

NUCLEAR, PLASMA, AND RADIOLOGICAL ENGINEERING

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<http://npres.illinois.edu>

Curriculum in Nuclear, Plasma, and Radiological Engineering (<http://npres.illinois.edu>)

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For the Degree of Bachelor of Science in Nuclear, Plasma, and Radiological Engineering

Nuclear, plasma, and radiological engineering is a branch of engineering that is concerned with the development and use of nuclear energy and radiation sources for a wide variety of applications in energy production, in materials processing and science, and for biomedical and industrial uses. Areas of interest include the continued safe and reliable application of fission reactors as central electric power plant thermal sources; plasma processing applications and the longer term development of fusion reactors for electric power generation; and the use of radiation sources in such areas as materials, biological systems, medical treatment, radiation instrumentation, environmental systems, and activation analysis.

The first two years of the curriculum provide a strong foundation in basic sciences (physics, mathematics, and chemistry), engineering sciences (analytical mechanics and thermodynamics), an introduction to digital computer use, and introduction to nuclear energy systems. Most technical concentration takes place in the third and fourth years of the curriculum according to the educational and career interest of the students. The curriculum provides three professional concentration areas: power, safety and the environment; plasma and fusion science and engineering; and radiological, medical, and instrumentation applications. Each concentration area allows flexibility in developing advanced technical expertise but also requires depth of understanding in the area. The third path meets pre-med requirements and facilitates the minor in bioengineering. To complete this concentration area, students should take certain chemistry and biology courses in the first two years of the curriculum.

Overview of Curricular Requirements

The curriculum requires 128 hours for graduation and is organized as follows.

Orientation and Professional Development

These courses introduce the opportunities and resources your college, department, and curriculum can offer you as you work to achieve your career goals. They also provide the skills to work effectively and successfully in the engineering profession.

Code	Title	Hours
ENG 100	Engineering Orientation ¹	0
NPRES 100	Orientation to NPRES	1
Total Hours		1

¹ External transfer students take ENG 300 instead.

Foundational Mathematics and Science

These courses stress the basic mathematical and scientific principles upon which the engineering discipline is based.

Code	Title	Hours
CHEM 102	General Chemistry I	3
CHEM 103	General Chemistry Lab I	1
MATH 221	Calculus I ¹	4
MATH 231	Calculus II	3
MATH 241	Calculus III	4
MATH 285	Intro Differential Equations	3
PHYS 211	University Physics: Mechanics	4
PHYS 212	University Physics: Elec & Mag	4
PHYS 214	Univ Physics: Quantum Physics	2
Total Hours		28

¹ MATH 220 may be substituted, with four of the five credit hours applying toward the degree. MATH 220 is appropriate for students with no background in calculus.

Nuclear, Plasma, and Radiological Engineering Technical Core

These courses stress fundamental concepts and basic laboratory techniques that comprise the common intellectual understanding of nuclear engineering.

Code	Title	Hours
CS 101	Intro Computing: Engrg & Sci ¹	3
ECE 205	Elec & Electronic Circuits	3
ECE 206	Elec & Electronic Circuits Lab	1
ME 300	Thermodynamics	3
NPRES 247	Modeling Nuclear Energy System	3
NPRES 431	Materials in Nuclear Engrg	3
NPRES 441	Radiation Protection	4
NPRES 446	Radiation Interact w/Matter I	3
NPRES 447	Radiation Interact w/Matter II	3
NPRES 448	Nuclear Syst Engrg & Design	4
NPRES 451	NPRES Laboratory	3
NPRES 455	Neutron Diffusion & Transport	4
NPRES 458	Design in NPRES	4
TAM 210	Introduction to Statics ^{1,2}	2
TAM 212	Introductory Dynamics ²	3
Total Hours		46

¹ Students may elect to take CS 125 in place of CS 101, and TAM 211 in place of TAM 210. The extra hour will be applied toward the Professional Concentration Area electives.

² Students in the Plasma and Fusion Science Engineering Professional Concentration Area may elect to take PHYS 325 in place of TAM 212. Further, students in this concentration may elect to take both PHYS 325 and PHYS 326 in place of TAM 210 and TAM 212. The extra hour from PHYS 325 and PHYS 326 will be applied toward the Professional Concentration Area electives.

