# Nuclear Engineering (NE)

**NE 201 Introduction to Nuclear Engineering** (2 credit hours)
An introduction to the concepts, systems and application of nuclear processes. Topics include radioactivity, fission, fusion, reactor concepts, biological effects of radiation, nuclear propulsion, and radioactive waste disposal. Designed to give students a broad perspective of nuclear engineering and an introduction to fundamentals and applications of nuclear energy.

Prerequisite: Grade of C or better in MA 241, PY 205
*Typically offered in Fall only*

**NE 202 Radiation Sources, Interaction and Detection** (4 credit hours)
Introduction to nuclear energy. Topics include radioactivity, radiation detection, interaction of radiation with matter, nuclear reactions, fission, fusion, nuclear reactors, radiation safety and protection, and laboratory measurement of nuclear radiation.

Prerequisites: C- or better in MA 242 and PY 208
*Typically offered in Spring only*

**NE 205 Thermodynamics for Nuclear Engineering** (3 credit hours)
NE 205 provides a detailed progression of thermodynamic concepts that are essential elements of an undergraduate education in nuclear engineering. Topic areas include nuclear reactor systems and examples, laws of thermodynamics, examples of nuclear reactor coolants, power cycles of light water reactors and advanced nuclear reactors, and transport phenomena. NE 205 provides a foundation of thermodynamics applicable to nuclear reactor systems that will prepare students for advancing to required upper-division heat transfer and thermal-hydraulic systems courses.

P: MA 242 and PY 208
*Typically offered in Spring only*

**NE 228 Introduction To Fusion Energy** (3 credit hours)
This course provides a comprehensive introduction to the fundamentals of fusion energy, plasma physics, and the technologies involved. The course compares the underlying nuclear physics concepts of fusion and fission reactors, atomic structure using the Bohr model, electron shells, and the processes of ionization and plasma generation. The properties of plasma and electromagnetic principles are then used to motivate plasma confinement concepts. The confinement approaches of magnetic confinement and inertial confinement fusion will be introduced. The second part of the course covers the critical technology for fusion energy, including vacuum and cryogenic systems, superconducting magnets, heating methods, tritium breeding and fuel cycle.

P: MA 242 and PY 208
*Typically offered in Spring only*

**NE 235 Nuclear Reactor Operations Training** (2 credit hours)
Principles of nuclear reactor operations. Lectures to cover basic nuclear engineering theory pertaining to fission reactor operations; laboratory sessions to provide hands on training with the PULSTAR nuclear reactor including facility pre-startup checks, approach to criticality, steady state operations, and measurement of various operating parameters. Qualified students may opt to enter training and study for the U.S. Nuclear Regulatory Commission exam to become federally licensed nuclear Reactor Operators. Does not count towards NE graduation requirements

*Typically offered in Fall only*

**NE 290 Introduction to Health Physics** (3 credit hours)
Fundamentals of ionizing radiation safety. The course will review basic physical principles, radiation sources, introductory radiation dosimetry, radiation safety guidelines, evaluation of safety measures, and basic radiation control principles for contamination and radioactive material safety to include measurement physics, counting statistics and basic radiobiology principles.

Prerequisite: MA 111 or MA 108 with grade of C- or better, or 550 or better on the SAT Subject Test in Mathematics Level 2 or the NCSU Math Skills Test, or 2 or better on an AP Calculus exam.
*GEP Interdisciplinary Perspectives, GEP Natural Sciences*
*Typically offered in Fall only*

**NE 291 Introduction to Health Physics Laboratory** (1 credit hours)
This laboratory course will accompany the Introduction to Health Physics Course as a practical means for the students to actually characterize normal radiation sources they experience every day in society. Students will meet for a 50 minute class once a week to go over measurement, analysis and reporting criteria to do on their own averaging 2 hours per week of lab work. Content of lectures and measurement includes natural radon, potassium in foods and geological sources such as granite. The students will summarize their findings in a final report with presentation at the end of the semester.

Corequisite: NE 290
*GEP Interdisciplinary Perspectives, GEP Natural Sciences*
*Typically offered in Fall only*

**NE 301 Fundamentals of Nuclear Engineering** (3 credit hours)
Introductory course in nuclear engineering. Neutron physics, reactor operation, and reactor dynamics. Basic principles underlying the design and operation of nuclear systems, facilities and applications.

Prerequisite: MA 341 and (CSC 112 or CSC 113) and C- or better in NE 202
*Typically offered in Fall only*

**NE 309 Introduction to Materials for Nuclear Energy** (3 credit hours)
This class is an introduction to fundamental concepts of materials science and engineering with an emphasis on materials for nuclear applications (e.g., materials used/under investigation for fission and fusion reactors, and defense technologies). Course materials will be presented in the context of structure-properties-processing-performance that is foundational to materials science and engineering needed for nuclear engineers. This course covers the following core topic areas: structure and bonding, thermodynamics, kinetics, mechanical properties, electronic and thermal properties. In addition, processing, testing, and characterization methods directly relevant to materials used in nuclear applications will be presented.

*Typically offered in Fall only*

**NE 350 Applied Mathematics in Nuclear Engineering** (3 credit hours)
Wide range of applied mathematics topics relevant to nuclear engineering modeling and simulation. Linear algebra that covers vector/matrix operations, matrix inverse, eigenvalues and eigenvectors. Introduction to probability theory and elementary statistics. Review of applied differential equations theory including first and second order ordinary differential equations and partial differential equations. Numerical methods for solving large systems of equations covering aspects of discretization, direct and iterative solutions, and convergence.

