pasic; F; D.*

512 Heat Transfer (4)
Prereq: 321, CE 340. Basic concepts of conduction in one or more dimensions, steady and transient modes. Radiation, dimensional analysis, fundamentals of convection in various modes, heat exchanger design. 4 lec. Graduate credit for non-mechanical engineering majors only. *Sp; Y.*

513 Conduction, Convection and Radiation (4)
Advanced analytical treatment of conduction, convection, and radiation. Boundary value problems, orthogonal expansions, moving heat sources, multidimensional problems with varying boundary conditions, finite difference analysis, conformal transformations, radiation network matrix analysis, diffuse-specular exchange, Monte Carlo techniques, etc. *Alam, W.*

514 Convection Heat Transfer (4)
Prereq: 546. Convection heat transfer. Hydrodynamic and thermal boundary layers in forced and free conversion. 3 lec. *Sp.*

515 Thermal Stress Analysis (4)
Prereq: CE 528. Thermal stresses developed in machine and structural components. Procedures for solving stress problems associated with elevated temperatures in such components as tubes, rods, and plates as encountered in nuclear reactors, engines, and airplane and missile structures. *D.*

516 Combustion (3)
Kinetic theory and properties of gases, chemical reactions in gases, diffusion flames, detonation, combustion of atomized sprays, combustion diagnostic techniques, combustion and air pollution. *Alam, Bayless; D.*

517 Design of Thermal Systems (4)
Design of systems in which thermodynamics and heat and mass transfer are major considerations. Emphasis on total design approach incorporating economic considerations and optimization techniques. Typical systems include power, propulsion, environmental, cryogenic. *D.*

518 Mechanical Engineering Experimentation (1)
Instruction in experimental procedure and experience in designing and executing laboratory experiments. Planning and execution of experiments to acquire answers to assigned problems. Variety of areas covered including control systems, energy conversion, fluid flow, heat transfer, motion measurements, stress-strain. Instructional guidance provided by entire mechanical engineering staff. Provides familiarity with variety of instrumentation and procedures. Three-quarter sequence with experimental subjects phased with prerequisites. *D.*

519 Mechanical Engineering Experimentation (1)
Continuation of 518. See 518 for description. *D.*

520 Mechanical Engineering Experimentation (1)
Continuation of 519. See 518 for description. *D.*

522 Stirling Cycle Machine Analysis (3)
Prereq: 328, ET 240, CE 340, and concurrent with ME 412. Analysis and simulation of Stirling cycle engines, in which the single phase working gas operates in a closed thermal power cycle. Development and use of computer simulation techniques to model the nonsteady flow conditions including thermodynamics, heat transfer, and fluid flow friction effects. *Urieli; W; Y.*

523 Fuel Cell Design (3)
Design of fuel cells using analytical tools based on thermodynamic and electrochemistry.

524 Gas Dynamics I (3)
Prereq: CE 340. One- and two-dimensional gas dynamics, isentropic flow, flow with heat transfer, friction, shocks, generalized one-dimensional flow. Applications to propulsion systems. 3 lec. *D.*

525 Vehicle Propulsion Systems (4)
Prereq: 524. Applications of basic engineering disciplines to design and analysis of ground vehicle propulsion systems. Emphasis on new concepts. Extensive use of computer modeling. Term report required. *D.*

526 Stirling Machine Design Colloquium (2)
Unstructured lecture, roundtable discussion, project and model presentation, laboratory. Topics include various practical problems and issues related to the design, development, and testing of Stirling cycle machines and components. Participation of all students is required in terms of podium presentations, projects, and models, as well as a final report. *D.*

527 Power Station Engineering (3)
Prereq: perm. Application of the principles of thermodynamics, fluid mechanics, and heat transfer to the analysis of combustion, pulverized coal combustion, control of gaseous emissions, nuclear fission, steam generators, economizers, preheaters, superheaters, turbines and turbomachinery, stacks, forced and induced draft, feed pumps, and heat balances. Optimization of power plant design and operation. *Bayless; Y.*

529 Mechanics and Control of Robotic Manipulators (4)
Prereq: perm. Classification and applications for mechanical manipulator systems. Manipulator motion description, forward kinematics transformations, and solution of inverse kinematics equations. Velocity kinematics and manipulator dynamics equations. Trajectory generation and control schemes including sensory feedback. Laboratory excercises to augment lecture material. Co-listed with EE 429/529. *Williams; Sp.*