Professional Concentration Area Electives

The NPRE Professional Concentration Area requirement is fulfilled by taking certain required technical and some elective technical courses stressing the rigorous analysis and design principles practiced in one of the three professional concentration areas: Power, Safety, and the Environment; Plasma and Fusion Science Engineering; or Radiological, Medical, and Instrumentation Applications.

Code	Title	Hours
	Professional Concentration Area electives. See the Professional Concentration Areas section below.	25

Liberal Education

The liberal education courses (<https://wiki.cites.illinois.edu/wiki/display/ugadvice/Liberal+Education+Electives>) develop students' understanding of human culture and society, build skills of inquiry and critical thinking, and lay a foundation for civic engagement and lifelong learning.

Code	Title	Hours
ECON 102	Microeconomic Principles	3
	or ECON 103 Macroeconomic Principles	
	Electives from the campus General Education Social and Behavioral Sciences list.	3
	Electives from the campus General Education Humanities and the Arts list.	6
	Electives either from a list approved by the college or from the campus General Education lists for Social and Behavioral Sciences or Humanities and the Arts.	6
Total Hours		18

Students must also complete the campus cultural studies requirement by completing (i) one western/comparative culture(s) course and (ii) one non-western/U.S. minority culture(s) course from the General Education cultural studies lists. Most students select liberal education courses that simultaneously satisfy these cultural studies requirements. Courses from the western and non-western lists that fall into free electives or other categories may also be used satisfy the cultural studies requirements.

Composition

These courses teach fundamentals of expository writing.

Code	Title	Hours
RHET 105	Writing and Research	4
	Advanced Composition. May be satisfied by completing a course in either the liberal education or free elective categories which has the Advanced Composition designation. Alternately, NPRE 481 should be considered, which may also be applied to the Professional Concentration elective hours.	
Total Hours		4

Free Electives

These unrestricted electives, subject to certain exceptions as noted at the College of Engineering Advising Website (<https://wiki.cites.illinois.edu/wiki/display/ugadvice/Free+Electives?src=search>), give the student the opportunity to explore any intellectual area of unique interest. This freedom plays a critical role in helping students to define research specialties or to complete minors.

Code	Title	Hours
	Free electives. Additional unrestricted course work, subject to certain exceptions as noted at the College of Engineering advising Web site, so that there are at least 128 credit hours earned toward the degree.	6

Professional Concentration Areas

Students are expected to develop a solid background in one of the various subfields within a Professional Concentration Area which are defined below.

Power, Safety, and the Environment

Code	Title	Hours
TAM 335	Introductory Fluid Mechanics	4
	or ME 310 Fundamentals of Fluid Dynamics	
NPRE 421	Plasma and Fusion Science	3
NPRE 432	Nuclear Engrg Materials Lab	2
Technical electives broken down as follows:		16
A minimum of 6 hours of departmentally approved NPRE Electives.		
Technical electives selected from departmentally approved Power, Safety, and the Environment elective course work in one of the following subfields: Thermal Sciences; Power and Control Systems; Solid, Fluid and Continuum Mechanics; Computational Sciences and Engineering; Environmental Engineering and Science. The student's academic advisor must approve the chosen course set to insure that a strong program is achieved. ¹		
Total Hours		25

¹ Power, Safety, and the Environment elective course work.

Plasma and Fusion Science and Engineering

Code	Title	Hours
TAM 335	Introductory Fluid Mechanics	4
	or ME 310 Fundamentals of Fluid Dynamics	
NPRE 421	Plasma and Fusion Science	3
NPRE 423	Plasma Laboratory	2
NPRE 429	Plasma Engineering	3
Technical electives selected from departmentally approved Plasma and Fusion Science and Engineering elective course work in one of the following subfields: Physical Science, Electrical Engineering, or Electronic Materials. The student's academic advisor must approve the chosen course set to insure that a strong program is achieved. ¹		13
Total Hours		25

¹ Plasma and Fusion Science and Engineering elective course work.