P: MA 341; C: MA 401
*Typically offered in Fall only*

**NE 360 Continuum Mechanics for Nuclear Engineers** (3 credit hours)
This course introduces stresses, displacements, strains, and strain-rates of systems subjected to applied loads. While these are traditionally covered in most mechanical and civil engineering curricula, the emphasis of this course is to cover advanced mechanics for nuclear applications and provide students with familiarity and hands on experience with finite element analysis software. It combines solid and fluid mechanics with models of material behavior to determine adequacy of nuclear systems design and analysis. It will be valuable for the senior capstone design class and is a prerequisite for NE 409, which focuses on atomistic and microstructural descriptions of nuclear materials.

P: MA 341
*Typically offered in Spring only*

**NE 400 Nuclear Reactor Energy Conversion** (4 credit hours)
Introduction to the concepts and principles of heat generation and removal in reactor systems. Power cycles, reactor heat sources, analytic and numerical solutions to conduction problems in reactor components and fuel elements, heat transfer in reactor fuel bundles and heat exchangers. Problem sets emphasize design principles. Heat transfer lab included. Credit will not be given for both NE 400 and NE 500.

Prerequisite: MAE 201 and a C- or better in NE 301
*Typically offered in Spring only*

**NE 401/NE 501 Reactor Analysis and Design** (3 credit hours)
Elements of nuclear reactor theory for reactor core design and operation. Includes one-group neutron transport and mutigroup diffusion models, analytical and numerical criticality search, and flux distribution and calculations for homogeneous and heterogeneous reactors, slowing down models, introduction to perturbation theory.

Prerequisites: MA 401 and C- or better in NE 301
*Typically offered in Spring only*

**NE 402 Reactor Engineering** (4 credit hours)
A course in thermal-hydraulic design and analysis of nuclear systems. Single and two-phase flow, boiling heat transfer, modeling of fluid systems. Design constraints imposed by thermal-hydraulic considerations are discussed. A thermal-hydraulics laboratory included. Credit will not be given for both NE 402 and NE 502.

Prerequisite: MAE 308 and either NE 400 or MAE 310
*Typically offered in Fall only*

**NE 403 Nuclear Reactor Laboratory** (2 credit hours)
Nuclear reactor laboratory. A laboratory course performed on the NCSU PULSTAR reactor. Topics include reactor startup and approach to critical. Neutron flux distributions. Reactivity balances. Control rod worth and power coefficients of reactivity.

Prerequisite: C- or better in NE 301 Co-requisite: NE 401
*Typically offered in Spring only*

**NE 404 Radiation Safety and Shielding** (3 credit hours)
Radiation safety and environmental aspects of nuclear power generation. Radiation interaction, photon attenuation, shielding theory and design project, external and internal dose evaluation, reactor effluents and release of radioactivity into the environment, transportation and disposal of radioactive waste; and environmental impact of nuclear power plants.

Prerequisite: NE 301 with a grade of C- or better or NE 419
*Typically offered in Fall only*

**NE 405 Reactor Systems** (3 credit hours)
Nuclear power plant systems: design criteria, design parameters, and economics. Topics covered include: PWR, BWR, core design, primary loops, auxiliary and emergency systems; containment, reactor control and protection systems, accident and transient behaviors.

Prerequisite: NE 401, NE 402
*Typically offered in Spring only*

**NE 406 Nuclear Engineering Senior Design Preparation** (1 credit hours)
Preliminary design phase in nuclear engineering systems to prepare for the final phase design. Preliminary designs developed by teams with advice of faculty, with reports presented in oral and written form. Current and future systems emphasized, and use of computers encouraged.

Prerequisite: NE 401, Corequisite: NE 402
*Typically offered in Fall only*

**NE 408 Nuclear Engineering Design Project** (3 credit hours)
Projects in design of practical nuclear engineering systems. Preliminary designs developed by teams with advice by faculty as needed, with reports presented in oral and written form. Current and future systems emphasized, and use of computers encouraged.

Prerequisite: NE 406
*Typically offered in Spring only*

**NE 409/MSE 409/NE 509/MSE 509 Nuclear Materials** (3 credit hours)
Introduces students to properties and selection of materials for nuclear steam supply systems and to radiation effects on materials. Implications of radiation damage to reactor materials and materials problems in nuclear engineering are discussed. Topics include an overview of nuclear steam supply systems, crystal structure and defects, dislocation theory, mechanical properties, radiation damage, hardening and embrittlement due to radiation exposure and problems concerned with fission and fusion materials. Students cannot receive credit for both 409 and 509.

Prerequisite: MSE 201
*Typically offered in Fall only*

**NE 412 Nuclear Fuel Cycles** (3 credit hours)
Processing of nuclear fuel with descriptions of mining, milling, conversion, enrichment, fabrication, irradiation, reprocessing, and waste disposal. In-core and out-of-core nuclear fuel management design, including objectives, constraints, decisionsand methodologies. Nuclear power plant and fuel cycle economics.

Prerequisite: NE 401
*Typically offered in Spring only*

**NE 414 Plasma and Fusion Design Project** (3 credit hours)
NE 414 is the design project course intended for students enrolled in the Plasma Sciences and Fusion Energy Concentration. The students will select a project in this area under the supervision of a faculty member, and will collectively use engineering design principles, data analysis, risk analysis and economic analysis to optimally design an engineering system to required specifications. The students will develop a design plan and a schedule, and will communicate the findings in writing and through oral presentations.

