DEPARTMENT OF NUCLEAR SCIENCE AND ENGINEERING

The Department of Nuclear Science and Engineering (NSE) provides undergraduate and graduate education for students interested in developing and understanding nuclear technologies for the benefit of society and the environment.

This is an exciting time to study nuclear science and engineering. There is an upsurge of innovative activity in the field, including a drastic increase in nuclear start-up companies, as energy resource constraints, security concerns, and the risks of climate change are creating new demands for safe, secure, cost-competitive nuclear energy systems. At the same time, powerful new tools for exploring, measuring, modeling, and controlling complex nuclear and radiation processes are laying the foundations for major advances in the application of nuclear technologies in medicine and industry as well as in fundamental science.

In response to these developments, the department has created programs of study that prepare students for scientific and engineering leadership roles in energy and non-energy applications of nuclear science and technology. Applications include nuclear fission energy systems, fusion energy systems, quantum engineering, and systems for securing nuclear materials against the threats of nuclear proliferation and terrorism. Underlying these applications are core fields of education and research, including low-energy nuclear physics; plasma physics; thermal sciences; radiation sources, detection, and control; the study of materials in harsh chemo-mechanical, radiation, and thermal environments; and advanced computation and simulation.

Students in nuclear science and engineering study the scientific fundamentals of the field, engineering methods for integrating these fundamentals into practical systems, and the interactions of nuclear systems with society and the environment. Undergraduate and graduate students take core subjects in the field and can then select from a wide variety of application areas through more specialized subjects.

Principle areas of research and education in the department are described below.

Nuclear Fission Energy. Nuclear reactors, utilizing the fission of heavy elements such as uranium, supply approximately 13% of the world's electricity, powering grids, ships and submarines. They produce radioisotopes for medical, biological, and industrial uses, and for long-lived on-board power sources for spacecraft. They can also provide energy for chemical and industrial processing and portable fuel production (e.g., synthetic fuels or hydrogen).

Electricity generation is the most familiar application. In some countries, the fraction of electricity obtained from nuclear power exceeds 50%. In the United States, 100 nuclear power plants supply almost 20% of the nation's electricity. Thirty countries generate nuclear power today, and more than 40 others have recently expressed an interest in developing new nuclear energy programs. Nuclear power is the only low-carbon energy source that is both inherently scalable and already generating a significant share of the world's electricity supplies. Fission technology is entering a new era in which upgraded existing plants, next-generation reactors, and new fuel cycle technologies and strategies will contribute to meeting the rapidly growing global demand for safe and cost-competitive low-carbon electricity supplies.

Fission energy research in the Nuclear Science and Engineering department is focused on developing advanced nuclear reactor designs for electricity, process heat, and fluid fuels production that include passive safety features; developing innovative proliferation-resistant fuel cycles; extending the life of nuclear fuels and structures; and reducing the capital and operating costs of nuclear energy systems. These research goals are pursued via targeted technology options, based on advanced modeling and simulation techniques and state-of-the-art experimental facilities. Progress toward these goals also entails advances in the thermal, materials, nuclear, and computational sciences. The overall objective is to advance the role of nuclear energy as an economical, safe, environmentally friendly, and flexible energy source, thereby contributing to energy security, economic growth, and a sustainable global climate.

Plasma Physics and Fusion Technology. A different source of nuclear energy results from the controlled fusion of light elements, notably hydrogen isotopes. Since the basic source of fuel for fusion can be easily and inexpensively extracted from the ocean or from very abundant lithium, the supply is virtually inexhaustible. Fusion reactions can only readily occur in a fully ionized plasma heated to ultra high temperatures (150 million K). Such hot plasmas cannot be contained by material walls and are usually confined instead by strong magnetic fields. An alternative approach entails inertial confinement, usually achieved with very high-power lasers. Recent progress within the international fusion community increases the likelihood that controlled fusion will become a practical source of energy within the next half-century. Attainment of a fusion power plant involves the solution of many intellectually challenging physics and engineering problems. Included among these challenges are a mastery of the sophisticated field of plasma physics; the discovery of improved magnetic geometries to enhance plasma confinement; the development of materials capable of withstanding high stresses and exposure to intense radiation; and the need for great engineering ingenuity in integrating fusion power components into a practical, safe, and economical system. The department has strong programs in plasma fundamentals, materials for intense radiation fields, and engineering of fusion systems.

Plasma processes are key to many naturally occurring phenomena, and to many practical applications. Solar physics, space weather, and dusty plasma physics, are basic plasma research areas of departmental expertise. Treatment of toxic gases, magnetohydrodynamic energy conversion, ion propulsion, radiation generation, materials processing, and various other industrial applications use the knowledge students gain in applied plasma physics. The Department of Nuclear Science and Engineering leads MIT's interdepartmental graduate instruction in plasma physics and many of its research applications.

Nuclear Security. The field of nuclear security concerns itself with the challenges and dangers of nuclear weapons and nuclear materials. Various areas of nuclear security include nuclear nonproliferation, arms control treaty verification, cargo security, as well as nuclear safeguards. In order for nuclear power to retain its societal relevance, it is important for the nuclear community to develop a culture of security just as it has developed a culture of safety. Thus, nuclear security in its broadest sense becomes of paramount importance to the nuclear engineering community. MIT in particular is perfectly positioned to perform long-term research in the field of nuclear security, to make the use of nuclear energy less risky for global security. Part of this effort of necessity contains a component of policy, as well as a component of technological research necessary to stop proliferation, improve nuclear safeguards, and intercept any attempts at nuclear terrorism: a successful program cannot be either purely technology driven or purely policy driven but rather a careful integration of these two areas. MIT is actively pursuing an integration of both technology and policy development.

Quantum Engineering. An exciting new frontier in nuclear science and engineering is to precisely control the quantum mechanical wave function of atomic and subatomic systems. Thus far, this has been achieved only in low-energy processes, particularly nuclear magnetic resonance, a form of nuclear spectroscopy which has allowed the basic techniques needed for quantum control to be explored in unprecedented detail. The department has initiated an ambitious program in this area, which promises to be widely applicable in nanotechnology. The ultimate achievement would be the construction of a "quantum computer," which would be capable of solving problems that are far beyond the capacities of classical computers. Other significant applications are quantum-enabled sensors and actuators, secure communication, and the direct simulation of quantum physics.