Radiological, Medical and Instrumentation Applications

Code	Title	Hours
NPRE 435	Radiological Imaging	3
Select one from:		2
MCB 403	Cell & Membrane Physiology Lab	
BIOE 415	Biomedical Instrumentation Lab	
NPRE 444	Nuclear Analytical Methods Lab	
Technical electives selected from departmentally approved Radiological, Medical and Instrumentation Applications elective course work in one of the following subfields: Biomolecular Engineering, Biomedical Engineering, and Radiation Detection and Analysis. The student's academic advisor must approve the chosen course set to ensure that a strong program is achieved. ¹		20
Total Hours		25

¹ Radiological, Medical and Instrumentation Applications elective course work

Suggested Sequence

The schedule that follows is illustrative, showing the typical sequence in which courses would be taken by a student with no college course credit already earned and who intends to graduate in four years. Each individual's case may vary, but the position of required named courses is generally indicative of the order in which they should be taken.

First Year

First Semester	Hours
CHEM 102 General Chemistry I	3
CHEM 103 General Chemistry Lab I	1
ENG 100 Engineering Orientation	0
MATH 221 Calculus I	4
NPRE 100 Orientation to NPRE	1
RHET 105 Writing and Research (or Free elective) ²	4-3
Liberal education elective ³	3
Semester Hours	
	16-15

Second Semester

CS 101 ⁴ Intro Computing: Engrg Sci	3
MATH 231 Calculus II	3
PHYS 211 University Physics: Mechanics	4
Liberal education elective ³	3
RHET 105 Writing and Research (or Free elective) ^{2,5}	3-4
Semester Hours	
	16-17

Second Year**First Semester**

MATH 241 Calculus III	4
PHYS 212 University Physics: Elec Mag	4
TAM 210 ^{4,6} Introduction to Statics	2
Professional Concentration Area elective ⁷	3
Liberal education elective ³	3
Semester Hours	
	16

Second Semester

MATH 285 Intro Differential Equations	3
ME 300 Thermodynamics	3
PHYS 214 Univ Physics: Quantum Physics	2
NPRE 247 Modeling Nuclear Energy System	3
TAM 212 ⁶ Introductory Dynamics	3
Liberal education elective ³	3
Semester Hours	
	17

Third Year**First Semester**

ECE 205 Elec Electronic Circuits	3
ECE 206 Elec Electronic Circuits Lab	1
NPRE 446 Radiation Interact w/Matter I	3
TAM 335 Introductory Fluid Mechanics or ME 310 (or Professional Concentration Area elective in Radiological, Medical, and Instrumentation Applications) ⁸	4
Liberal education elective ³	3
Free elective	3
Semester Hours	
	17

Second Semester

NPRE 421 Plasma and Fusion Science (or Professional Concentration Area elective in Radiological, Medical, and Instrumentation Applications) ⁸	3
NPRE 447 Radiation Interact w/Matter II	3
NPRE 451 NPRE Laboratory	3
NPRE 455 Neutron Diffusion Transport	4
Professional Concentration Area elective ⁷	3
Semester Hours	
	16

Fourth Year**First Semester**

NPRE 431 Materials in Nuclear Engrg	3
NPRE 448 Nuclear Syst Engrg Design	4
Professional Concentration Area electives ⁷	6
Liberal education elective ³	3
Semester Hours	
	16