Prerequisite: NE 406
*Typically offered in Spring only*

**NE 415 Radiological Engineering Design Project** (3 credit hours)
NE 415 is the design project course intended for students enrolled in the Radiological Engineering Concentration. The students will select a project in this area under the supervision of a faculty member, and will collectively use engineering design principles, data analysis, risk analysis and economic analysis to optimally design an engineering system to required specifications. The students will develop a design plan and a schedule, and will communicate the findings in writing and through oral presentations.

Prerequisite: NE 406
*Typically offered in Spring only*

**NE 418 Nuclear Power Plant Instrumentation** (3 credit hours)
Instrumentation and supporting systems required for control and protection of a nuclear power plant. Radiation measurement, process measurement, and reactor operating principles used to develop instrumentation requirements and characteristics. Requirements and implementations of instrumentation, control and protection systems for pressurized and boiling water reactors. Design and implementation issues include power supplies, signal transmission, redundancy and diversity, response time, and reliability.

Prerequisite: ECE 221 or ECE 331
*Typically offered in Spring only*

**NE 419 Introduction to Nuclear Energy** (3 credit hours)
The course NE 419 is an introduction to the concepts, systems, and applications of nuclear energy. The first half of the course focuses on fundamental nuclear physics and nuclear energetics, while the second half focuses on nuclear energy processes, nuclear reactors, and nuclear technology. The course topics include fundamental concepts of nuclear physics and nuclear models, nuclear energetics and nuclear reactions, radiation interaction with matter, radiation detection and radiation doses, nuclear reactors and applications of nuclear technology.

Prerequisite: MA 241 and PY 205 (or equivalent)
*Typically offered in Fall and Spring*

**NE 428 Introduction to Plasma Physics and Fusion Energy** (3 credit hours)
Concepts in plasma physics, basics of thermonuclear reactions; charged particle collisions, single particle motions and drifts, radiation from plasmas and plasma waves, fluid theory of plasmas, formation and heating of plasmas, plasma confinement, fusion devices and other plasma applications.

*Typically offered in Fall only*

**NE 431/NE 531 Nuclear Waste Management** (3 credit hours)
Scientific and engineering aspects of nuclear waste management. Management of spent fuel, high-level waste, uranium mill tailings, low-level waste and decommissioning wastes. Fundamental processes for the evaluation of waste management systems with emphasis on the safety assessment of waste disposal facilities to include nuclear criticality safety, free release and transportation. There is also a required research project for the graduate version of the course.

Prerequisite: MA 341 and PY208 (or any equivalent)
*Typically offered in Spring only*
*This course is offered alternate even years*

**NE 433/NE 533 Nuclear Fuel Performance** (3 credit hours)
In this course we will study the basic role of fuel in reactor operation and understand how the fuel impacts heat generation and transport to the coolant. The course will begin with an overview of different fuels and the fabrication processes required to construct nuclear fuel. This will include various fuel types and geometries, with a focus on light water reactor fuel and cladding. Thermal transport, mechanics, and thermomechanics affecting fuel behavior will be introduced, and methods to solve the governing equations numerically and analytically will be developed. Subsequently, changes in the fuel and cladding material that degrade the performance of the fuel will be examined. Finally, the knowledge gained throughout the course will be utilized to conduct fuel performance simulations with MOOSE.

Corequisite: NE 409 or equivalent
*Typically offered in Spring only*

**NE 442 Biomedical Applications of Plasma** (3 credit hours)
Concepts of plasma sources for medical and agricultural applications of plasma are introduced together with a general introduction to atmospheric pressure plasmas. Plasma components and their mode of action are discussed and the impact of plasma on eukaryotic cells is explored. Safety aspects, in particular with respect to medical plasma applications, are discussed. Applications ranging from plasma-assisted wound healing to plasma oncology and plasma agriculture are introduced together with brief introductions to each application.

Prerequisite: PY 208
*Typically offered in Fall only*

**NE 460/NE 560 Probabilistic Risk Assessment and Management of Nuclear Systems** (3 credit hours)
This course introduces principles of probabilistic risk assessment and management of complex engineering systems, with a particular focus on nuclear power applications. Fundamental safety and risk concepts, accidents and risk management, a review of major probabilistic risk assessment studies, hazard analysis, qualitative and quantitative systems analysis, human and software reliability, uncertainty quantification, and risk-informed and performance-based design and licensing of advanced nuclear reactors under development. Risk and safety principles are emphasized in homework and in-class problems. Course project is required.

*Typically offered in Fall only*

**NE 470/NE 570 Monte Carlo Methods for Radiation Transport** (3 credit hours)
This course provides a detailed discussion over the fundamental concepts associated with the Monte Carlo (MC) method for particle/radiation transport. Students will be able to learn the fundamental and advanced topics on the application of MC to solve radiation transport problems in nuclear engineering. Applications of generalized MC techniques using the MCNP code to solve neutron, photon, and electron radiation transport problems typically encountered in reactor physics, shielding, criticality safety, and radiation dosimetry will be addressed. The students will also learn how to use the MCNP code to solve these problems. Students will improve their programming skills for Monte Carlo particle transport and statistical analysis. Therefore, a basic understanding of nuclear reactor physics is highly recommended. Also, students in this class are expected to have some undergraduate-level background in Probability and Statistics. Also, programming experience (e.g., Python, MATLAB) is highly recommended.

*Typically offered in Fall only*

**NE 490/NE 590 Health Physics and Radiological Emergency Response** (3 credit hours)
This is an advanced health physics course encompassing internal and external radiological dosimetry along with control of radiation fields including airborne radioactivity. Students will learn basic interactions and response functions, biological effects as well as natural and manmade sources allowing emphasis on the final coverage of nuclear emergency response.