Materials for Extreme Environments. An important area of research in the department which unites many of the primary applications of nuclear science and technology involves the study of materials in extreme environments. To achieve the full potential of nuclear energy from both fission and fusion reactors, it is necessary to develop special materials capable of withstanding intense radiation for long periods of time as well as high temperatures and mechanical stresses. It is also crucial to understand the phenomenon of corrosion in radiation environments. To develop a fundamental understanding of these phenomena, chemical and physical processes must be followed at multiple scales, from the atomic to the macroscopic, over timescales from less than a nanosecond to many decades, and even, in the case of nuclear waste, thousands of years. Materials research in the department draws on a wide array of new scientific tools, including advanced compact radiation sources, material probes and characterization at the nanoscale, and advanced computational simulations.

Interdisciplinary Research. Students and faculty in the department work closely with colleagues in several other departments, including Physics, Materials Science and Engineering, Mechanical Engineering, Electrical Engineering and Computer Science, and Political Science, and with the Sloan School of Management. The department is an active participant in the MIT Energy Initiative and in MIT's interdisciplinary programs of instruction and research in the management of complex technological systems and technology and public policy.

Undergraduate Study

The department's undergraduate programs offer a strong foundation in science-based engineering, providing the skills and knowledge for a broad range of careers, with an emphasis on hands-on exploration of the subject matter. The programs develop scientific and engineering fundamentals in the production, interactions, measurement, and control of radiation arising from nuclear processes. In addition, the program introduces students to thermal-fluid engineering and computational methods. Building upon these fundamentals, students understand the principles, design, and appropriate application of nuclear-based or nuclear-related systems that have broad societal impacts in energy, human health, and security—for example, reactors, imaging systems, detectors, and plasma confinement. In addition, they develop professional skills in quantitative research, written and oral technical communication, team building, and leadership. The program provides excellent preparation for subsequent employment, graduate education, and/or research in a broad range of fields. In the nuclear field, there is high demand for nuclear engineers around the world as the nuclear energy industry continues to expand. Other nuclear and radiation applications are increasingly important in medicine, industry, and government.

A characteristic of the curriculum is the development of practical skills through hands-on education to reinforce the fundamentals of the nuclear discipline. This is accomplished through various required and elective subjects, such as a laboratory subject on radiation physics, measurement, and protection (22.09 Principles of Nuclear Radiation Measurement and Protection), and through the laboratory components and exercises of the electronics (22.071 Analog Electronics and Analog Instrumentation Design), ionizing radiation, and computational subjects. Even foundational courses in nuclear unit processes (22.01 Introduction to Nuclear Engineering and Ionizing Radiation) and neutronics (22.05 Neutron Science and Reactor Physics) include hands-on activities and analyses of real objects/systems. Examples include measuring the radioactivity of fruits with high potassium content, predicting and measuring the neutron multiplication of a large graphite/uranium pile, and analyzing trace impurities in various foods, minerals, or biological tissues in our nuclear reactor. The concept of experiential learning is continued with a 15-unit design subject focusing on nuclear-centric design and prototyping and/or a 12-unit undergraduate thesis that is normally organized between the student and a faculty member of the department. Thesis subjects can touch on any area of nuclear science and engineering, including nuclear energy applications (fission and fusion) and nuclear science and technology (medical, physical, chemical, security, political science, and materials applications).

Bachelor of Science in Nuclear Science and Engineering (Course 22)

The Bachelor of Science in Nuclear Science and Engineering (Course 22) (*https://catalog.mit.edu/degree-charts/nuclear-science-engineering-course-22*) prepares students for a broad range of careers, from practical engineering work in the energy industry to graduate study in a wide range of technical fields, as well as entrepreneurship, law, medicine, and business. The degree program includes foundational subjects in physics, mathematics, and programming, leading to core subjects in the areas of nuclear energy (fission and fusion), as well as nuclear energy policy, social issues surrounding nuclear energy, quantum engineering, radiation physics, and product design.

The Course 22 degree program is accredited by the Engineering Accreditation Commission of Accreditation Board for Engineering and Technology (ABET) (*http://www.abet.org*).

Bachelor of Science in Engineering (Course 22-ENG)

The 22-ENG degree program (*https://catalog.mit.edu/degree-charts/engineering-nuclear-science-engineering-course-22-eng*) is designed to offer flexibility within the context of nuclear science and engineering applications. This program is designed to enable students to pursue a deeper level of understanding in a specific nuclear application or interdisciplinary field related to the nuclear science and engineering core discipline. The degree requirements include core subjects relevant to a broad array of nuclear and related interdisciplinary areas, a specialization subject in energy systems, and a senior project, as well as a focus area consisting of 72 units of additional coursework.

A significant part of the 22-ENG degree program consists of focus area electives chosen by the student to provide in-depth study in a field of the student’s choosing. Focus areas should complement a foundation in nuclear science and engineering and General Institute Requirements. Some examples of potential focus areas include nuclear medicine, energy or nuclear policy, fusion energy or plasma science, clean energy technologies, nuclear materials, modeling and simulation of complex systems, and quantum engineering, or an area of study within one of the departmental focus areas. Focus areas are not limited to these examples. Advising on students' development of focus areas is available from the undergraduate officer or the Academic Office. Students enrolled in the flexible major must submit a proposal to the Academic Office no later than Add Date of the second term in the program, to be reviewed by the Undergraduate Committee.

Combined Bachelor's and Master's Programs

The five-year programs leading to a joint Bachelor of Science in Chemical Engineering, Civil Engineering, Electrical Engineering, Mechanical Engineering, Nuclear Science and Engineering, or Physics and a Master of Science in Nuclear Science and Engineering are designed for students who decide relatively early in their undergraduate career that they wish to pursue a graduate degree in nuclear science and engineering. Students must submit their application for this program during the second term of their junior year and be judged to satisfy the graduate admission requirements of the department. The normal expectations of MIT undergraduates for admission to the five-year program are an overall MIT grade point average (GPA) of at least 4.3, and a strong mathematics, science, and engineering background with a GPA in these subjects of at least 4.0.

The nuclear science and engineering thesis requirements of the two degrees may be satisfied either by completing both an SB thesis and an SM thesis, or by completing an SM thesis and any 12 units of undergraduate credit.

For further information, interested students should contact either their undergraduate department or the Department of Nuclear Science and Engineering.