Second Semester

NPRE 441 Radiation Protection	4
NPRE 458 Design in NPRE	4

Professional Concentration Area electives	6
Semester Hours	14
Total Hours:	128

- ¹ MATH 220 may be substituted, with four of the five credit hours applying toward the degree. MATH 220 is appropriate for students with no background in calculus.
- ² RHET 105 may be taken in the first or second semester of the first year as authorized. The alternative is a free elective.
- ³ Liberal education electives (<https://wiki.cites.illinois.edu/wiki/display/ugadvice/Liberal+Education+Electives>) must include 6 hours of social & behavioral sciences and 6 hours of humanities & the arts course work from the campus General Education lists. ECON 102 or ECON 103 must be one of the social & behavioral sciences courses, recommended to be taken early. The remaining 6 hours may be selected from a list maintained by the college, or additional course work from the campus General Education lists for social & behavioral sciences or humanities & the arts. Students must also complete the campus cultural studies requirement by completing (i) one western/comparative culture(s) course and (ii) one non-western/U.S. minority culture(s) course from the General Education cultural studies lists. Most students select liberal education courses that simultaneously satisfy these cultural studies requirements. Courses from the western and non-western lists that fall into free electives or other categories may also be used satisfy the cultural studies requirements.
- ⁴ Students may elect to take CS 125 in place of CS 101, and TAM 211 in place of TAM 210. The extra hour will be applied toward the Professional Concentration Area electives.
- ⁵ Consideration should be given to NPRE 101 as a free elective in the spring semester of the freshman or sophomore year. Alternately, free elective hours provide a means to fulfill requirements for campus minors such as Bioengineering, Computer Science, International Minor in Engineering, Mathematics, or Physics, without excessive additional hours beyond the normal degree requirements.
- ⁶ Students in the Plasma and Fusion Science Engineering Professional Concentration Area may elect to take PHYS 325 in place of TAM 212. This facilitates the minor in Physics. Further, students in this concentration may elect to take both PHYS 325 and PHYS 326 in place of TAM 210 and TAM 212. The extra hour from PHYS 325 and PHYS 326 will be applied toward the Professional Concentration Area electives.
- ⁷ A student must fulfill the NPRE Professional Concentration Area requirement (<http://npre.illinois.edu/academics/undergraduate-program/technical-electives>) by taking the required technical courses and technical elective courses in one of the three professional concentration areas: Power, Safety, and the Environment; Plasma and Fusion Science Engineering; or Radiological, Medical, and Instrumentation Applications.
- ⁸ Students in the Power, Safety, and the Environment and in the Plasma and Fusion Science Engineering Professional Concentration Areas must take a fluid mechanics course (TAM 335 or ME 310) and NPRE 421. Students in the Radiological, Medical, and Instrumentation Applications Concentration are not required to take these courses. They may instead use the hours otherwise filled with these courses to take electives in the Radiological, Medical and Instrumentation Applications Areas.

NPRE Class Schedule (<https://courses.illinois.edu/schedule/DEFAULT/DEFAULT/NPRE>)

Courses

NPRE 100 Orientation to NPRE credit: 1 Hour.

Introduction to nuclear, plasma, and radiological engineering. Demonstrations and discussion of nuclear phenomena (reactor operation, plasma behavior, and others). Experiments on radioactive decay and radiation shielding with formal laboratory report and a student project.

NPRE 101 Introduction to Energy Sources credit: 3 Hours.

Explanation of energy technologies using an elementary approach presupposing no prior scientific or technical background. Coverage of all energy sources including fossil fueled, solar, hydro, and nuclear power. Integral demonstrations and a tour of the University's power plant. Discussion of energy related incidents with emphasis on environmental, economic, and social impact. Same as ENV5 101.

This course satisfies the General Education Criteria for:
Nat Sci Tech - Phys Sciences
Quantitative Reasoning II

NPRE 199 Undergraduate Open Seminar credit: 1 to 5 Hours.

May be repeated in separate terms to a maximum of 2 times.

NPRE 201 Energy Systems credit: 2 or 3 Hours.

Patterns of energy production and utilization and technical aspects of renewable energy resources, advanced fossil fuel systems, and advanced nuclear systems. Same as GLOBL 201. Prerequisite: MATH 220 or MATH 221; one of PHYS 101, PHYS 211, CHEM 104, CHEM 204, ME 300.

NPRE 241 Intro to Radiation Protection credit: 2 Hours.

Elements of radiation protection and health physics, emphasizing practical applications. Prerequisite: MATH 220 or MATH 221; one of CHEM 102, IB 150, MCB 150, PHYS 211.

NPRE 247 Modeling Nuclear Energy System credit: 3 Hours.

Applications of elementary nuclear physics in nuclear engineering. Nuclear reactor materials and components. Steady-state and transient operation of nuclear reactors. Nuclear energy removal and conversion. Radiation shielding. Prerequisite: PHYS 212; credit or concurrent registration in MATH 285.

NPRE 397 Independent Study credit: 1 to 4 Hours.

Individual investigations or studies of any phase of nuclear engineering selected by the student and approved by the department. May be repeated. Prerequisite: Consent of instructor.

NPRE 398 Special Topics credit: 1 to 4 Hours.

Subject offerings of new and developing areas of knowledge in nuclear, plasma, and radiological engineering intended to augment the existing curriculum. See Class Schedule or departmental course information for topics and prerequisites. May be repeated in the same or separate terms if topics vary.