Prerequisite: MA 341 and PY 208 (or equivalent)
*Typically offered in Spring only*

**NE 491 Special Topics in Nuclear Engineering** (1-4 credit hours)
Detailed coverage of special topics.

**NE 500 Advanced Energy Conversion in Nuclear Reactors** (3 credit hours)
A course which introduces concepts and principles of heat generation and removal in reactor systems. Power cycles, reactor heat sources, analytic and numerical solutions to conduction problems in reactor components and fuel elements, heat transfer in reactor fuel bundles and heat exchangers. Design principles are emphasized in homework and in-class problems. Course project is required. Credit will not be given for both NE 400 and NE 500.

Prerequisite: MAE 201
*Typically offered in Spring only*

**NE 501/NE 401 Reactor Analysis and Design** (3 credit hours)
Elements of nuclear reactor theory for reactor core design and operation. Includes one-group neutron transport and mutigroup diffusion models, analytical and numerical criticality search, and flux distribution and calculations for homogeneous and heterogeneous reactors, slowing down models, introduction to perturbation theory.

Prerequisites: MA 401 and C- or better in NE 301
*Typically offered in Spring only*

**NE 502 Reactor Engineering** (3 credit hours)
Thermal-hydraulic design and analysis of nuclear systems. Single and two-phase flow, boiling heat transfer, modeling of fluid systems. Design constraints imposed by thermal-hydraulic considerations are discussed. Credit will not be given for bothNE 402 and NE 502.

Prerequisite: MAE 308
*Typically offered in Fall only*

**NE 504 Radiation Safety and Shielding** (3 credit hours)
A basic course in radiation safety and environmental aspects of nuclear power generation. Topics include radiation interaction, photon attenuation, shielding, internal and external dose evaluation, reactor effluents and release of radioactivity into the environment, transportation and disposal of radioactive waste; and environmental impact of nuclear power plants. Term-long project.

Prerequisite: NE 401 or NE 520
*Typically offered in Fall only*

**NE 505 Reactor Systems** (3 credit hours)
Nuclear power plant systems: PWR, BWR and advanced concepts. Design criteria, design parameters, economics, primary and secondary loops, safety systems, reactor control and protection systems, containment, accident and transient behaviors, core design, and reactivity control mechanisms. Term-long project. Credit for both NE 405 and NE 505 is not allowed

Prerequisite: NE 401, NE 402
*Typically offered in Spring only*

**NE 509/MSE 509/NE 409/MSE 409 Nuclear Materials** (3 credit hours)
Introduces students to properties and selection of materials for nuclear steam supply systems and to radiation effects on materials. Implications of radiation damage to reactor materials and materials problems in nuclear engineering are discussed. Topics include an overview of nuclear steam supply systems, crystal structure and defects, dislocation theory, mechanical properties, radiation damage, hardening and embrittlement due to radiation exposure and problems concerned with fission and fusion materials. Students cannot receive credit for both 409 and 509.

Prerequisite: MSE 201
*Typically offered in Fall only*

**NE 511 Multi-physics of Nuclear Reactors** (3 credit hours)
Graduate level course focused on reactor multi-physics methods and techniques for multi-dimensional reactor analysis.

P: NE 301
*Typically offered in Spring only*

**NE 512 Nuclear Fuel Cycle** (3 credit hours)
Processing of nuclear fuel with description of mining, milling, conversion, enrichment, fabrication, irradiation, shipping, reprocessing and waste disposal. Fuel cycle economics and fuel cost calculation. In-core and out-of-core nuclear fuel management, engineering concepts and methodology. Term-long project. Credit for both NE 412 and NE 512 is not allowed.

Prerequisite: NE 401
*Typically offered in Spring only*

**NE 520 Radiation and Reactor Fundamentals** (3 credit hours)
Basics of nuclear physics and reactor physics that are needed for graduate studies in nuclear engineering. Concepts covered include, atomic and nuclear models, nuclear reactions, nuclear fission, radioactive decay, neutron interactions, nuclear reactors, neutron diffusion in non-multiplying and multiplying systems, and basic nuclear reactor kinetics.

Prerequisite: MA 341 and PY 208
*Typically offered in Fall only*

**NE 521 Principles of Radiation Measurement** (3 credit hours)
Radiation detection measurement methods employed in nuclear engineering. Topics include: physics of nuclear decay and nuclear reactions, interaction of charged particles, photons, and neutrons with matter, fundamental properties of radiation measurement systems, statistical analysis of radiation measurements, common radiation detectors (gas-filled detectors, scintillators, and semiconductor detectors), data acquisition and processing methods, and radiation measurement applications.

Prerequisites: Graduate standing in Nuclear Engineering or instructor permission
*Typically offered in Fall only*

**NE 522 Principles of Nuclear Reactor Engineering** (3 credit hours)
Graduate level course designed as an intensive course introducing nuclear reactor engineering principles to graduate students with non-nuclear engineering background or returning students.

Prerequisite: Graduate Standing
*Typically offered in Fall only*

**NE 523 Computational Transport Theory** (3 credit hours)
Derivation of the nonlinear Boltzmann equation for a rarefied gas and linearization to the equation of transport of neutral particles. Deterministic methods for solving the neutron transport equation: Multigroup energy discretization; Discrete Ordinates angular discretization; various spatial discretization methods. Convergence of numerical solutions with discretization refinement. Iterative solution algorithms: inner, outer, and power iterations. Spectral analysis of inner iterations convergence and acceleration. Selection of advanced topics.

