

Suggested Electives for Systems Engineering Graduate Degrees

If your S.E. degree has an elective requirement, the following courses may be used. This is not an exhaustive list of appropriate electives. For courses not on this list that you find relevant to your interests/program, please check with the Systems Engineering Department to see if it may count as an elective. **It is the student's responsibility to ensure they meet all current prerequisites for electives listed at the time of registration or to contact the instructor to request permission to enroll.**

Note: The 42-credit PhD or DEng programs do not permit open electives. Courses with **shaded backgrounds** may not be used as electives toward the 72-credit PhD.

Course Number	On-Campus?	Online?	Title	Credits	Prerequisite	Description
AREC 540/ ECON 540	X		Economics of Natural Resources	3	AREC 340 / ECON340, 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	X		Environmental Economics	3		Economics of environmental policy; partial equilibrium and general equilibrium model; pollution; natural environments; population and economic growth.
BUS 500	X	X	Foundations for Business Impact	2		Introductory course to graduate business studies focused on business strategy, organizational performance, economic systems and opportunity, and the role of enterprise in value creation. May not apply to SE PhD degree.
BUS 601	X	X	Quantitative Business Analysis	2	BUS 500, may be taken concurrently.	Uses and management of information; decision tools and concepts; quality control. May not apply to SE PhD degree.
BUS 620	X	X	Leadership and Teams	2	BUS 500, may be taken concurrently or BUS 601 to 665	Ethical leadership and team dynamics; basic models of motivation utilized by leaders. May not apply to SE PhD degree.
BUS 626	X	X	Managing Human Capital	2	BUS 500, may be taken concurrently.	Management of human capital for competitive advantage and superior results.
BUS 630	X	X	Information Management	2	(BUS 500 or BUS 601 to 665) and (BUS 614 or BUS 615)	Role and value of information in business functions; risks and rewards of enterprise information; fundamentals of information storage and retrieval. May not apply to SE PhD degree.
BUS 635	X	X	Business Economics for the Current Market	2	(BUS 601) and (BUS 614 or BUS 615)	Application of economic principles to current business problems within context of global marketplace.
BUS 650	X	X	Supply Chain Management	2	BUS 500, may be taken concurrently.	Value-driven supply chain principles, design and management of supply chains, and supply chain management software and applications.
BUS 660	X	X	Ethical, Legal, and Regulatory Issues	2	BUS 500 or BUS 601 to 665	Legal, regulatory, societal and ethical issues encountered by business professionals; analytical skills for making judgments.
CIS 600A	X	X	Information Technology and Project Management	3		Strategic role in and management of information technology and software development projects.
CIS 610	X	X	Software Development Methodology	3		Methods for all phases of software development focusing upon the establishment of economical software that is reliable and cross platform.
CIS 611	X	X	Object-Oriented Systems	3	CIS 610	Object-oriented and web-based software; object model describing classes; relationships to other objects, attributes, and operations.
CIS 670	X	X	Advanced IT Project Management	3	CIS 600A	Applied examination of project management with an emphasis on preparing for and completing PMI certification.

CIVE 527	X		Tools for Food-Energy-Water System Analysis	3	CHEM 103 or CHEM 107 or CHEM 111	Analysis of complex food-energy-water (FEW) issues to explore prevailing relationships under varying conditions. Introduction to tools and approaches for systems thinking and FEW analysis.
CIVE 544	X	X	Water Resources Planning and Management	3	Basic Hydrology	Management and planning of natural and constructed water systems. Integrated management and case studies of water use and environmental resources.
CIVE547/ STAT 547	X	X	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.
CIVE 574	X	X	Civil Engineering Project Management	3		Principles of civil engineering project management including proposals, contracts, scheduling, quality assurance, budgeting, and risk management.
CIVE 575	X	X	Sustainable Water and Waste Management	3	Basic Hydrology	The science, engineering, and policy behind sustainable water and waste practices. Sustainable urban water and wastewater management.
CIVE 578	X	X	Infrastructure and Utility Management	3	10 cr of engineering, economics, public admin, or planning courses	The course explains the critical roles played by infrastructure in the economy and sustainable and smart cities. Continuing political debates about the need for upgrading infrastructure illustrate issues discussed in the course to include financial strategies, transportation systems and supply chains, and safe drinking water, among others.
CON 561	X		Applied Productivity Improvement	3		The course will emphasize construction productivity improvement by group field studies and discrete event simulation modeling. In-depth study of the way overtime, changes, weather, and staffing levels influence productivity. Industrial engineering techniques are applied to the construction environment to improve the use of equipment and human and material resources.
CON 580A3	X	X	Multi-Criteria Decision-Making Techniques	3		Designed to strengthen managerial and research skills of graduate level construction management and engineering students through the use of modern approaches to multi-criteria decision-making.
CS 522	X	X	Foundations of Cyber-Physical Systems	4	CS 320 or CS 420	Principles of design, specification, modeling, and analysis of cyber-physical systems and software. Topics include model-based design, formal methods for specification and verification, and control theory.
CS 528/ ECE 528	X	X	Embedded Systems and Machine Learning	4	CS 270 with a minimum grade of C or ECE 251 with a minimum grade of C	Machine learning for embedded computing systems; hardware/software optimizations for machine learning; hardware accelerators for deep learning; data reuse and sharing techniques; memory and network design for machine learning acceleration; processing-in-memory; applications of machine learning in embedded applications.
CS 545	X	X	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	X	X	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