531 Atmosphere Pollution Control (4)
Prereq: perm. Sources of air pollution from major industries, internal combustion engines, and other sources. Techniques available for measuring particulate and gaseous pollutants in atmosphere and at their sources. Techniques available for control and future possibilities for control of air pollution. *Bayless; Y.*

532 Analysis and Simulation of Transport Processes (4)
Use of CFD software to study conduction, convection, and radiation. Analyze governing equations by simulation and visualization. Fundamentals of CFD programming. *Staff.*

534 Fundamentals of Aerosol Behavior (3)
Prereq: 321, 412. Aerosol characterization transport properties, convective and inertial deposition, light scattering and visibility, experimental methods, coagulation, gas to particle conversion, general dynamic equation for aerosols. *Alam, Bayless; D.*

535 Energy Engineering and Management (3)
Basic concepts and objectives of energy management, energy audit, engineering evaluation of several energy systems, availability analysis, second law efficiency, economic evaluation, and application of these principles to case studies. *D.*

540 Direct Energy Conversion (4)
Coupled flows, irreversible thermodynamics, behavior of ionized gases, general principles of unconventional thermodynamic cycles; thermoelectricity, thermionics MHD, fuel cells. *D.*

545 Advanced Numerical Methods (4)
Prereq: 597 or equiv. Numerical methods for solution of ordinary and partial differential equations, stability considerations and error estimates, application to variety of engineering problems, numerical method of lines and integration procedures for stiff ODE systems. *W; Y.*

546 Potential Flow Theory (3)
Inviscid flow theory. General equations of fluid mechanics, study of potential flows. 3 lec. *Alam; F; Y.*

547 Viscous Flow Theory (3)
Mechanics of fluid resistance, laminar and turbulent flow, applications to external boundary layer flow and to flow in ducts. 3 lec. *Graham; W; Y.*

550N Computer-Aided Design I (4)
Applications of contemporary computer modeling techniques to solve complex problems in stress, heat transfer, dynamic systems, and fluid flow. Emphasis given to applications of these techniques to solve specific problems in mechanical engineering design. *Gunasekera; W; Y.*

551 Computer-Aided Design II (4)
Prereq: 550. Existing CAD techniques, graphics input and output of data, advanced CAD system, requirements for a general CAD system, graphical and utility functions, filing facilities, editors, software designs and organization, solid modeling, 3-D display, facilities, application of CAD techniques for finite element data preparation and display, automated mesh generation. *Gunasekera; D.*

555 Mechatronics I (4)
Design of intelligent devices. Interfacing of micro- and minicomputers with machines. Microprocessor characteristics, actuator characteristics, visual pattern recognition, design of devices. Theory and laboratory. *Sp.*

556 Mechatronics II (3)
Prereq: 455. Kinematics and dynamics of computer-controlled machines, robot sensors, and robot-control language concepts. Short laboratory exercises and major robotics project on subjects mentioned above required. *D.*

557 CAD/CAM I (4)
Emphasis on teaching computer-aided design/computer-aided manufacturing with following topics covered: menu basis, training files, interactive graphics design system, mechanical design system, system interfaces with other software, data base management retrieval system, EDG-graphics editor, EDT-VAX/VMS editor and VI UNIX editor; VAX/VMS-based DCL commands, introduction to UNIX and "C," and other topics as needed. Successful completion of an approved minor project also required. *Gunasekera, Mehta; D.*

558 CAD/CAM II (5)
Prereq: 557. Continuation of 557; emphasis on advanced application in (a) programming, (b) finite element pre/post processing and analysis, (c) B-Spline and sculptured surfaces, and (d) computer and direct numerical controls (CNC/DNC). Introduction to usage of third-party finite-element analysis software for metals, polymers, and composites, e.g., ALPID, NIKE, DYNA, TOPAZ, ABAQUS, POLY-CON, NASTRAN, etc. Successful completion of an approved major project also required. *Gunasekera, Mehta; D.*

560 Computer-Integrated Manufacturing/Processes (4)
Prereq: 450. Introduction to numerical control; control systems for NC; communication media; NC programming languages—SPPL and APT; mathematics for NC; Parametric Splines, Bezier Curves and B-Splines; sculptured surfaces, including Coons bi-cubic patch and B-surf. *Gunasekera; D.*

