

Systems Engineering-Energy Systems Technical Electives

The following courses represent some of the content currently available university-wide that could serve as acceptable technical elective courses for the Systems Engineering - Energy Systems graduate programs (provided these courses have not already been used to satisfy core program requirements). The intent of the technical electives is to allow, with advisor approval, any graduate level courses that are consistent with the System Engineering-Energy Systems degree and the student's particular program of study. The following course list is a sample of such courses, meant to illustrate the broad and diverse elective course offerings available to students enrolled in these programs.

Technical Electives (non-exhaustive listing):

Course Number	Title	Credits	Prerequisite	Catalog Description
AREC 540 / ECON 540	Economics of Natural Resources	3	AREC 340 / ECON 340, MATH 141	Public natural resources policy, effect on resource use in private sector, optimal pricing of minerals, timber and fisheries, and public project analysis.
AREC 541 / ECON 541	Environmental Economics			Economics of environmental policy; partial equilibrium and general equilibrium model; pollution; natural environments; population and economic growth.
CHEM 537	Electrochemical Methods	3	CHEM 431	Theory and methods of electrochemistry; applications of modern electrochemical techniques.
CIS 601 / MGT 601	Enterprise Computing and Systems Integration	3	Admission to M.S. program	Integrated extended enterprise planning and execution systems concepts including ERP, CRM, SCM, MRP II, business processes, front/back office systems.
CIS 610	Software Development Methodology	3	Admission to M.S. program	Methods for all phases of software development focusing upon the establishment of economical software that is reliable and cross platform.
CIVE 504	Wind Engineering	3		Influence of wind on humanity. Applications to structures, air pollution, wind

				energy, agricultural aerodynamics, snow movement, human comfort.
CIVE 514	Hydraulic Structures/ Systems	3	CIVE 401	Analysis and design of hydraulic structures which make up components of water resource systems.
CIVE 520	Physical Hydrology	3	CIVE 322/ENVE 322	Hydrologic, atmospheric processes in the water cycle; linear systems, hydrologic response; geomorphologic description of hydrologic processes, response.
CIVE 522	Engineering Hydrology	3	CIVE 520	Hydrologic design under uncertainty; conventional and remote sensing; design flows and storms; river routing; reservoir design; watershed models.
CIVE 540	Fundamental Environmental Biotechnology	2		Fundamentals of environmental biotechnology: environmental microbiology, microbial kinetics, basic reactor design.
CIVE 546	Water Resource Systems Analysis	3	CIVE 322/ENVE 322 or concurrent registration; ENGR 510/MATH 510 or concurrent registration	Applications of systems analysis and optimization techniques in water resources planning and management.
CON 574	Sustainable Technology in Built Environments			
CS 518	Distributed Software System Development	4	CS 414; CS 451. Must register for lecture and laboratory.	Principles of developing distributed systems; middleware technologies and techniques for building complex distributed component-based systems.
CS 533	Database Management Systems	4	CS 430. Must register for lecture and laboratory.	Theory and implementation of concurrency control, recovery, and query processing as it applies to centralized and distributed systems.
CS 545	Machine Learning	4	CS 440. Must register for lecture and laboratory.	Computational methods that allow computers to learn; neural networks, decision trees, genetic algorithms, bagging and boosting.
CS 556	Computer Security	3	CS 451. Must register for lecture and laboratory.	Topics in computer security: concepts, threats, risks, access control models, trusted systems, cryptography, authentication.