NE 401/501: Reactor Analysis and Design Advanced math & moderate programming skills are necessary. Permissible programming languages: Fortran or C++
*Typically offered in Spring only*

**NE 528/PY 528 Introduction to Plasma Physics and Fusion Energy** (3 credit hours)
Concepts in plasma physics, basics of thermonuclear reactions; charged particle collisions, single particle motions and drifts, radiation from plasmas and plasma waves, fluid theory of plasmas, formation and heating of plasmas, plasma confinement, fusion devices and other plasma applications.

Prerequisite: MA 401 and PY 208; Graduate standing or departmental consent
*Typically offered in Fall only*

**NE 529/PY 529 Plasma Physics and Fusion Energy II** (3 credit hours)
This course expands on the treatment of plasmas as a system of coupled fluids and introduces the foundations of plasma kinetic theory. Derivation of the plasma kinetic equation and the Vlasov equation serve as the starting point to introduce the kinetic study of plasma systems. From this introduction of the governing equations for full kinetic treatment, methods for analyzing plasma response to electromagnetic and electrostatic perturbations using the linearized Vlasov model for uncorrelated plasmas are introduced. Kinetic stability of Vlasov plasmas is introduced and the Nyquist method is used to determine conditions for kinetic stability. The concept of correlated plasmas is then introduced through the introduction of reduced distribution functions and the BBGKY heirarchy. Finally, simple correlated systems and the Liouville model for two-system correlation is covered to look at the impact of particle correlation due to collisions and coulomb interaction.

Prerequisite: NE 528
*Typically offered in Spring only*

**NE 531/NE 431 Nuclear Waste Management** (3 credit hours)
Scientific and engineering aspects of nuclear waste management. Management of spent fuel, high-level waste, uranium mill tailings, low-level waste and decommissioning wastes. Fundamental processes for the evaluation of waste management systems with emphasis on the safety assessment of waste disposal facilities to include nuclear criticality safety, free release and transportation. There is also a required research project for the graduate version of the course.

Prerequisite: MA 341 and PY208 (or any equivalent)
*Typically offered in Spring only*
*This course is offered alternate even years*

**NE 533/NE 433 Nuclear Fuel Performance** (3 credit hours)
In this course we will study the basic role of fuel in reactor operation and understand how the fuel impacts heat generation and transport to the coolant. The course will begin with an overview of different fuels and the fabrication processes required to construct nuclear fuel. This will include various fuel types and geometries, with a focus on light water reactor fuel and cladding. Thermal transport, mechanics, and thermomechanics affecting fuel behavior will be introduced, and methods to solve the governing equations numerically and analytically will be developed. Subsequently, changes in the fuel and cladding material that degrade the performance of the fuel will be examined. Finally, the knowledge gained throughout the course will be utilized to conduct fuel performance simulations with MOOSE.

Corequisite: NE 409 or equivalent
*Typically offered in Spring only*

**NE 541 Nuclear Nonproliferation Technology and Policy** (3 credit hours)
Technology and policy challenges and solutions to prevent the spread of nuclear weapons. Topics include: issues of nuclear proliferation inherent to civilian nuclear power development; technologies, processes, and policies for safeguarding nuclear materials and technology; integrating the preceding subjects to strengthen the global nuclear nonproliferation regime.

Graduate standing in Nuclear Engineering or instructor consent.
*Typically offered in Spring only*

**NE 542 Biomedical Applications of Plasma** (3 credit hours)
Concepts of plasma sources for medical and agricultural applications of plasma are introduced together with a general introduction to atmospheric pressure plasmas. Plasma components and their mode of action are discussed and the impact of plasma on eukaryotic cells is explored. Safety aspects, in particular with respect to medical plasma applications, are discussed. Applications ranging from plasma-assisted wound healing to plasma oncology and plasma agriculture are introduced together with brief introductions to each application.

R: Graduate Standing
*Typically offered in Fall only*

**NE 550 Introduction to Atomistic Simulations** (3 credit hours)
NE 550 is an introductory course on molecular dynamics simulations. The course covers the principles of classical and statistical mechanics that underpin the simulation methods. Emphasis is placed on writing computer programs for determining thermodynamic, structural and transport properties of different types of materials.

*Typically offered in Spring only*

**NE 560/NE 460 Probabilistic Risk Assessment and Management of Nuclear Systems** (3 credit hours)
This course introduces principles of probabilistic risk assessment and management of complex engineering systems, with a particular focus on nuclear power applications. Fundamental safety and risk concepts, accidents and risk management, a review of major probabilistic risk assessment studies, hazard analysis, qualitative and quantitative systems analysis, human and software reliability, uncertainty quantification, and risk-informed and performance-based design and licensing of advanced nuclear reactors under development. Risk and safety principles are emphasized in homework and in-class problems. Course project is required.

*Typically offered in Fall only*

**NE 570/NE 470 Monte Carlo Methods for Radiation Transport** (3 credit hours)
This course provides a detailed discussion over the fundamental concepts associated with the Monte Carlo (MC) method for particle/radiation transport. Students will be able to learn the fundamental and advanced topics on the application of MC to solve radiation transport problems in nuclear engineering. Applications of generalized MC techniques using the MCNP code to solve neutron, photon, and electron radiation transport problems typically encountered in reactor physics, shielding, criticality safety, and radiation dosimetry will be addressed. The students will also learn how to use the MCNP code to solve these problems. Students will improve their programming skills for Monte Carlo particle transport and statistical analysis. Therefore, a basic understanding of nuclear reactor physics is highly recommended. Also, students in this class are expected to have some undergraduate-level background in Probability and Statistics. Also, programming experience (e.g., Python, MATLAB) is highly recommended.