ECE 512	X	X	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.
ECE 513	X	X	Digital Image Processing	3	ECE 303/STAT 303 with grade of C- or better; ECE 312 with grade of C- or better	Image acquisition and display systems, image enhancement, restoration and encoding, image analysis; real-life applications.
ECE 528/ CS 528	X	X	Embedded Systems and Machine Learning	4	CS 270 with a minimum grade of C or ECE 251 with a minimum grade of C	Machine learning for embedded computing systems; hardware/software optimizations for machine learning; hardware accelerators for deep learning; data reuse and sharing techniques; memory and network design for machine learning acceleration; processing-in-memory; applications of machine learning in embedded applications.
ECE 532/ SYSE 532	X	X	Dynamics of Complex Engineering Systems	3	SYSE 501, may be concurrent	Higher-level behavior and issues that emerge from interaction between components in complex socio-technical systems.
ECE 549	X	X	Radar Systems and Design	3	ECE 444	Fundamental ideas of radar operation and basic design of various radar types including current topics.
ECE 561	X	X	Hardware/Software Design of Embedded Systems	4	CS 270 or CS 470 or ECE 251 or ECE 452	Embedded systems design including system level modeling, design space exploration, hardware-software partitioning, high level synthesis.
ECE 562	X	X	Power Electronics I	3	ECE 332 with a 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 565/ ENGR 565	X	X	Electrical Power Engineering	3	ECE 332 and ECE 342	Analysis of power systems in terms of current, voltage, and active/reactive power; introduction of computer-aided tools for power systems.
ECE 566	X	X	Grid Integration of Wind Energy Systems	3	ECE 461; ECE 462 or ECE 565	Aspects of integration of wind energy conversion systems (WECS) to electric power transmission grids.
ECE 611	X	X	Nonlinear Control Systems	3	ECE 412	Controller analysis and design for nonlinear systems.
ECE 612	X	X	Robust Control Systems	3	ECE 411	Introduction to modern robust control theory techniques for analysis and design of large- scale uncertain multivariable systems.
ENGR	X	X	Any non-research graduate course with 'ENGR' subject code may apply as an elective			
ESS 524	X	X	Foundations for Carbon/Greenhouse Gas Management	3	Upper division cr in biology, ecology or chemistry	This course examines carbon cycle science and greenhouse gas management, including carbon cycling in natural systems, anthropogenic greenhouse gas emissions by sector, measurement and monitoring, and mitigation opportunities.
ESS/ENGR 555	X	X	Life Cycle Assessment for Sustainability	3	Upper division cr in BIOM, BZ, CHEM, ENGR, CIVE, or MECH	The quantitative and qualitative measure of cradle-to-grave impacts of products and services on the environment, the economy, and society.
GRAD 530	X	X	Introduction to Graduate Research	1		Students learn about: using databases for research; citations; academic reading; writing expectations; social elements of graduate school; resources for goal setting; resources for overcoming challenges; resources for mentor/mentee relationships