NPRE 402 Nuclear Power Engineering credit: 3 or 4 Hours.

Principles of utilization of fission energy in nuclear power engineering; includes such topics as fission processes and controlled chain reactions; nuclear reactor types, design principles, and operational characteristics; power reactor design criteria; radiation hazards and radioactive waste treatment; economics; other applications such as propulsion and research reactors. 3 undergraduate hours. 4 graduate hours. Credit is not given for both NPRE 402 and NPRE 247.

NPRE 412 Nuclear Power Econ & Fuel Mgmt credit: 3 or 4 Hours.

Quantitative analysis of the impact of the nuclear power industry; nuclear fuel cycle and capital costs for thermal and fast reactors; optimization of the use of nuclear fuels to provide the lowest energy costs and highest system performance; comparison between fossil fuel systems, fission systems, and controlled thermonuclear fusion systems. 3 undergraduate hours. 4 graduate hours. Prerequisite: NPRE 402 or NPRE 247. Junior standing is required.

NPRE 421 Plasma and Fusion Science credit: 3 Hours.

Physics of plasmas, including particle and fluid descriptions, waves, collisions, stability, and confinement, with applications to controlled thermonuclear fusion reactors, problems in fusion engineering, and astrophysics. 3 undergraduate hours. 3 graduate hours. Prerequisite: For engineering or physical science majors with junior standing.

NPRE 423 Plasma Laboratory credit: 2 Hours.

Experiments relating to plasma engineering and fusion energy. Topics in ultra-high vacuum technology rf and dc electric plasma probes, measurements of dc and pulsed magnetic fields, dynamics of a theta pinch, and laser interferometry to measure plasma density. 2 undergraduate hours. 2 graduate hours. Prerequisite: NPRE 421 and NPRE 451.

NPRE 429 Plasma Engineering credit: 3 Hours.

Basic principles and examples for adapting and applying the plasma state to solve a number of modern engineering problems. Plasma processing of materials for microelectronics and other uses, lighting, plasma displays, and other technologies. 3 undergraduate hours. 3 graduate hours. Prerequisite: ECE 329 or PHYS 435.

NPRE 431 Materials in Nuclear Engrg credit: 3 Hours.

Development of a materials engineering background in the context of nuclear systems and radiation applications; relation of structure of materials to their physical and mechanical properties; development of phase formation and reaction kinetics from basic thermodynamics principles; charged particle interactions with surfaces; transport concepts of neutral and charged particles in matter; materials performance in nuclear and radiation applications, including radiation damage and effects. 3 undergraduate hours. 3 graduate hours.

NPRE 432 Nuclear Engrg Materials Lab credit: 2 Hours.

Experiments relating to materials applications in nuclear engineering and energy systems. Examination of topics in room and elevated temperature mechanical properties of structural materials, corrosion, physical properties, radiation damage and effects, and materials selection in design. 2 undergraduate hours. 2 graduate hours. Prerequisite: Credit or concurrent registration in NPRE 431.

NPRE 435 Radiological Imaging credit: 3 Hours.

Physical, mathematical and experimental foundations of radiological imaging techniques, such as typical sources of ionizing radiation, the interactions of radiation with matter, image formation techniques, linear systems theory applied to radiological imaging, and the techniques for tomographic image reconstruction. Includes diagnostic radiological imaging modalities, such as X-ray computed tomography (CT), single photon computed emission tomography (SPECT), positron emission tomography (PET), as well as modern X-ray imaging techniques, such as phase contrast imaging and diffraction-enhanced X-ray imaging. Provides a solid foundation for understanding of modern radiological imaging techniques, and in-depth discussions on the strengths and limitations of various modalities in application to medical, physical, security and environmental imaging. 3 undergraduate hours. 3 graduate hours. Prerequisite: NPRE 446.

NPRE 441 Radiation Protection credit: 4 Hours.

Sources of nuclear radiation; ionization and energy deposition in matter with an emphasis on biological systems; principles of dosimetry; determination of exposure and limits for internal and external emitters; basic shielding calculations. 4 undergraduate hours. 4 graduate hours. Prerequisite: NPRE 446.