*Typically offered in Fall only*

**NE 577/MAE 577 Multiscale Two-phase Flow Simulations** (3 credit hours)
Modeling and simulation of two-phase flows using interface tracking approach and ensemble averaging approaches. Model validation and verification based on interface-tracking data, boiling models. Nuclear reactor applications. The course focuses on interface tracking methods understanding as applied to bubbly flow simulations. Students will develop a simplified solver to track 2D bubbles/droplets throughout the course homework assignments and will learn how to apply this approach for better understanding of multi-phase flow as part of the course project.

*Typically offered in Spring only*
*This course is offered alternate odd years*

**NE 590/NE 490 Health Physics and Radiological Emergency Response** (3 credit hours)
This is an advanced health physics course encompassing internal and external radiological dosimetry along with control of radiation fields including airborne radioactivity. Students will learn basic interactions and response functions, biological effects as well as natural and manmade sources allowing emphasis on the final coverage of nuclear emergency response.

Prerequisite: MA 341 and PY 208 (or equivalent)
*Typically offered in Spring only*

**NE 591 Special Topics In Nuclear Engineering I** (1-6 credit hours)
Credits Arranged

*Typically offered in Fall and Spring*

**NE 592 Special Topics In Nuclear Engineering II** (1-6 credit hours)
Credits Arranged

*Typically offered in Fall and Spring*

**NE 601 Seminar** (1 credit hours)
Discussion of selected topics in nuclear engineering.

*Typically offered in Fall and Spring*

**NE 685 Master's Supervised Teaching** (1-3 credit hours)
Teaching experience under the mentorship of faculty who assist the student in planning for the teaching assignment, observe and provide feedback to the student during the teaching assignment, and evaluate the student upon completion of the assignment.

Prerequisite: Master's student
*Typically offered in Fall, Spring, and Summer*

**NE 690 Master's Examination** (1-9 credit hours)
For students in non thesis master's programs who have completed all other requirements of the degree except preparing for and taking the final master's exam.

Prerequisite: Master's student
*Typically offered in Fall only*

**NE 693 Master's Supervised Research** (1-9 credit hours)
Instruction in research and research under the mentorship of a member of the Graduate Faculty.

Prerequisite: Master's student
*Typically offered in Fall, Spring, and Summer*

**NE 695 Master's Thesis Research** (1-9 credit hours)
Thesis research.

Prerequisite: Master's student
*Typically offered in Fall, Spring, and Summer*

**NE 696 Summer Thesis Research** (1 credit hours)
For graduate students whose programs of work specify no formal course work during a summer session and who will be devoting full time to thesis research.

Prerequisite: Master's student
*Typically offered in Summer only*

**NE 699 Master's Thesis Preparation** (1-9 credit hours)
For students who have completed all credit hour requirements and full-time enrollment for the master's degree and are writing and defending their theses.

Prerequisite: Master's student
*Typically offered in Spring and Summer*

**NE 721 Nuclear Laboratory Fundamentals** (3 credit hours)
Labratory experiments and techniques that are useful and instructive to a Nuclear Engineer. The labs include experiments on radiation detectors and detection techniques, Gamma-and X-ray spectroscopy, and use of the thermal neutron beam of the nuclear reactor for neutron imaging. All state-of-the art radiation detectors are taught and used. Restricted to Nuclear Engineering Graduate Students.

Prerequisite: MA 401 and NE 401
*Typically offered in Spring only*

**NE 722 Reactor Dynamics and Control** (3 credit hours)
Methods of describing and analyzing dynamic behavior of systems. These methods applied to reactor systems and the effects of feedbacks studies. Methods of measuring the behavior of reactor systems and development of logic systems for control and safety.

Prerequisite: NE 401 or NE 520
*Typically offered in Fall only*

**NE 723 Neutron Transport Theory** (3 credit hours)
Advanced theory of neutron transport and computational methods of solving particle transport (linear Boltzmann) equation for reactor physics problems. Principle topics: models of neutron transport; analytic methods for solving transport equation; asymptotic diffusion limit; PN and SPN methods, homogenization methodology; numerical methods for multidimensional problems; computational methods for multiphysics problems. Objective is to enable students to read literature and perform relevant analysis of neutron transport and reactor-physics problems.

P:NE 520 or NE 401/501
*Typically offered in Fall only*

**NE 724 Reactor Heat Transfer** (3 credit hours)
Consideration of heat generation and transfer in nuclear power reactors. Topics include reactor heat generation, steady-state and transient heat combustion in reactor fuel elements, boiling heat transfer and single and two-phase flow.

Prerequisite: NE 402 and NE 401 or NE 520
*Typically offered in Spring only*
*This course is offered alternate even years*

**NE 726 Radioisotopes Measurement Applications** (3 credit hours)
Introduction the student to measurement applications using radioisotopes and radiation. Discussion of all major tracing, gauging and analyzer principles and treatment of several specific applications in detail. Objective is to familiarize student with design and analysis of industrial measurement systems using radioisotopes and/or radiation.

Prerequisite: NE 401 or NE 520
*Typically offered in Spring only*

**NE 727 Nuclear Engineering Analysis** (3 credit hours)
Fundamental material on: (1) numerical methods for solving the partial differential equations pertinent to nuclear engineering problems, (2) Monte Carlo simulation of radiation transport and (3) data and error analysis techniques including estimation of linear and nonlinear model parameters from experimental data.

Prerequisite: NE 401 or NE 520
*Typically offered in Fall only*

**NE 729 Reactor Theory and Analysis** (3 credit hours)
Theoretical aspects of neutron diffusion and transport related to the design computation and performance analysis of nuclear reactors. Principal topics: a unified view of the neutron cycle including slowing down, resonance capture and thermalization; reactor dynamics and control; fuel cycle studies; and neutron transport methods. Background provided for research in power and test reactor analysis.