Minor in Nuclear Science and Engineering

This minor allows students from any major outside of Course 22 to delve deeper into advanced topics within the department or to support interdisciplinary areas of interest in nuclear science and engineering.

Required subjects		
18.03	Differential Equations	12
22.01	Introduction to Nuclear Engineering and Ionizing Radiation	12
NSE Electives		
Select two of the following:		24
22.02	Introduction to Applied Nuclear Physics	
22.033	Nuclear Systems Design Project	
22.05	Neutron Science and Reactor Physics	
22.06	Engineering of Nuclear Systems	
22.09	Principles of Nuclear Radiation Measurement and Protection	
Foundation and Specialized Subjects		
Select one of the following options:		24
Option 1		
2.005	Thermal-Fluids Engineering I [1]	
or 8.03	Physics III	
12 units of Course 22 coursework [2]		

Option 2	
24 units of Course 22 coursework [2]	
Total Units	**72**

1. Subject has prerequisites that are outside the program.
2. Selected subjects must be letter-graded. Research/UROP subjects cannot be used.

Inquiries

Further information on undergraduate programs, admissions, and financial aid may be obtained from the department's Academic Office (*cegan@mit.edu*), Room 24-102, 617-258-5682.

Graduate Study

The nuclear science and engineering field is broad and many undergraduate disciplines provide suitable preparation for graduate study.

An undergraduate degree in physics, engineering physics, chemistry, mathematics, materials science, or chemical, civil, electrical, mechanical, or nuclear science and engineering can provide a good foundation for graduate study in the department. Optimal undergraduate preparation would include the following:

- **Physics:** At least three introductory subjects covering classical mechanics, electricity and magnetism, and wave phenomena. An introduction to quantum mechanics is quite helpful, and an advanced subject in electricity and magnetism (including a description of time-dependent fields via Maxwell's equations) is recommended for those wishing to specialize in fusion.
- **Mathematics:** It is essential that incoming students have a solid understanding of mathematics, including the study and application of ordinary differential equations. It is also highly recommended that students will have studied partial differential equations and linear algebra.
- **Chemistry:** At least one term of general, inorganic, and physical chemistry.
- **Engineering fundamentals:** The graduate curriculum builds on a variety of engineering fundamentals, and incoming students are expected to have had an introduction to thermodynamics, fluid mechanics, heat transfer, electronics and measurement, and computation. A subject covering the mechanics of materials is recommended, particularly for students wishing to specialize in fission.
- **Laboratory experience:** This component is essential. It may have been achieved through an organized subject, and ideally was supplemented with an independent undergraduate research activity or a design project.

Applicants for admission can find information about admission requirements in the Graduate Education Admissions section (*https://catalog.mit.edu/mit/graduate-education/admissions*) and on the Nuclear Science and Engineering at MIT Department website (*http://web.mit.edu/nse/education/grad/admissions.html*).

Master of Science in Nuclear Science and Engineering

The object of the master of science program is to give the student a good general knowledge of nuclear science and engineering and to provide a foundation either for productive work in the nuclear field or for more advanced graduate study. The general requirements for the SM degree are listed under Graduate Education.

Subjects are selected in accordance with the student's particular field of interest. Master of science candidates may specialize in one of several fields: including nuclear fission technology, applied plasma physics, nuclear materials, nuclear security, and nuclear science and technology. Some students pursue a master of science degree in technology and policy in parallel with the Course 22 master of science program.

Students with adequate undergraduate preparation take approximately 18 months to complete the requirements for the master of science. Actual completion time ranges from one to two years. Additional information concerning the requirements for the Master of Science in Nuclear Science and Engineering, including lists of recommended subjects, may be obtained from the department's Academic Office, Room 24-102.

Nuclear Engineer

The program of study leading to the nuclear engineer's degree provides deeper knowledge of nuclear science and engineering than is possible in the master's program and is intended to train students for creative professional careers in engineering application or design.

The general requirements for this degree, as described under Graduate Education, include 162 units of subject credit plus a thesis. Each student must plan an individually selected program of study, approved in advance by the faculty advisor, and must complete, and orally defend, a substantial project of significant value.

The objectives of the program are to provide the candidate with broad knowledge of the profession and to develop competence in engineering applications or design. The emphasis in the program is more applied and less research-oriented than the doctoral program.

The engineering project required of all candidates for the nuclear engineer's degree is generally the subject of an engineer's thesis. A student with full undergraduate preparation normally needs two years to complete the program. Additional information may be obtained from the department.

Doctor of Philosophy and Doctor of Science in Nuclear Science and Engineering

The program of study leading to either the Doctor of Philosophy or the Doctor of Science in Nuclear Science and Engineering (*https://catalog.mit.edu/degree-charts/phd-nuclear-science-engineering*) aims to give comprehensive knowledge of nuclear science and engineering, to develop competence in advanced engineering research, and to develop a sense of perspective in assessing the role of nuclear science and technology in our society.

General Institute requirements for the doctorate are described under Graduate Education (*https://catalog.mit.edu/mit/graduate-education/general-degree-requirements/#doctoraldegreetext*) and in the Office of Graduate Education Policy and Procedures manual (*https://oge.mit.edu/gpp/degrees/doctoral*). The specific requirements of the Department of Nuclear Science and Engineering are the core requirement, the field of specialization requirement, the oral examination, the advanced subject and minor requirements, and the doctoral thesis. Upon satisfactory completion of the requirements, the student ordinarily receives a PhD in nuclear science and engineering, unless he or she requests an ScD. The requirements for both degrees are the same.

Students admitted for the master of science or nuclear engineer's degree must apply to the Department of Nuclear Science and Engineering's Admissions Committee for admission to the doctoral program.

Candidates for the doctoral degree must demonstrate competence at the graduate level in the core areas of nuclear science and engineering; the core requirement must be completed by the end of the fourth graduate term. Candidates for the doctoral degree are also required to complete three 12-unit (or greater than 12-unit) graduate subjects in their field of specialization with a grade of B or better. The field-of-specialization subjects should together provide a combination of depth and breadth of knowledge.

Candidates for a doctoral degree are required to demonstrate their readiness to undertake doctoral research by passing an oral examination by the end of their fourth graduate term. Oral exams are held twice a year, at the end of January or beginning of February and at the end of May. Students will generally take the oral exam for the first time in January or February of their second year. Two attempts are allowed at the oral exam. An overall GPA in graduate subjects of 4.0 is required to take the oral.