562 Manufacturing Processes (4)
Prereq: grad in ME, CHE, or IMSE. The basic theory of plasticity and its application to manufacturing processes. Applied theories of metal working processes such as forging, extrusion, rolling, and some aspects of machining; theories of polymer processing, composite and reinforced materials processing, use of application of materials information systems, and mapping techniques. *Gunasekera; W; Y.*

563 Mechanical Metallurgy (3)
Origin and control of mechanical properties of metals. Elasticity, plasticity, fatigue behavior, corrosion, and wear. Introduction to fracture mechanics. Thermal, mechanical, and chemical strengthening techniques. *Halliday; D.*

565 High Temperature Alloys (4)
Physical, mechanical properties of superalloys. Application of superalloys.

576 Automotive Engineering (4)
Overview of automotive engineering, including modeling, simulation, design, and testing of land vehicle systems with emphasis on performance, safety, fuel economy, and emissions. Broad exposure to all topics through case studies.

580 Graduate Colloquium (1)
Structured as an open graduate colloquium for discussion of present research topics as well as possible future areas of interest. Guest speakers, faculty, and graduate students presenting the results of their investigations, with discussion moderated by speakers. *F, W, Sp; Y.*

584 Problems in Thermal Machinery I (3)
Prereq: good academic record. Supervised research in thermal machines. Individual work on experimental or analytical project involving current problems. Elect two-term sequence to allow adequate time for completion of meaningful project. *D.*

585 Problems in Thermal Machinery II (3)
Continuation of 584. See 584 for description. *D.*

586 Problems in Thermal Machinery III (3)
Continuation of 584 and 585. See 584 for description. *D.*

589 Special Investigation (1–6)
F, W, Sp; Y.

591 Mechanical Vibrations I (4)
Characteristic phenomena of mechanical vibrations encountered in machines and structures (of one-degree-of-freedom) in their quantitative investigation. Simple harmonic motion; free, transient, and forced vibrations; damping effects; demonstrations; computer applications. Graduate credit for non–mechanical engineering majors only. *Halliday; F; Y.*

592 Mechanical Vibrations II (4)
Prereq: 591. Application of matrix methods; two-degree-of-freedom systems; lumped mass systems with several degrees of freedom; and methods for normal mode determination. 3 lec, 1 computation session. *Halliday; W.*

593 Lubrication and Bearing Analysis (3)
Concepts of boundary, hydrostatic, and hydrodynamic lubrication and their application to different bearing geometries. McKee and McKee, Boyd, and

Raimondi methods of bearing design and their optimization. Solid lubrication, porous, and gas bearings. Lubrication and wear in living and artificial human joints and human hipjoint prostheses. *Halliday; D.*

594 Advanced Machine Design (3)
Prereq: 403. Advanced considerations in design and analysis of machine members, pressure vessels, impact loading, thermal stress analysis, fatigue in metals. 3 lec. *D.*

595 Introduction to Kinetic Theory and Statistical Thermodynamics (4)
Kinetic theory, classical and quantum statistical mechanics with application to engineering devices. 3 lec. *D.*

596 Experimental Methods in Design (3)
Investigation and evaluation of experimental methods used to obtain design and performance data. Techniques of photoelasticity, strain measurements, and vibration measurement. *Y.*

597 Methods of Engineering Analysis I (4)
Prereq: MATH 340. Methods of analyzing equilibrium and eigenvalue problems in mechanical engineering and engineering mechanics; matrix methods; variational methods; numerical methods. *Pasic; F; Y.*

601 Advanced System Analysis and Control (3)
Prereq: 401, MATH 211 or 410 or 411. The application of modern control theories to the synthesis of dynamical systems. Topics include the analysis of the behavior of linear systems, controllability and observability. Synthesis in the eigenvalue domain: modal control. Synthesis of stable systems and optimal linear systems in the time domain. *Williams; W.*

604 Mechanics and Control of Multi-Degree-of-Freedom-Systems I (3)
Techniques of analysis and design of multi-degree of freedom planar and spatial mechanical systems: kinematic structure, coordinate transformations, inverse solutions, workspace, path selection, dynamics, and control. *Williams; F.*