Prerequisite: NE 723, NE 727
*Typically offered in Spring only*
*This course is offered alternate years*

**NE 732 Principles of Industrial Plasmas** (3 credit hours)
Theory and fundamental physical principles of industrial plasmas. Applications in plasma processing, plasma manufacturing technology, arcs and torches, plasma sprayers, high-voltage high-current switching devices, plasma-driven devices and plasma-aided technology. Emphasis on particle transport and plasma flow.

Prerequisite: NE/PY 528
*Typically offered in Spring only*

**NE 737 Plasma Spectroscopy** (3 credit hours)
The purpose of this course is to provide you with the necessary background to pursue specific topics in nuclear engineering with a focus on plasma science and engineering. This course covers the fundamental science of plasma spectroscopy, which includes radiation processes in plasmas, collisional processes, kinetics of the population of atomic levels in plasmas, sources of line broadening, spectroscopic instruments, detectors and calibration, diagnostic applications, and laser spectroscopy of plasmas. Applications of plasma spectroscopy will be covered and include laser induced breakdown spectroscopy, low temperature thermal and non-thermal plasmas, and fusion plasma.

Prerequisite: MA341 and PY208 (or equivalent)
*Typically offered in Spring only*

**NE 740 Laboratory Projects In Nuclear Engineering** (3 credit hours)
Enhancement of laboratory skills pertinent to nuclear engineering research through projects that requiring student to design the experiment, assemble equipment, carry out the measurements and analyze and interpret data. Students work in groups of two and perform to completion two laboratory projects.

Prerequisite: NE 721
*Typically offered in Spring only*

**NE 745 Plasma Laboratory** (3 credit hours)
Experimental plasma generation and plasma diagnostic techniques. Lecture topics include high vacuum techniques, perturbing and non-perturbing probe techniques, and laser and emission spectroscopy. Laboratories utilize various methods of measuring plasma parameters discussed in lectures.

Prerequisite: NE 528 or PY 508 or PY 509
*Typically offered in Spring only*
*This course is offered alternate years*

**NE 751 Nuclear Reactor Design Calculations** (3 credit hours)
Application of digital computer to problems in reactor core nuclear design. Study and exercise of available reactor core physics computer modules. Description of systems and programs used by industry for power reactor core design and core follow. A review of relevant analytic and numerical methods facilitates computer program development by students.

Prerequisite: NE 723
*Typically offered in Spring only*
*This course is offered alternate years*

**NE 752 Thermal Hydraulic Design Calculations** (3 credit hours)
Advanced presentation of thermal-hydraulic analysis of nuclear power systems. Topics including development of single phase and two-phase fluid flow equations, subchannel analysis, interphase phenomena and numerical solution methods relevant to design and safety analysis codes.

Prerequisite: NE 724
*Typically offered in Fall only*
*This course is offered alternate years*

**NE 753 Reactor Kinetics and Control** (3 credit hours)
The control of nuclear reactor systems. Development of basic control theory including the use of Bode, Nyquist and S-plane diagrams and state-variable methods. Analysis of reactor and reactor systems by these methods and development of control methods and optimum-control methods. Discussion of models of reactors and reactor-associated units, such as heat exchangers. Presentation of effects of nonlinearities.

Prerequisite: NE 722
*Typically offered in Spring only*

**NE 755 Reactor Theory and Analysis** (3 credit hours)
Theoretical aspects of neutron diffusion and transport related to the design computation and performance analysis of nuclear reactors. Principal topics: a unified view of the neutron cycle including slowing down, resonance capture and thermalization; reactor dynamics and control; fuel cycle studies; and neutron transport methods. Background provided for research in power and test reactor analysis.

Prerequisite: NE 723, NE 727
*Typically offered in Spring only*
*This course is offered alternate years*

**NE 757 Radiation Effects On Materials** (3 credit hours)
Interaction of radiation with matter with emphasis on microstructural modification, physical and mechanical effects. Defects generation and annealing, void swelling, irradiation growth and creep, and irradiation induced effects in reactor materialsare discussed. Current theories and experimental techniques are discussed.

*Typically offered in Fall only*

**NE 758 Magnetic Confinement Fusion Energy Engineering** (3 credit hours)
This advanced graduate course covers the multifaceted design aspects of fusion reactor systems, addressing critical considerations such as plasma physics, engineering limits and tradeoffs between these constraints. The parameter requirements for ignition devices, engineering test facilities, and safety/environmental concerns, all will be addressed. The course explores magnet principles, covering resistive and superconducting magnets, along with associated cryogenic requirements. The curriculum covers blanket and first wall design considerations, encompassing both liquid and solid breeders, heat removal strategies, and structural considerations. Fueling requirements and technologies will be introduced and discussed. Additionally, the course explores heating and current drive devices, including radio frequency and neutral beam methods. Participants will develop a thorough understanding of the elements and tools involved in designing fusion reactors and have the practical experience of applying them in an assigned course research project.

Prerequisite: NE 528
*Typically offered in Fall only*
*This course is offered alternate years*

**NE 761 Radiation Detection** (3 credit hours)
Advanced aspects of radiation detection such as computer methods applied to gamma-ray spectroscopy, absolute detector efficiencies by experimental and Monte Carlo techniques, the use and theory of solid state detectors, time-of-flight detection experiments and MÂ¿ssbauer and other resonance phenomena.