Candidates for a doctoral degree must also pass a thesis prospectus defense and submit an approved thesis prospectus by the end of the fourth term.

Students will be permitted to embark on doctoral research only if, by the end of their fourth graduate term, they have demonstrated satisfactory performance in the core requirement, the field of specialization, and the oral examination, and have passed the thesis prospectus defense and final thesis prospectus submission by the end of the fifth term.

Candidates for the doctoral degree must satisfactorily complete (with an average grade of B or better) an approved program of two advanced subjects (24 units) that are closely related to the student's doctoral thesis topic. Neither of these subjects may be from the list of three subjects selected to satisfy the field-of-specialization requirement. The advanced subjects should be arranged in consultation with the student's thesis advisor and the student's registration officer, and should have the approval of the registration officer. In addition, students must satisfactorily complete at least 12 units of coursework in an NSE subject outside of their field of specialization to fulfill the breadth requirement, and 12 units of unrestricted electives.

Doctoral research may be undertaken either in the Department of Nuclear Science and Engineering or in a nuclear-related field in another department. Appropriate areas of research are described generally in the introduction to the department, and a detailed list may be obtained from the Department of Nuclear Science and Engineering.

Interdisciplinary Programs

Computational Science and Engineering Doctoral Program

The Doctoral Program in Computational Science and Engineering (CSE PhD) (*https://cse.mit.edu/programs/phd*) allows students to specialize in a computation-related field of their choice through focused coursework and a doctoral thesis through a number of participating host departments. The CSE PhD program is administered jointly by the Center for Computational Science and Engineering (CCSE) and the host departments, with the emphasis of thesis research activities being the development of new computational methods and/or the innovative application of computational techniques to important problems in engineering and science. For more information, see the full program description (*https://catalog.mit.edu/interdisciplinary/graduate-programs/computational-science-engineering*) under Interdisciplinary Graduate Programs.

Leaders for Global Operations

The 24-month Leaders for Global Operations (LGO) (*https://catalog.mit.edu/interdisciplinary/graduate-programs/leaders-global-operations*) program combines graduate degrees in engineering and management for those with previous postgraduate work experience and strong undergraduate degrees in a technical field. During the two-year program, students complete a six-month internship at one of LGO's partner companies, where they conduct research that forms the basis of a dual-degree thesis. Students finish the program with two MIT degrees: an MBA (or SM in management) and an SM from one of eight engineering programs, some of which have optional or required LGO tracks. After graduation, alumni lead strategic initiatives in high-tech, operations, and manufacturing companies.

Technology and Policy

The Master of Science in Technology and Policy is an engineering research degree with a strong focus on the role of technology in policy analysis and formulation. The Technology and Policy Program (TPP) (*http://tpp.mit.edu*) curriculum provides a solid grounding in technology and policy by combining advanced subjects in the student's chosen technical field with courses in economics, politics, quantitative methods, and social science. Many students combine TPP's curriculum with complementary subjects to obtain dual degrees in TPP and either a specialized branch of engineering or an applied social science such as political science or urban studies and planning. See the program description (*https://catalog.mit.edu/schools/mit-schwarzman-college-computing/data-systems-society*) under the Institute for Data, Systems, and Society.

Financial Support

Financial aid for graduate students is available in the form of research and teaching assistantships, department-administered fellowships, and supplemental subsidies from the College Work-Study Program. Assistantships are awarded to students with high quality academic records. The duty of a teaching assistant is to assist a faculty member in the preparation of subject materials and the conduct of classes, while that of a research assistant is to work on a research project under the supervision of one or more faculty members.

Most fellowships are awarded in April for the following academic year. Assistantships are awarded on a semester basis. The assignment of teaching assistants is made before the start of each semester, while research assistants can be assigned at any time. Essentially all students admitted to the doctoral program receive financial aid for the duration of their education.

Application for financial aid should be made to Professor Jacopo Buongiorno, Room 24-206, 617-253-7316.

Inquiries

Additional information on graduate admissions and academic and research programs may be obtained from the department's Academic Office (*cegan@mit.edu*), Room 24-102, 617-253-3814.

Research Facilities

The department's programs are supported by a number of outstanding experimental facilities for advanced research in nuclear science and engineering.

The MIT Research Reactor in the Nuclear Reactor Laboratory operates at a thermal power of 6 MW and is fueled with U-235 in a compact light-water cooled core surrounded by a heavy-water reflector. This reactor provides a wide range of radiation-related research and teaching opportunities for the students and faculty of the department. Major programs, sponsored by industry and government, to study materials performance and degradation under irradiation are currently in place. Details of the laboratory's research programs and facilities are given at Research | MIT Nuclear Reactor Laboratory.

The department's theoretical and experimental research in plasma physics and fusion energy is primarily carried out through the Plasma Science and Fusion Center (PSFC) with faculty leadership in key areas of astrophysical plasma science, magnetic confinement fusion physics, high energy density physics, fusion materials science, and superconducting magnet engineering. The department's faculty, research scientists, and students have access to on-campus midscale experimental facilities at the PSFC to carry out their research, including particle accelerators, neutron generators, linear plasma devices, high energy density physics devices, and magnet fabrication and test facilities, and three large high-bay experimental halls for experiments. A full range of shops (welding, vacuum, electronics, etc) as well as a professional engineering and technical staff support the reseach. In addition, the PSFC theory group has significant computational resources to support departmental research in these areas.

The thermal hydraulics laboratory is equipped with state-of-the-art instrumentation for measurement of fluid thermo-physical properties, fabrication facilities to engineer surfaces at the micro and nano scale, and flow loops for characterizing convective heat transfer and fluid dynamics behavior. A particularly novel facility uses high-speed infrared thermography to study fundamental phenomena of boiling, such as bubble nucleation, growth, and departure from a heated surface over a broad range of operating pressures, flow rates, and heat fluxes.

The study of nuclear materials plays a central role in the department. Research in the Laboratory for Electrochemical Interfaces centers on understanding the response of surface structure and physical chemistry when driven by dynamic environments of chemical reactivity and mechanical stress. This laboratory is equipped with surface science tools including scanning tunneling microscopy and X-ray photoelectron spectroscopy as well as electrochemical and electronic characterization tools. The H. H. Uhlig Corrosion Laboratory investigates the causes of failure in materials, with an emphasis on nuclear materials. The Mesoscale Nuclear Materials group studies reasons for material property changes due to radiation and rapid ways of measuring them. The Cambridge Laboratory of Accelerator Study of Surfaces provides unique capabilities for studying synergistic radiation effects in various environments, including plasma-facing materials, molten salt and liquid metal corrosion, and superconductors at cryogenic temperatures. This lab is also used for ion beam analysis, implantation, and self-ion damage studies.