605 Dynamics: Theory and Applications I (3)
Partial differentiation of vector functions in a reference frame, configuration constraints, generalized speeds, motion constraints, partial angular velocities, and partial linear velocities, inertia scalars, vectors, matrices, and dyadics, principal moments of inertia. *W.*

606 Dynamics: Theory and Applications II (3)
Prereq: 605. Generalized active forces, contributing and noncontributing forces, generalized inertia forces, relationships between generalized active forces and potential energy, generalized inertia forces and kinetic energy. A continuation of 605. *Williams; D.*

607 Optimal Control of Dynamic Systems (3)
Optimization problems for dynamic systems: functional and extremums; continuous systems with terminal and path constraints; integral constraints; multistage systems; feedback control for linear systems with quadratic costs; neighborhood extremal paths and second variation. *D.*

611 Advanced Kinematics (3)
Kinematic analysis and synthesis of planar and three-dimensional mechanisms using classical and modern analytical approaches. Application of matrix methods, optimization technique, and computer solutions.

620 Free-Piston Stirling Machines (3)
Prereq: 509 or 592, with 522. Analysis of free-piston Stirling cycle machines. Covers applications to power production, heat pumping, cryocooling, and refrigeration. Analytical solutions to multibody dynamics and mechanical oscillators. Transient performance and stability.

622 Design of Stirling Machines (3)
Prereq: 522, with 620. Introduction to the design process. Stirling machine design procedures—scaling, heat exchanger sizing, pV sizing; configurations—crank, hybrid and free piston machines; examination and comparison of existing designs; general issues—materials, stress (fatigue, creep, rupture), seals and bearings, balancing; heat exchanger design, heat transport systems and burners. Group design projects may typically be one of the following: appropriate technology FPSE, regenerator test rig, free cylinder engine with linear alternator, simple crank engine, cooler, free-piston alpha engine, Ringbom engine, Rallis engine. *D.*

625 Stirling Machine Design Project (1–15)
Prereq: 526, 514, 622. The capstone design project for the Stirling cycle machines—design option; students choose a mentor from the Stirling machine design specialists involved in the Stirling machine industry. *D.*

630 Active Structures (3)
Prereq: perm. Advanced analysis, design, and control for active structures (variable geometry trusses). Classification and application of active truss modules.

633 Numerical Heat Transfer and Fluid Flow (4)
Prereq: 513, 546, or 547. Numerical solution techniques in heat and mass transfer, fluid flow, and related processes. Includes governing conservation equations, discretization methods, heat conduction, convection, diffusion, and calculation of flow field. *Alam; D.*

636 Applications of Numerical Methods in Mechanical Design (4)
Prereq: CE 520/ME 557, ME 633. Application of engineering analysis and boundary element method to solve linear and nonlinear problems in engineering related to fluid flow, heat transfer, dynamics, plasticity, and convection. Selection and application of appro-priate numerical technique. Other advanced topics related to Gaussian integration, frontal solutions, and algorithms for parallel processing will be introduced as needed. *Alam, Mehta; W.*

651 Advanced CAD (4)
Application of CAD to mechanical design. Use of CAD/CAM software.

659 Finite Element Applications in Bioengineering (5)
Includes review of finite element technique (FEM); introduction to boundary element method (BEM); the biology and composition of bone; mechanical properties of bone and tissue; stress analysis of the femur, tibia, skull, spinal cord, and joints using finite element method; application of FE and BE techniques in bone prostheses and implants; composite material modeling of bones using Abaqus; analysis of blood flow in arteries treating it as a non-Newtonian fluid. Finite element packages such as I/FEM, Patran, Abaqus, BET, FIDNAP, NIKE, DYNA, and TOPAZ are used. *Mehta; Su; Y.*

675 Destructive Testing of Materials (3)
Prereq: CE 524. Testing and analytical considerations in destructive testing of materials; interpretation of results and sources of errors in hardness, tensility, impact, fatigue, and pressure testing of materials; residual stress determination in formed metallic parts.

677 Biomedical Engineering Materials (4)
Prereq: Grad Status. Course covers Biomaterials and Biological Materials, their application and modeling. The course contents are more focused on developing new biomaterials and their use in the biomedical industry.