Prerequisite: NE 726
*Typically offered in Spring only*

**NE 762 Radioisotope Applications** (3 credit hours)
Presentation of advanced principles and techniques of radioisotope applications. Topics include radiotracer principles; radiotracer applications to engineering processes; radioisotope gauging principles; charged particle, gamma ray and neutron radioisotope gauges.

Prerequisite: NE 726
*Typically offered in Fall only*

**NE 763 Advanced Reactor Materials and Materials Performance** (3 credit hours)
This course discusses materials evolution and performance in advanced reactor systems, addressing the current state of knowledge for advanced fuels, cladding, and coolants. Students will gain relevant knowledge to address advanced materials questions in the next generation of nuclear reactors. Systems of interest include high-temperature gas reactors, sodium-cooled fast reactors, molten salt reactors, small modular reactors, research reactors, and more.

Prerequisite: NE 509
*Typically offered in Fall only*

**NE 765 Verification and Validation in Scientific Computing** (3 credit hours)
Advances in scientific computing have made modeling and simulation an important part of engineering and science. This course provides students with understanding and knowledge of comprehensive and systematic development of concepts, principles and procedures for verification, and validation of models and simulations. The methods discussed in class will be applied to wide range of technical fields of engineering (including nuclear and mechanical engineering) and technology. The theory lectures and assignments will be complemented with demonstration computer exercises, examples, and a computer project on uncertainty propagation in modeling.

Restriction: Graduate Standing in College of Engineering or College of Science
*Typically offered in Fall only*

**NE 770 Nuclear Radiation Attenuation** (3 credit hours)
Advanced course in computational methods for neutron and photon transport. Methods include Monte Carlo and deterministic solutions to the transport equation for both fixed source and eigenvalue problems. Digital computers employed in the solution of practical problems.

Prerequisite: NE 723 or equivalent
*Typically offered in Fall only*
*This course is offered alternate years*

**NE 772/CE 772 Environmental Exposure and Risk Analysis** (3 credit hours)
Course covers the identification, transport, and fate of hazardous substances in the environment; quantification of human exposures to such substances; dose-response analysis; and uncertainty and variability analysis. The general risk assessment framework, study design aspects for exposure assessment, and quantitative methods for estimating the consequences and probablity of adverse health outcomes are emphasized.

Prerequisite: ST 511 or 515
*Typically offered in Spring only*
*This course is offered alternate odd years*

**NE 777 Radiological Assessment** (3 credit hours)
Principles of analyzing environmental radiation transport and resulting human exposure and dose and dose management. Source terms of radiation exposure, the radon problem, transport or radionuclides in the atmosphere, effluent pathways modeling, radiation dosimetry, probabilistic models for environmental assessment, uncertainty analysis, and radiation risk management. A laboratory research project report will be developed as an outcome of this course.

Prerequisite: NE520 & NE504 or NE590 and a semester long statistics course or permission by instructor
*Typically offered in Fall only*

**NE 780 Magnetohydrodynamics & Transport in Plasmas** (3 credit hours)
Advanced fluid description of plasmas for magnetic fusion, space and industrial plasmas, and other applications. Emphasis on a first principles approach to transport, equilibria, and stability.

Prerequisite: NE 528, NE/PY 414 and 415
*Typically offered in Fall only*
*This course is offered alternate odd years*

**NE 781 Kinetic Theory, Waves, & Non-Linear Effects in Plasmas** (3 credit hours)
Kinetic theory, waves, and non-linear phenomena in magnetized plasmas. First principles approach to the treatment of instabilities and other collective effects.

Prerequisite: NE 528, NE/PY 414 and 415, Corequisite: MA 775
*Typically offered in Fall only*
*This course is offered alternate even years*

**NE 795 Advanced Topics In Nuclear Engineering I** (1-3 credit hours)
A study of recent developments in nuclear engineering theory and practice.

*Typically offered in Fall and Spring*

**NE 796 Advanced Topics In Nuclear Engineering II** (3 credit hours)
A study of recent developments in nuclear engineering theory and practice.

*Typically offered in Fall and Spring*

**NE 801 Seminar** (1 credit hours)
Discussion of selected topics in nuclear engineering.

*Typically offered in Fall and Spring*

**NE 885 Doctoral Supervised Teaching** (1-3 credit hours)
Teaching experience under the mentorship of faculty who assist the student in planning for the teaching assignment, observe and provide feedback to the student during the teaching assignment, and evaluate the student upon completion of the assignment.

Prerequisite: Doctoral student
*Typically offered in Fall, Spring, and Summer*

**NE 890 Doctoral Preliminary Examination** (1-9 credit hours)
For students who are preparing for and taking written and/or oral preliminary exams.

Prerequisite: Doctoral student
*Typically offered in Spring only*

**NE 893 Doctoral Supervised Research** (1-9 credit hours)
Instruction in research and research under the mentorship of a member of the Graduate Faculty.

Prerequisite: Doctoral student
*Typically offered in Fall and Spring*

**NE 895 Doctoral Dissertation Research** (1-9 credit hours)
Dissertation research.

Prerequisite: Doctoral student
*Typically offered in Fall, Spring, and Summer*

**NE 896 Summer Dissertation Research** (1 credit hours)
For graduate students whose programs of work specify no formal course work during a summer session and who will be devoting full time to thesis research.

Prerequisite: Doctoral student
*Typically offered in Summer only*

**NE 899 Doctoral Dissertation Preparation** (1-9 credit hours)
For students who have completed all credit hour, full-time enrollment, preliminary examination, and residency requirements for the doctoral degree, and are writing and defending their dissertations.

Prerequisite: Doctoral student
*Typically offered in Fall and Spring*