The Cappellaro lab is located in the Research Laboratory of Electronics and consists of a 1,200 sq-ft-space dedicated to magnetic resonance and spin physics. One laboratory houses a 7 Tesla superconducting magnet with a wide bore and in-house-made probes, equipped with a spectrometer providing RF modulation and detection for the manipulation and detection of nuclear spins. Two other laboratories are dedicated to NV-based research. The laboratories house three state-of-the art confocal photoluminescence setups with all of the necessary microwave electronics, RF electronics, and control hardware for manipulating NV quantum spins and one confocal microscope for imaging only.

The Quantum Measurement Group is located in Building NW13 and boasts a state-of-the-art laboratory facility, complete with advanced crystal growth and quantum materials measurement systems. The laboratory is equipped with a range of crystal growth techniques, including flux and vapor transport growth capabilities, with a specially designed tetra-arc furnace being a particular highlight. The arc generators can produce temperatures up to 3000 degrees Celsius, streamlining single crystal growth and making it especially suitable for synthesizing high-melting-temperature materials. The laboratory's characterization capability features a Physical Property Measurement System (PPMS) with a temperature range of 1.8 Kelvin to 400 Kelvin and an external magnetic field up to 9 Tesla. The PPMS system is equipped to conduct a wide range of measurements, including DC/AC electrical transport, Hall measurement, heat capacity, thermal transport, and thermoelectric measurements, with the additional advantage of angular-resolved capability from the horizontal rotator. The laboratory also features angular-resolved dilatometry and magneto-restriction capabilities, along with a custom-made steup for high-precision nonlinear electrical transport measurements.

In addition to the above facilities, the department has a nuclear instrumentation laboratory and a 14 MeV neutron source and a tunable-energy proton cyclotron source up to 12 MeV. Laboratory space and shop facilities are available for research in all areas of nuclear science and engineering. A state-of-the-art scanning electron microscope with an integrated focused ion beam that can be used to study irradiated specimens is available. The Department of Nuclear Science and Engineering owns high performance computing resources that are part of the Engaging cluster housed at the MGHPCC facility and maintained by the Office of Research Computing and Data, and also leverages other shared campus computing resources for research and education.

Faculty and Teaching Staff

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Neil E. Todreas, PhD
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Professor Emeritus of Mechanical Engineering

Sidney Yip, PhD
Professor Emeritus of Nuclear Science and Engineering
Professor Emeritus of Materials Science and Engineering

Undergraduate Subjects

22.00 Introduction to Modeling and Simulation
Engineering School-Wide Elective Subject.
Offered under: 1.021, 3.021, 10.333, 22.00
Prereq: 18.03 or permission of instructor
U (Spring)
4-0-8 units. REST

See description under subject 3.021.
M. Buehler

22.001 Introduction to Undergraduate Research I (New)
Prereq: None
U (Spring)
1-0-2 units

Provides instruction in communication and basic research skills needed for effective undergraduate research. Addresses a wide range of communication, from within the research group to formal papers and presentations. Basic research skills include time management, building strong relationships with research advisors and lab groups, and cultivating the habit of regular self-reflection. Current participation in a UROP within the Nuclear Science and Engineering Department or Plasma Science and Fusion Center is strongly recommended. Limited to 25. Preference to students accepted into the FUSars program, followed by students UROPing on any nuclear-related project.
M. Short

22.002 Introduction to Undergraduate Research II (New)
Prereq: 22.001
U (Fall)
1-0-2 units

Instruction in formal communications for undergraduate research, particularly preparing journal manuscripts. Students practice self-reflection and motivation skills to enable independent research. Provides foundation to build and maintain professional networks. Current participation in a UROP within the Nuclear Science and Engineering Department or Plasma Science and Fusion Center with one term of prior experience is strongly recommended. Limit to 25. Preference to students accepted into the FUSars program, followed by students UROPing on any nuclear-related project.
M. Short

22.003 NEET Seminar: Renewable Energy Machines
Prereq: Permission of instructor
U (Fall, Spring)
1-0-2 units
Can be repeated for credit.

Seminar for students enrolled in the Renewable Energy Machines NEET thread. Focuses on topics around renewable energy via guest lectures and research discussions.
M. Short

22.01 Introduction to Nuclear Engineering and Ionizing Radiation
Prereq: None
U (Fall)
3-1-8 units. REST

Provides an introduction to fundamental concepts in nuclear science and its engineering applications. Describes basic nuclear structure, radioactivity, nuclear reactions, and kinematics. Covers the interaction of ionizing radiation with matter, emphasizing radiation detection, shielding, and radiation effects on human health and materials. Presents energy systems based on fission and fusion nuclear reactions, as well as industrial and medical applications of nuclear science.
E. Jossou, M. Short

22.011 Nuclear Engineering: Science, Systems, and Society
Prereq: None
U (Spring)
Not offered regularly; consult department
1-0-2 units

Discusses the field of nuclear science and engineering, including technologies essential to combating climate change and ensuring human health and well-being. Introduces and provides beginner-level experience with programming, radiation, detection, nuclear physics, and nuclear engineering. Students work on projects such as building radiation-sensing robots to navigate a maze of radioactive sources using autonomous navigation via machine learning. No previous experience with electronics, building robots, programming, or nuclear science required. Subject can count toward the 6-unit discovery-focused credit limit for first-year students. Limited to 20. Preference to first-year undergraduates.
A. White, M. Short, J. Buongiorno, J. Parsons

22.015 Radiation and Life: Applications of Radiation Sources in Medicine, Research, and Industry
Prereq: None
U (Spring)
3-0-0 units

Introduces students to the basics of ionizing and non-ionizing radiation; radiation safety and protection; and an overview of the variety of health physics applications, especially as it pertains to the medical field and to radioactive materials research in academia. Presents basic physics of ionizing and non-ionizing radiation, known effects of the human body, and the techniques to measure those effects. Common radiation-based medical imaging techniques and therapies discussed. Projects, demonstrations, and experiments introduce students to standard techniques and practices in typical medical and MIT research lab environments where radiation is used. Subject can count toward the 6-unit discovery-focused credit limit for first-year students. Limited to 10. Preference to first-year students.
T. Durak