GRAD 540	X	X	Graduate Research Communication	2	GRAD 530 or concurrent enrollment	Students practice: academic reading strategies; writing for different audiences; writing different types of manuscripts; talking about their studies & research; communication theories; writing two pieces of polished writing for their program of study; using feedback to improve
GRAD 544	X		Ethical Conduct of Research	1		Principles and practice of ethical conduct of research.
GRAD 550	X	X	STEM Communication	1		Review and practice of key communication principles for Science, Technology, Engineering, and Mathematics (STEM) professionals.
IDEA 510	X	X	Processes of Human-Centered Design Thinking	3		Introduction to theoretical concepts, philosophies, and psychosocial processes associated with design thinking in design and non-design contexts.
IDEA 520	X	X	Methods for Human-Centered Design Thinking	3		Introduces designing and conducting human-centered research and co-design methods common to innovation frameworks such as design thinking.
IDEA/MGT 555	X	X	Managing Design for Defense	3	IDEA 510 or 3 graduate credits of BUS/MGT	Interdisciplinary teams work on national security challenges in close contact with national security agencies (sponsors).
MATH 519	X		Complex Variables I	3	MATH 317	Analytic functions, complex integration theory, singularities, elementary functions, and mapping.
MATH 520	X		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	X		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	X		Mathematics for Scientists and Engineers	4	MATH 340 or MATH 345	Proof-oriented linear algebra, ordinary and partial differential equations.
MATH 532	X		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.
MECH 502	X	X	Advanced/Additive Manufacturing Engineering	3	MECH 202; MECH 331	Materials, controls, and mechanics applied to additive manufacturing; rapid prototyping; direct digital manufacturing.
MECH 513	X	X	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 518	X	X	Orbital Mechanics	3	MATH 340 or PH 142	Explore orbital elements, motion, and analyses. Investigate the design and characteristics of the common orbit regimes, and focus on orbital maneuver options and design. Emphasis on developing technical analytical capabilities, engineering judgement, and intuitive understanding of orbital maneuvers.
MECH 519	X	X	Aerospace Vehicles Trajectory and Performance	3	MATH 340; PH 142	Overview of orbital mechanics theory, elements, and orbit regimes. Investigate trajectory modeling physics and philosophy, and then implement the theories to create and optimize trajectories to six orbits over the course of the semester (LEO, GTO, Sun Synch, Molniya, GEO, and Interplanetary). Perform launch vehicle conceptual design and sizing, optimal staging, and definition of margins and prediction of mission losses.

MECH 534	X	X	Energy & Env. Impacts of Transportation	3	MECH 337	Energy use and environmental impacts of the transportation sector. Topics include vehicle design, dynamics and efficiency; combustion and emission formation; internal combustion engines, fuel cells, batteries, and powertrains; conventional and alternative fuels; travel demand and modes; and life cycle analysis and criteria pollutant emissions.
MECH 536	X		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 561	X		Space Propulsion and Mission Analysis	4	MATH 340	Analysis of space flight missions and propulsion systems.
MECH 563	X		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	X	X	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 676	X		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/IDEA 555	X	X	Managing Design for Defense	3	IDEA 510 or 3 graduate credits of BUS/MGT	Interdisciplinary teams work on national security challenges in close contact with national security agencies (sponsors).
MGT 600	X		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 503	X		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	X		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	X		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 550	X	X	Sustainable Military Lands Management	3	Graduate Standing	The course content will include discussions on the purpose and use of military lands as they relate to national defense requirements. It will also discuss the principles and implementation of environmental stewardship of the natural and cultural resources on these lands.
NR 565	X	X	Principles of Natural Resources Ecology	3	Consent of Instructor	This is a unique graduate-level course designed to provide students with a fundamental understanding of ecological principles as applied to current natural resource management issues, such as invasive species management or fostering healthy forests.
POLS 670	X		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	X		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 739	X		International Environmental Politics	3	POLS 530; POLS 670	Theories and methodologies used in analyzing international environmental politics and policy.
POLS 759	X		Environmental Policy and Administration	3	POLS 670	Effects of regulation, intergovernmental relations, and resource availability on federal environmental programs in U.S.
STAT 500	X	X	Statistical Computer Packages	1	STAT 340 and STAT 350	Comparison, evaluation, and use of computer packages for univariate and multivariate statistical analyses.
STAT 501	X		Statistical Science	1		Overview of statistics: theory; use in agriculture, business, environment, engineering; modeling; computing; statisticians as researchers/consultants.
STAT 511A		X	Design and Data Analysis for Researchers I: R Software	4	STAT 301 or STAT 307 or ERHS 307 or STAT 311 or STAT 315	Statistical methods for experimenters and researchers emphasizing design and analysis of experiments.
STAT 512	X	X	Design and Data Analysis for Researchers II	4	STAT 511	Statistical methods for experimenters and researchers emphasizing design and analysis of experiments.
STAT 540	X		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/ CIVE547	X	X	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.
SYSE	X	X	Any non-research graduate course with subject code 'SYSE' may apply as an elective			
SYSE 711	X	X	Ethics in Systems Engineering	1		Ethical principles and their application to systems engineering. May not apply to SE PhD degree.
WR 511	X	X	Water Resource Development	3	Graduate Standing	We will explore the physical basis for water management to set the stage for addressing the social, economic, environmental, historical, and technical forces that have led to our current methods of water distribution, management, and policy in Colorado and around the world.
WR 514	X	X	GIS and Data Analysis in Water Resources	3	Graduate Standing	Exposure to multiple data analysis and GIS tools used to study water resources. Assess online data sources, download and pre-process digital data, and analyze water information.