CS 557	Advanced Networking	3	CS 457	LAN/WAN technologies, congestion/flow control, traffic analysis, intra-/inter-domain routing, multicast, overlays, P2P systems and quality of service.
ECE 512	Digital Signal Processing	3	ECE 312 with grade of C- or better	Discrete time signals and systems, digital filter design and implementation, fast algorithms, quantization effects.
ECE514	Applications of Random Processes	3	ECE 303/STAT 303 with grade of C- or better; ECE 312 with grade of C- or better	Bit-error rates, signal-to-noise power ration, signal detection, signal estimation, Wiener filter, application.
ECE520	Optimization Methods-Control and Communication	3	MATH 229; MATH 317	Linear and nonlinear optimization theory and methods; applications in systems, control, and communication.
ECE524	Wireless Telecommunications	3	ECE 421	Physical layer design, including channel modeling, receiver design and performance, and multiple access techniques.
ECE 549	Radar Systems and Design	3	ECE 444	Fundamental ideas of radar operation and basic design of various radar types including current topics.
ECE 550B	Microprocessors Based Systems	3	ECE 451	High-performance microprocessors, e.g., 68000 family; intelligent I/O processors. Asynchronous bus, virtual memory, microprocessor in control and multi-user systems.
ECE 562	Power Electronics I	3	EE 332 with grade of C- or better	Switch mode and resonant converters, control using switch averaged dynamic models, modeling of all circuit components including sources, loads, and switches.
ECE 563	Power Electronics II	3	ECE 562	Electrical energy, processing circuits, lightweight power management, and power conversion circuits emphasizing small signal transfer functions.
ECE580**/ECE581**	Experimental Course Offerings	1-4	Varies	Content will vary
ECE 611	Nonlinear Control Systems	3	ECE 412	Controller analysis and design for nonlinear systems.
ECE 612	Robust Control Systems	3	ECE 411	Introduction to modern robust control theory techniques for analysis and design of large-

				scale uncertain multivariable systems.
ECE 614	Principles of Digital Communications	3	ECE 514	Information theory, optimal receiver design, waveform coding, error correcting coding.
ECE 652	Estimation and Filtering Theory	3	ECE 411 or ECE 412; ECE 514 or STAT 525	Linear and Nonlinear parameter and state estimation methods; Optimal Kalman state estimation and applications.
ECE655	Multi-dimensional Digital Signal Processing	3	ECE 512	Multidimensional signals and systems, 2-D transforms, stability methods, design and implementations, spectral factorization, and image modeling.
ECE 656	Neural Networks and Adaptive Systems	3	EE 512	Various adaptation rules, neural network paradigms, learning, stability and convergence, applications in signal/image processing and control.
ECE 658 / CS 658	Internet Engineering	3	ECE 456 or CS 457. Credit not allowed for both ECE 658 and CS 658. Must register for lecture and laboratory.	Link technologies, multiple access, hardware and software for internetworks routing, switching flow control, multicast, performance, and applications.
ECE680**/ECE681**	Experimental Course offering	1-4	Varies	Content will vary
ENGR 510	Engineering Optimization: Methods & Applications	3	MATH 261	Optimization methods; linear programming, simplex algorithm, duality, sensitivity analysis, minimal cost network flows, transportation problem.
ENGR 520	Engineering Decision Support/Expert Systems	3	ENGR 510/MATH 510	Decision support systems for complex engineering problems; multicriteria decision making and optimization; hybrid knowledge-based/algorithmic methods.
ENGR 532	Dynamics of Complex Engineering Systems	3	ECE 411 or MECH 417 or CBE 430; ENGR/ECE 501 or concurrent registration	Higher-level behavior and issues that emerge from interaction between components in complex socio-technical systems.
ENGR 565	Electrical Power Engineering	3	ECE332	Basic characteristics of power systems; power flow, reactive power control, and voltage stability.