22.016 Seminar in Fusion and Plasma Physics
Prereq: None
U (Fall)
1-0-0 units

Discusses the challenges and opportunities on the path to fusion energy through a range of plasma and fusion energy topics, including discussion of the global energy picture, basic plasma physics, the physics of fusion, fusion reactors, tokamaks, and inertial confinement facilities. Covers why nuclear science, computer science, and materials are so important for fusion, and how students can take next steps to study fusion while at MIT. Includes tours of laboratories at the Plasma Science and Fusion Center. Subject can count toward the 6-unit discovery-focused credit limit for first-year students. Limited to 20. Preference to first years and sophomores majoring in Course 22.
A. White

22.017 Nuclear in the News
Prereq: None
U (Fall)
Not offered regularly; consult department
1-0-1 units

Covers the state of nuclear energy and technologies in popular media and current events. Topics include: modern-day Chernobyl, advances in fission reactor building, and the corporate use of fusion devices. Discussions guided by student interest and questions. Includes presentations by expert faculty in nuclear science and engineering. Subject can count toward the 6-unit discovery-focused credit limit for first-year students.
B. Forget

22.02 Introduction to Applied Nuclear Physics
Prereq: None
U (Spring)
5-0-7 units. REST

Covers basic concepts of nuclear physics with emphasis on nuclear structure and interactions of radiation with matter. Topics include elementary quantum theory; nuclear forces; shell structure of the nucleus; alpha, beta and gamma radioactive decays; interactions of nuclear radiations (charged particles, gammas, and neutrons) with matter; nuclear reactions; fission and fusion.
M. Li, J. Li

22.022 Quantum Technology and Devices
Subject meets with 8.751[J], 22.51[J]
Prereq: 8.04, 22.02, or permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Spring)
3-0-9 units

Examines the unique features of quantum theory to generate technologies with capabilities beyond any classical device. Introduces fundamental concepts in applied quantum mechanics, tools and applications of quantum technology, with a focus on quantum information processing beyond quantum computation. Includes discussion of quantum devices and experimental platforms drawn from active research in academia and industry. Students taking graduate version complete additional assignments.
P. Cappellaro

22.03[J] Introduction to Design Thinking and Rapid Prototyping
Same subject as 3.0061[J]
Prereq: None
U (Fall)
2-2-2 units

Focuses on design thinking, an iterative process that uses divergent and convergent thinking to approach design problems and prototype and test solutions. Includes experiences in creativity, problem scoping, and rapid prototyping skills. Skills are built over the course of the semester through design exercises and projects. Enrollment limited; preference to Course 22 & Course 3 majors and minors, and NEET students.
M. Short, E. Olivetti

22.033 Nuclear Systems Design Project
Subject meets with 22.33
Prereq: None
U (Fall)
3-0-12 units

Group design project involving integration of nuclear physics, particle transport, control, heat transfer, safety, instrumentation, materials, environmental impact, and economic optimization. Provides opportunity to synthesize knowledge acquired in nuclear and non-nuclear subjects and apply this knowledge to practical problems of current interest in nuclear applications design. Past projects have included using a fusion reactor for transmutation of nuclear waste, design and implementation of an experiment to predict and measure pebble flow in a pebble bed reactor, and development of a mission plan for a manned Mars mission including the conceptual design of a nuclear powered space propulsion system and power plant for the Mars surface, a lunar/Martian nuclear power station and the use of nuclear plants to extract oil from tar sands. Students taking graduate version complete additional assignments.
Z. Hartwig, M. Short

22.039 Integration of Reactor Design, Operations, and Safety
Subject meets with 22.39
Prereq: 22.05 and 22.06
U (Fall)
3-2-7 units

Covers the integration of reactor physics and engineering sciences into nuclear power plant design, focusing on designs projected to be used in the first half of this century. Topics include materials issues in plant design and operations, aspects of thermal design, fuel depletion and fission-product poisoning, and temperature effects on reactivity. Addresses safety considerations in regulations and operations, such as the evolution of the regulatory process, the concept of defense in depth, general design criteria, accident analysis, probabilistic risk assessment, and risk-informed regulations. Students taking graduate version complete additional assignments.
E. Baglietto

22.04[J] Social Problems of Nuclear Energy
Same subject as STS.084[J]
Prereq: None
U (Fall)
3-0-9 units. HASS-S

Surveys the major social challenges for nuclear energy. Topics include the ability of nuclear power to help mitigate climate change; challenges associated with ensuring nuclear safety; the effects of nuclear accidents; the management of nuclear waste; the linkages between nuclear power and nuclear weapons, the consequences of nuclear war; and political challenges to the safe and economic regulation of the nuclear industry. Weekly readings presented from both sides of the debate, followed by in-class discussions. Instruction and practice in oral and written communication provided. Limited to 18.
R. S. Kemp

22.05 Neutron Science and Reactor Physics
Prereq: 18.03, 22.01, and (1.000, 2.086, 6.100B, or 12.010)
U (Fall)
5-0-7 units

Introduces fundamental properties of the neutron. Covers reactions induced by neutrons, nuclear fission, slowing down of neutrons in infinite media, diffusion theory, the few-group approximation, point kinetics, and fission-product poisoning. Emphasizes the nuclear physics bases of reactor design and its relationship to reactor engineering problems.
B. Forget

22.051 Systems Analysis of the Nuclear Fuel Cycle
Subject meets with 22.251
Prereq: 22.05
Acad Year 2024-2025: U (Fall)
Acad Year 2025-2026: Not offered
3-2-7 units

Studies the relationship between technical and policy elements of the nuclear fuel cycle. Topics include uranium supply, enrichment, fuel fabrication, in-core reactivity and fuel management of uranium and other fuel types, used fuel reprocessing, and waste disposal. Presents principles of fuel cycle economics and the applied reactor physics of both contemporary and proposed thermal and fast reactors. Examines nonproliferation aspects, disposal of excess weapons plutonium, and transmutation of long lived radioisotopes in spent fuel. Several state-of-the-art computer programs relevant to reactor core physics and heat transfer are provided for student use in problem sets and term papers. Students taking graduate version complete additional assignments.
K. Shirvan