681 Research (1–15)
F, W, Sp, Su; Y.

689 Graduate Internship
Supervised work-study experience in an established industrial or government environment. *Alam; F, W, S; Y.*

695 Thesis (1–15)
F, W, Sp, Su; Y.

704 Mechanics and Control of Multi-Degree-of-Freedom Systems II (3)
Prereq: 604. Advanced analysis and control techniques for multi-degree-of-freedom mechanical systems: closed-chain mechanisms, space manipulators and structures, redundant mechanisms, dynamic characterization, advanced strategies of control. *Williams; D.*

705 Dynamics: Theory and Applications III (3)
Prereq: 606. Dynamical equations of motion, linearization, steady motions, and motions resembling state of rest, integrals of equations of motion, exact closed form solutions, numerical integration of differential equations of motion, determination of constraint forces and constraint torques, collisions, and small vibrations. A continuation of 605, 606. *Williams.*

712 Advanced Heat Transfer (5)
Prereq: 513 or 514. Advanced analysis of heat transfer, with emphasis on mechanical engineering processes. Lumped, integral, and differential formulations, time dependent boundary conditions, steady periodic problems. Combined conduction, convection, and mass transfer in complex heat transfer processes. *Alam, Graham.*

720 Advanced Nonlinear Finite Element Analysis (5)
Prereq: 551 or CE 520. Advanced study in finite element analysis of solids and fluids, with emphasis on methodologies for nonlinear problems. Fundamental theory and computer implementations of various techniques are examined. Restricted to small groups, with extensive student participation required. *Graham, Gunasekera, Sargand; F; Y.*

751 Advanced Computer-Aided Design (4)
Prereq: CE 520 or ME 550N and ME 557. Application of advanced CAD techniques to mechanical design problems. Interactive computer programming, mechanical tolerancing. Solid modeling and finite element applications. Pre- and post-processing of FEM data. Automated mesh generation techniques. Cubic splines, B-splines, and sculptured surfaces. *Gunasekera; D.*

760 Advanced CAD/CAM/CAE of Dies and Molds (4)
Prereq: 551 or 557. Formulation of the design basis for dies and molds; analysis of material flow through dies; development of criteria for design optimization, heat transfer, and die stress analysis. Theoretical basis for describing 3-D die geometry of complex dies for computer-aided manufacture. Applications in extrusion, forging die casting, and injection molding dies. Development and use of computer software in CAD/CAM/CAE of dies. *Gunasekera; D.*

762 Advanced Topics in Non-Newtonian Fluid Dynamics (5)
Prereq: 557, 633, or CE 520. Includes constitutive modeling including power law fluids, maxwell fluids, and models of differential and integral type. Formulation schemes for non-Newtonian fluid dynamics using finite element analysis and its applications. *Gunasekera, Mehta.*

776 Special Topics in Materials Processing (4)
Prereq: 563 or CHE 620. Advanced topics in selected areas of materials processing technology. Processing by deformation, solidification, and deposition are possible areas of study. *Alam, Gulino; D.*

780 Doctoral Colloquium
Presentation and discussion of research topics. *Alam; F, W, Sp, S; Y.*

784 Fracture and Fatigue of Engineering Materials (4)
Prereq: CE 528 or CE 523. Analysis of crack-tip stress field, energy concepts and crack growth criteria, conservation integrals, crack life prediction, mechanisms of fatigue damage, and high-cycle and low-cycle fatigue damage. *Pasic; D.*

785 Plasticity: Theory and Application (4)
Prereq: 597, CE 523, or CE 529. Theory of plasticity, stress-strain relations for perfectly plastic and strain hardening materials, yield criteria and constitutive equations of plastic bodies, boundary value problems of plasticity, the slip-line theory and applications. *Pasic; D.*

790 Special Topics in Mechanical Engineering (1–6)
Prereq: perm. Advanced topics in selected areas in mechanical engineering.

791 Special Investigations (1–6)
Prereq: perm. Advanced topics in mechanical engineering with an emphasis on individual study.

797 Advanced Engineering Analysis (4)
Prereq: 597, CHE 642. Unified approach for obtaining solutions to a variety of engineering problems, with emphasis on mechanical engineering topics such as transport processes, nonlinear vibrations, and dynamics. Focus on advanced/approximate methods. *Pasic, Alam; D.*