ENGR 566	Energy Conversion for Electrical Power Systems	3	ECE332	Power Electronics and Energy Conversion; Converters and Inverters.
ENGR 567	Systems Engineering Architecture	3	ENGR/ECE501	This course provides a toolset for observing and classifying systems architecture, and its practical application through design studies.
ENGR 568	Electrical Energy Generation Systems	3		Overview of energy systems; basic operation of solar-photovoltaic, wind energy, gas, coal, and nuclear plants.
ENGR 621	Energy Storage for Electric Power Systems	3		Overview of energy storage systems; batteries, mechanical storage, and thermal storage systems.
ENGR 622	Energy Networks and Power Distribution Grids	3	ECE411 or MECH417, and ENGR/ECE565	Systems approach to analyzing energy distribution networks; smart grid systems.
MATH 519	Complex Variables I	3	MATH 317	Analytic functions, complex integration theory, singularities, elementary functions, and mapping.
MATH 520	Nonlinear Programming	3	MATH 510/ENGR 510	Theoretical, computational, practical aspects of nonlinear programming (NLP); unconstrained, constrained NLP; quadratic programming; large-scale NLP.
MATH 525	Optimal Control	3	MATH 340 or MATH 345	Theory and application of optimal control and optimal estimation theory; continuous and discrete time systems; Pontryagin maximum principle.
MATH 530	Mathematics for Scientists and Engineers	4	MATH 340 or MATH 345	Proof-oriented linear algebra, ordinary and partial differential equations.
MATH 531	Discrete Models of Physical Systems	3	MATH 340 or MATH 345	Discrete models for physical systems; systems of ordinary differential equations, applied linear algebra; introduction to finite elements.
MATH 532	Mathematical Modeling of Large Data Sets	3	MATH 369 or MATH 530; preparedness to do programming in a standard language.	Mathematical theory and algorithms for modeling large data sets. Application to real world problems. Emphasis on geometric ideas.
MATH 540	Dynamical Systems	3	MATH 369; MATH 417	Linear and nonlinear systems, orbits, phase space, flows of vector fields, stability, bifurcation theory, chaos,

				strange attractors and applications.
MATH 545	Partial Differential Equations I	3	MATH 340 or MATH 345 or MATH 530	Second order linear PDEs, elliptic and parabolic equations, equations of math physics, separation of variables, Fourier series.
MATH 546	Partial Differential Equations II	3	MATH 545	Distribution theory, Green's functions, Sobolev spaces, elliptic and parabolic equations.
MATH 550	Difference Methods – Partial Differential Equations	3	MATH 530 or MATH 545	Explicit, implicit methods for second order equations, higher-dimensional problems, stability analysis, method of characteristics.
MATH 560	Linear Algebra	3	MATH 369	Finite dimensional vector spaces, inner products, dual spaces, transformations, projections, adjoints, norms, eigenvalues, eigenvectors.
MATH 561	Numerical Analysis I	4	CS 156 or CS 160 or CS 253 or MATH 151; MATH 560	Numerical linear algebra, solving nonlinear systems, least squares, and minimization.
MATH 633	Industrial and Applied Mathematics	3	MATH 530 or MATH 560 or MATH 561; preparedness to do programming in a standard language. Must register for lecture and laboratory.	Team solution of problems arising in industrial and applied mathematics. Problem formulation, solution proposal, implementation and analysis.
MATH 640	Ordinary Differential Equations I	3	MATH 340 or MATH 345 or MATH 530; MATH 369; MATH 517	Existence and uniqueness, continuation, continuous dependence, linear systems, and stability.
MATH 641	Ordinary Differential Equations II	3	MATH 640	Topics selected from nonlinear boundary value problems, periodic phenomena, differential operators, and others.
MATH 645	Advanced Partial Differential Equations I	3	MATH 546	Abstract methods for linear partial differential equations.
MATH 646	Advanced Partial Differential Equations II	3	MATH 645	Problems in nonlinear partial differential equations.
MATH 651	Numerical Analysis II	4	CS 156 or CS 160 or CS 253 or MATH 151; MATH 340 or MATH 345 or MATH 369 or MATH 530	Interpolation, approximation, quadrature, initial and boundary value problems.