22.052 Quantum Theory of Materials Characterization
Subject meets with 22.52
Prereq: 8.231 or 22.02
U (Fall)
3-0-9 units

Holistic theoretical foundation of characterization techniques with photons, electrons, and neutron probes in various spaces. Techniques for assessing real space, reciprocal space, energy space, and time space utilizing microscopy, diffraction, spectroscopy, and time-domain methods. Elucidation of microscopic interaction mechanisms of materials. Practical assessment of what each characterization measures, methods for linking experimental features to microscopic materials information, state of the art methods for combining information, and machine learning aids. Students taking graduate version complete additional assignments.
M. Li

22.054[J] Materials Performance in Extreme Environments
Same subject as 3.154[J]
Prereq: 3.013 and 3.044
U (Spring)
Not offered regularly; consult department
3-2-7 units

See description under subject 3.154[J].
Staff

22.055 Radiation Biophysics
Subject meets with 22.55[J], HST.560[J]
Prereq: Permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Fall)
3-0-9 units

Provides a background in sources of radiation with an emphasis on terrestrial and space environments and on industrial production. Discusses experimental approaches to evaluating biological effects resulting from irradiation regimes differing in radiation type, dose and dose-rate. Effects at the molecular, cellular, organism, and population level are examined. Literature is reviewed identifying gaps in our understanding of the health effects of radiation, and responses of regulatory bodies to these gaps is discussed. Students taking graduate version complete additional assignments.
Staff

22.06 Engineering of Nuclear Systems
Prereq: 2.005
U (Spring)
4-0-8 units

Using the basic principles of reactor physics, thermodynamics, fluid flow and heat transfer, students examine the engineering design of nuclear power plants. Emphasizes light-water reactor technology, thermal limits in nuclear fuels, thermal-hydraulic behavior of the coolant, nuclear safety and dynamic response of nuclear power plants.
K. Shirvan

22.061 Fusion Energy
Prereq: 22.01 or permission of instructor
U (Spring)
4-1-7 units

Surveys the fundamental science and engineering required to generate energy from controlled nuclear fusion. Topics include nuclear physics governing fusion fuel choice and fusion reactivity, physical conditions required to achieve net fusion energy, plasma physics of magnetic confinement, overview of fusion energy concepts, material challenges in fusion systems, superconducting magnet engineering, and fusion power conversion to electricity. Includes in-depth visits at the MIT Plasma Science and Fusion Center and active learning laboratories to reinforce lecture topics.
Z. Hartwig

22.071 Analog Electronics and Analog Instrumentation Design
Prereq: 18.03
U (Spring)
Not offered regularly; consult department
3-3-6 units. REST

Presents the basics of analog electronics, covering everything from basic resistors to non-linear devices such as diodes and transistors. Students build amplifiers with op amps and study the behavior of first- and second-order oscillating circuits. Lectures followed by short laboratory exercises reinforce theoretical knowledge with experiments. Includes project in second half of the term in which students design radiation instruments of their choice (e.g. Geiger radiation counters, or other types of sensors and instruments). Teaches use of Arduino microcontrollers as simple data acquisition systems, allowing for real-time data processing and display. Culminates in student presentations of their designs in an open forum. Limited to 20.
A. Danagoulian, M. Short

22.072 Corrosion: The Environmental Degradation of Materials
Subject meets with 22.72
Prereq: Permission of instructor
U (Fall)
Not offered regularly; consult department
3-0-9 units

Applies thermodynamics and kinetics of electrode reactions to aqueous corrosion of metals and alloys. Application of advanced computational and modeling techniques to evaluation of materials selection and susceptibility of metal/alloy systems to environmental degradation in aqueous systems. Discusses materials degradation problems in marine environments, oil and gas production, and energy conversion and generation systems, including fossil and nuclear. Students taking graduate version complete additional assignments.
M. Li

22.074 Radiation Damage and Effects in Nuclear Materials
Subject meets with 3.31[J], 22.74[J]
Prereq: Permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Spring)
3-0-9 units

Studies the origins and effects of radiation damage in structural materials for nuclear applications. Radiation damage topics include formation of point defects, defect diffusion, defect reaction kinetics and accumulation, and differences in defect microstructures due to the type of radiation (ion, proton, neutron). Radiation effects topics include detrimental changes to mechanical properties, phase stability, corrosion properties, and differences in fission and fusion systems. Term project required. Students taking graduate version complete additional assignments.
M. Short, B. Yildiz

22.078[J] Nuclear Energy and the Environment: Waste, Effluents, and Accidents
Same subject as 1.098[J]
Subject meets with 1.878[J], 22.78[J]
Prereq: Permission of instructor
U (Spring)
3-0-9 units

Introduces the essential knowledge for understanding nuclear waste management. Includes material flow sheets for nuclear fuel cycle, waste characteristics, sources of radioactive wastes, compositions, radioactivity and heat generation, chemical processing technologies, geochemistry, waste disposal technologies, environmental regulations and the safety assessment of waste disposal. Covers different types of wastes: uranium mining waste, low-level radioactive waste, high-level radioactive waste and fusion waste. Provides the quantitative methods to compare the environmental impact of different nuclear and other energy-associated waste. Students taking graduate version complete additional assignments.
H. Wainwright

22.081[J] Introduction to Sustainable Energy
Same subject as 2.650[J], 10.291[J]
Subject meets with 1.818[J], 2.65[J], 10.391[J], 11.371[J], 22.811[J]
Prereq: Permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Fall)
3-1-8 units

Assessment of current and potential future energy systems. Covers resources, extraction, conversion, and end-use technologies, with emphasis on meeting 21st-century regional and global energy needs in a sustainable manner. Examines various renewable and conventional energy production technologies, energy end-use practices and alternatives, and consumption practices in different countries. Investigates their attributes within a quantitative analytical framework for evaluation of energy technology system proposals. Emphasizes analysis of energy propositions within an engineering, economic and social context. Students taking graduate version complete additional assignments. Limited to juniors and seniors.
M. W. Golay

22.09 Principles of Nuclear Radiation Measurement and Protection
Subject meets with 22.90
Prereq: 22.01
U (Fall)
1-5-9 units. Institute LAB

Combines lectures, demonstrations, and experiments. Review of radiation protection procedures and regulations; theory and use of alpha, beta, gamma, and neutron detectors; applications in imaging and dosimetry; gamma-ray spectroscopy; design and operation of automated data acquisition experiments using virtual instruments. Meets with graduate subject 22.90, but homework assignments and examinations differ. Instruction and practice in written communication provided.
A. Danagoulian, G. Kohse

22.091, 22.093 Independent Project in Nuclear Science and Engineering
Prereq: Permission of instructor
U (Fall, IAP, Spring, Summer)
Units arranged
Can be repeated for credit.