NPRE 442 Radioactive Waste Management credit: 3 Hours.

Radiation and radiological concepts and measurement, the fuel cycle and waste classification, Part 61, state and federal regulations and regulatory agencies, radiochemistry and the environmental fate of radionuclides, uranium-related wastes, low-level wastes, high-level wastes, used fuel reprocessing, private fuel storage, waste package stability, risk assessment, geologic repositories, transporting radioactive wastes, decommissioning wastes, transmutation, an international perspective on radioactive waste management, and the global nuclear energy partnership. 3 undergraduate hours. 3 graduate hours. Prerequisite: MATH 231; PHYS 102 or PHYS 212.

NPRE 444 Nuclear Analytical Methods Lab credit: 2 or 3 Hours.

Experiments relating to nuclear analytical methods and techniques. Emphasis on neutron activation analysis, energy dispersive x-ray fluorescence and particle spectroscopy. Use of radiation for medical and materials imaging. 2 or 3 undergraduate hours. 2 or 3 graduate hours. Credit of 2 hours is given if NPRE 451 or equivalent has been taken. Prerequisite: CHEM 102 and NPRE 446.

NPRE 446 Radiation Interact w/Matter I credit: 3 Hours.

Experimental and theoretical foundations of interaction of neutrons, photons, and charged particles with matter. Emphasis on topics that underlie the following applications: radiation detection, biological effects and radiation dosimetry, radiation damage and nuclear materials, neutron activation analysis, and fission and fusion energy systems. Classical theory of charged particle cross sections. Introductory quantum mechanics. Exact and numerical solutions of the Schrodinger equation. Quantum theory of cross sections. Photon interactions with atomic electrons and nuclei. Radioactive-series decay. Computer assignments illustrate fundamental concepts. 3 undergraduate hours. 3 graduate hours. Credit is not given to NPRE majors for graduate hours. Prerequisite: MATH 285 and ME 300.

NPRE 447 Radiation Interact w/Matter II credit: 3 Hours.

Continuation of NPRE 446. Quantum theory of ionization of matter by charged particles. Nuclear models and structure. Alpha decay, fission and fusion reactions. Beta and gamma decay. Nuclear reactions. Radiation damage effects. Special topics. Computer assignments to illustrate fundamental concepts. 3 undergraduate hours. 3 graduate hours. Prerequisite: NPRE 446.

NPRE 448 Nuclear Syst Engrg & Design credit: 4 Hours.

Engineering principles underling nuclear systems designed with emphasis on nuclear power reactors. Materials for nuclear systems. Energy generation and removal in single- and two-phase flows. Reactor and component control systems and nuclear fuel reloading patterns. 4 undergraduate hours. 4 graduate hours. Prerequisite: MATH 285, ME 300, and NPRE 455.

NPRE 451 NPRE Laboratory credit: 3 Hours.

Radiation detection and instrumentation; radiation dosimetry and shielding; basic measurements in nuclear engineering; engineering applications; micro computer data acquisition and experimental control. 3 undergraduate hours. 3 graduate hours. Prerequisite: NPRE 446.

NPRE 455 Neutron Diffusion & Transport credit: 4 Hours.

Neutron migration, neutron slowing down and thermalization; neutron continuity equation, multigroup diffusion theory, homogeneous and heterogeneous medium, thermal and fast assemblies; numerical methods for multigroup diffusion equations; reactor dynamics perturbation theory; reactivity coefficients; introductory transport theory. 4 undergraduate hours. 4 graduate hours. Prerequisite: NPRE 247.

NPRE 457 Safety Anlys Nucl Reactor Syst credit: 3 or 4 Hours.

Basic safety philosophy in nuclear reactor systems; brief review of nuclear reactor systems; regulatory processes; siting considerations; safety problems related to reactor dynamics; evaluation of postulated accidents; risks associated with nuclear fuel cycle; methods of systems safety analysis. 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: NPRE 402 or NPRE 247.

NPRE 458 Design in NPRE credit: 4 Hours.

Design in nuclear, plasma, and radiological engineering systems; basic principles of definition, organization, constraints, modeling and optimization of system design; case studies; class design projects applying these basic principles. 4 undergraduate hours. 4 graduate hours. Prerequisite: NPRE 448.