MECH 509	Manufacturing Quality Design & Control	3	MATH 340; STAT315	Design of Decision Making Models for Industrial Engineering
MECH 510	Advanced Engineering Economy	3	MECH 410; STAT315	Evaluation of independent and interrelated proposals with compound interest, discrete and continuous cash flows, complete and incomplete information.
MECH 512	Reliability Engineering	3	MECH 513; STAT 315	Models to predict time to failure of mechanical or electronic devices, reliability data analysis and case studies.
MECH 513	Simulation Modeling and Experimentation	3	STAT 315	Logic/analytic modeling in simulations. Event and transient entity-based simulation languages. Simulation design, experimentation and analysis.
MECH 524	Principles of Dynamics	3	MECH 324	Kinematics and dynamics of rigid body motion; Lagrangian and Hamiltonian formulations of mechanics; applications to engineering problems.
MECH 536	Materials Applications in Renewable Energy	3	MECH 331	Materials science applied to renewable energy, transmission and storage; study of solar cells, fuel cells, Li-ion batteries and related technologies. Required field trips.
MECH 551	Physical Gas Dynamics I	3	MECH 342	Characteristics of real gases in reacting and nonequilibrium systems; equilibrium air; statistical mechanics, chemical thermodynamics.
MECH 558	Combustion	3	MECH 342	Combustion processes: explosions, detonations, flame propagation, ignition, generation of pollutants in moving and stationary energy conversion systems.
MECH 561	Space Propulsion and Mission Analysis	4	MATH 340	Analysis of space flight missions and propulsion systems.
MECH 563	Air Pollution Control	3	MECH 337	Abatement of emissions from mobile and stationary sources; monitoring, dispersion, air quality standards, electrostatic precipitation, energy consumption.
MECH 575	Solar and Alternative Energies	3	MECH 337; MECH 342; MECH 344	Solar radiation, flat-plate collectors, energy storage, space heating and cooling,

				power generation, applications, simulation.
MECH 580	Renewable Energy for Mechanical Engineers	3	MECH 331	Various sustainable renewable energy technologies; technology development, current state-of-the-art, fundamental limitations, mechanisms for advancing the technologies.
MECH 609	Experimental Optimization	3	MECH 509	Application of design of experiments, response surface and optimization methods to experimental investigations.
MECH 644	Conduction Heat Transfer	3	MECH 344	Linear and nonlinear, isotropic and nonisotropic conduction; analytical, numerical techniques, inverse methods.
MECH 645	Radiation Heat Transfer	3	MECH 344	Radiation fundamentals; properties; spectral, directional variations; transfer between surfaces; participating media; numerical Monte Carlo methods.
MECH 646	Convection Heat Transfer	3	MECH 344	Fundamentals; conservation, constitutive equations; second law; forced, free convection; internal, external flows; laminar, turbulent flows.
MECH 676	Building Energy Design	4	MECH 575. Must register for lecture and laboratory	Design of space heating and cooling systems. Solar thermal electric power systems, industrial and agricultural process heat.
MGT 600	Manufacturing Process and Systems Design	3	BUS 620 and BUS 625	Strategic understanding of alternate manufacturing processes and systems design support needed to manage those processes.
NR 501	Leadership and Public Communications	3	Introductory course to natural resource management fields; communication course. Offered as correspondence course only.	Two-way communication skills used to involve publics, write for various media, and understand role of leadership within natural resources profession.
NR 503	Remote Sensing of Natural Resources	4	Must register for lecture and laboratory.	Interpretation and analysis of photographic, multispectral scanner, and radar data; sensor systems; applications to resource management.
NR 504	Computer Analysis of Remote Sensing Data	4	NR 323 or NR 503	Computer-aided analysis techniques for extracting resource information from aerial and satellite remote sensing data.