NPRE 461 Probabilistic Risk Assessment credit: 3 or 4 Hours.

Multidisciplinary theories and techniques of risk, safety, and reliability of complex systems and state-of-the-art Probabilistic Risk Assessment (PRA), which provides input for risk-informed decision-making for design, operation, and regulatory oversight in diverse high-consequence industries such as nuclear power, aviation, space, chemical processes, oil and gas, and healthcare. Topics include: Systematic Risk Scenario Modeling, Consequence Analysis, Bayesian Updating, Bayesian Belief Network, Binary Decision Diagram, Uncertainty Propagation, Hardware Reliability, Human Error Modeling, Failure Causal Modeling, Maintenance and Repair Modeling, Risk Importance Ranking, and Data Analytics. PRA and Reliability Engineering software codes will be utilized for assignments. 3 undergraduate hours. 4 graduate hours. Prerequisite: Junior, Senior or Graduate Standing in any Engineering Department.

NPRE 470 Fuel Cells & Hydrogen Sources credit: 3 Hours.

The role of hydrogen as a global energy form, hydrogen production by nuclear, fossil and renewable energy sources; hydrogen handling, safety; transportation and storage methods including high-pressure, cryogenic, metal hydrides and chemical hydrides; basic science and technology of fuel cells, including electrochemical processes; fuel cell thermodynamics; low- and high-temperature fuel cells; applications including portable electronics, automotive vehicles, distributed and back-up power, and space power. 3 undergraduate hours. 3 graduate hours. Prerequisite: CHEM 102, MATH 285, and PHYS 212.

NPRE 475 Wind Power Systems credit: 3 or 4 Hours.

Overview of wind energy systems; historical development, safety aspect, environmental considerations, wind properties and measurement, site selection, and wind turbine design; transmission systems considerations; mechanical, electrical, control aerodynamic and environmental engineering of modern wind turbines; fatigue failure; annual power production; economics and environmental aspects and accident prevention and mitigation; computational fluid dynamics (CFD) analysis of wind flow and blade interactions; energy storage options; hydrogen production; electrical power transmission issues; licensing issues; alternative wind energy systems; design project involving a wind farm or the construction of a specific type of wind turbine based on a wind park site visit. 3 undergraduate hours. 4 graduate hours. Prerequisite: CS 101, MATH 241; one of CHBE 421, ECE 110, ECE 205, ME 310, TAM 335.

NPRE 480 Energy and Security credit: 3 Hours.

Security and supplies of energy, mineral resources, and water. Evolution of the importance of various fuels in conflicts (including coal, oil, uranium, and natural gas) starting with the Franco-Prussian Wars. Theories of international conflict and examination of the role of individual leaders versus institutional factors in the precipitation and outcome of pivotal wars. Econometric analyses relevant to past and projected future energy use. Same as GLBL 480 and PS 480. 3 undergraduate hours. 3 graduate hours. Prerequisite: Composition I and Quantitative Reasoning I.

NPRE 481 Writing on Technol & Security credit: 3 or 4 Hours.

Development of writing skills in standard computer, desktop publishing, and electronic publishing formats. On themes such as, global and regional security environments, arms control, nuclear energy, and climate change. For graduate credit, writing projects include documentation of computational work using software appropriate for typesetting of mathematical formulas. Same as GLBL 481. 3 undergraduate hours. 3 or 4 graduate hours. 4 graduate hours with consent of instructor. This course satisfies the General Education Criteria for: Advanced Composition

NPRE 483 Seminar on Security credit: 1 Hour.

Preparation of reports on a set of introductory lectures and student choices from various on-campus seminar series relevant to technology of domestic and international security and the regional and international contexts that influence the nature of security problems. Same as GLBL 483. 1 undergraduate hour. 1 graduate hour. May be repeated in separate terms to a maximum of 2 hours. Prerequisite: Composition I.

NPRE 498 Special Topics credit: 1 to 4 Hours.

Subject offerings of new and developing areas of knowledge in nuclear, plasma, and radiological engineering intended to augment the existing curriculum. See Class Schedule or departmental course information for topics and prerequisites. 1 to 4 undergraduate hours. 1 to 4 graduate hours. May be repeated in the same or separate terms if topics vary.