NR 505	Concepts in GIS	4	STAT 301 or STAT 511. Must register for lecture and laboratory.	Concepts of geographic information systems and spatial data analysis.
NR 506	GIS Methods for Resource Management	4	NR 505. Must register for lecture and laboratory.	Current methods in applied geographic information systems and spatial data analysis.
NR 512	Spatial Statistical Modeling – Natural Resources	3	STAT 301; NR 322; NR 323. Must register for lecture and laboratory.	Statistical techniques used to model natural and environmental resources; GIS, remote sensing, and spatial statistics.
NR 523 / STAT 523	Quantitative Spatial Analysis	3	STAT 301 or STAT 307/ERHS 307. Credit not allowed for both NR 523 and STAT 523.	Techniques in spatial analysis: point pattern analysis, spatial autocorrelation, trend surface and spectral analysis.
PH 641	Electro magnetism I	3	PH 351; PH 572	Electrostatics in a vacuum and a medium, general solution of Laplace's equation, Green's functions, magnetostatics in a vacuum and a medium.
PH 642	Electro magnetism II	3	PH 641	Maxwell's equations, electromagnetic waves, radiation by accelerated charges, special relativity, Lagrangian formulation of electromagnetism.
PH 672 / ECE 672	Principles of Semiconductors	3	PH 531 or ECE 471. Credit not allowed for both PH 672 and ECE 672.	Electronic properties of semiconductors; band structure, statistics, transport properties, photoelectronic properties, potential barriers, interfaces.
POLS 670	Politics of Environment and Sustainability	3	Written consent of instructor.	Domestic, international, and comparative dimensions of environment and natural resource politics and policy.
POLS 709	Environmental Politics in the U.S.	3	POLS 500 or POLS 501; POLS 670	Selected primary materials on governmental performance, groups, and mass public in American environmental politics.
POLS 729	Political Theory and the Environment	3	POLS 520; POLS 670	Political thought applied to questions of the environment.
POLS 739	International Environmental Politics	3	POLS 530; POLS 670	Theories and methodologies used in analyzing international environmental politics and policy.
POLS 749	Comparative Environmental Politics	3	POLS 540 or POLS 541; POLS 670	Application of comparative political theory to analysis of environmental politics.

POLS 759	Environmental Policy and Administration	3	POLS 670	Effects of regulation, intergovernmental relations, and resource availability on federal environmental programs in U.S.
RS 578	Ecology of Disturbed Lands	3	LAND 220/SOCR 220; SOCR 240	Analysis of basic and applied ecological principles involved in reclamation of drastically disturbed western lands.
STAT 501	Statistical Science	1	None	Overview of statistics: theory; use in agriculture, business, environment, engineering; modeling; computing; statisticians as researchers/consultants.
STAT 520	Introduction to Probability Theory	4	MATH 229; MATH 261; MATH 317	Probability, random variables, distributions, expectations, generating functions, limit theorems, convergence, random processes.
STAT 523 / NR 523	Quantitative Spatial Analysis	3	STAT 301 or STAT 307/ERHS 307	Techniques in spatial analysis: point pattern analysis, spatial autocorrelation
STAT 525	Analysis of Time Series I	3	STAT 430	Trend and seasonality, stationary processes, Hilbert space techniques, spectral distribution function, fitting ARIMA models, linear prediction.
STAT 526	Analysis of Time Series II	3	STAT 525	Spectral analysis; the periodogram; spectral estimation techniques; multivariate time series; linear systems, optimal control; Kalman filtering, prediction.
STAT 530	Mathematical Statistics	3	STAT 520	Sampling distributions, estimates, testing, confidence intervals, exact and asymptotic theories of maximum likelihood and distribution-free methods.
STAT 540	Data Analysis and Regression	3	Six credits of upper-division statistics courses.	Introduction to multiple regression and data analysis with emphasis on graphics and computing.
STAT 547 / CIVE 547	Statistics for Environmental Monitoring	3	STAT 301	Applications of statistics in environmental pollution studies involving air, water, or soil monitoring; sampling designs; trend analysis; censored data.
STAT 605	Theory of Sampling Techniques	3	STAT 301 or STAT 307/ERHS 307 or STAT 311 or STAT 315; STAT 430	Survey designs; simple random, stratified, cluster samples; theory of estimation; optimization techniques for

				minimum variance or costs.
STAT 640	Design and Linear Modeling I	4	MATH 369; STAT 540	Introduction to linear models; experimental design; fixed, random, and mixed models.
STAT 645	Categorical Data Analysis and GLIM	3	Concurrent registration in STAT 640	Generalized linear models, binary and polytomous data, log linear models, quasiliikelihood, survival data models.
STAT 650	Design and Linear Modeling II	3	STAT 640	Mixed factorials; response surface methodology; Taguchi methods; variance components.

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