For undergraduates who wish to conduct a one-term project of theoretical or experimental nature in the field of nuclear engineering, in close cooperation with individual staff members. Topics and hours arranged to fit students' requirements. Projects require prior approval by the Course 22 Undergraduate Office. 22.093 is graded P/D/F.
Consult Undergraduate Officer

22.099 Topics in Nuclear Science and Engineering
Prereq: None
U (Fall, Spring)
Units arranged
Can be repeated for credit.

Provides credit for work on material in nuclear science and engineering outside of regularly scheduled subjects. Intended for study abroad with a student exchange program or an approved one-term or one-year study abroad program. Credit may be used to satisfy specific SB degree requirements. Requires prior approval. Consult department.
Consult Undergraduate Officer

22.S092-22.S094 Special Subject in Nuclear Science and Engineering
Prereq: None
U (Spring)
Units arranged
Can be repeated for credit.

Seminar or lecture on a topic in nuclear science and engineering that is not covered in the regular curriculum.
Consult Undergraduate Officer

22.S095 Special Subject in Nuclear Science and Engineering
Prereq: None
U (Spring)
Units arranged [P/D/F]
Can be repeated for credit.

Seminar or lecture on a topic in nuclear science and engineering that is not covered in the regular curriculum.
Consult Undergraduate Officer

22.S097 Special Subject in Nuclear Science and Engineering
Prereq: None
U (Fall, Spring)
Not offered regularly; consult department
Units arranged [P/D/F]
Can be repeated for credit.

Seminar or lecture on a topic in nuclear science and engineering that is not covered in the regular curriculum.
Consult Undergraduate Officer

22.C01 Modeling with Machine Learning: Nuclear Science and Engineering Applications
Subject meets with 22.C51
Prereq: Calculus II (GIR), 6.100A, and 6.C01
U (Spring)
2-0-4 units

Building on core material in 6.C01, focuses on applying various machine learning techniques to a broad range of topics which are of core value in modern nuclear science and engineering. Relevant topics include machine learning on fusion and plasma diagnosis, reactor physics and nuclear fission, nuclear materials properties, quantum engineering and nuclear materials, and nuclear security. Special components center on the additional machine learning architectures that are most relevant to a certain field, the implementation, and picking up the right problems to solve using a machine learning approach. Final project dedicated to the field-specific applications. Students taking graduate version complete additional assignments. Students cannot receive credit without completion of the core subject 6.C01.
E. Jossou, M. Li

22.C25[J] Real World Computation with Julia
Same subject as 1.C25[J], 6.C25[J], 12.C25[J], 16.C25[J], 18.C25[J]
Prereq: 6.100A, 18.03, and 18.06
U (Fall)
3-0-9 units

See description under subject 18.C25[J].
A. Edelman, R. Ferrari, B. Forget, C. Leiseron,Y. Marzouk, J. Williams

22.C51 Modeling with Machine Learning: Nuclear Science and Engineering Applications
Subject meets with 22.C01
Prereq: Calculus II (GIR), 6.100A, and 6.C51
G (Spring)
2-0-4 units

Building on core material in 6.C51, focuses on applying various machine learning techniques to a broad range of topics which are of core value in modern nuclear science and engineering. Relevant topics include machine learning on fusion and plasma diagnosis, reactor physics and nuclear fission, nuclear materials properties, quantum engineering and nuclear materials, and nuclear security. Special components center on the additional machine learning architectures that are most relevant to a certain field, the implementation, and picking up the right problems to solve using a machine learning approach. Final project dedicated to the field-specific applications. Students taking graduate version complete additional assignments. Students cannot receive credit without completion of the core subject 6.C51.
E. Jossou, M. Li

22.EPE UPOP Engineering Practice Experience
Engineering School-Wide Elective Subject.
Offered under: 1.EPE, 2.EPE, 3.EPE, 6.EPE, 8.EPE, 10.EPE, 15.EPE, 16.EPE, 20.EPE, 22.EPE
Prereq: None
U (Fall, Spring)
0-0-1 units
Can be repeated for credit.

See description under subject 2.EPE. Application required; consult UPOP website for more information.
K. Tan-Tiongco, D. Fordell

22.EPW UPOP Engineering Practice Workshop
Engineering School-Wide Elective Subject.
Offered under: 1.EPW, 2.EPW, 3.EPW, 6.EPW, 10.EPW, 16.EPW, 20.EPW, 22.EPW
Prereq: 2.EPE
U (Fall, IAP, Spring)
1-0-0 units

See description under subject 2.EPW. Enrollment limited to those in the UPOP program.
K. Tan-Tiongco, D. Fordell

22.THT Undergraduate Thesis Tutorial
Prereq: None
U (Fall)
1-0-2 units

A series of lectures on prospectus and thesis writing. Students select a thesis topic and a thesis advisor who reviews and approves the prospectus for thesis work in the spring term.
P. Cappallaro

22.THU Undergraduate Thesis
Prereq: 22.THT
U (Fall, IAP, Spring, Summer)
Units arranged
Can be repeated for credit.

Program of research, leading to the writing of an SB thesis, to be arranged by the student and appropriate MIT faculty member. See department undergraduate headquarters.
Consult Undergraduate Officer

22.UAR[J] Climate and Sustainability Undergraduate Advanced Research
Same subject as 1.UAR[J], 3.UAR[J], 5.UAR[J], 11.UAR[J], 12.UAR[J], 15.UAR[J]
Prereq: Permission of instructor
U (Fall, Spring)
2-0-4 units
Can be repeated for credit.

See description under subject 1.UAR[J]. Application required; consult MCSC website for more information.
D. Plata, E. Olivetti

22.UR Undergraduate Research Opportunities Program
Prereq: None
U (Fall, IAP, Spring, Summer)
Units arranged [P/D/F]
Can be repeated for credit.

The Undergraduate Research Opportunities Program is an excellent way for undergraduate students to become familiar with the Department of Nuclear Engineering. Student research as a UROP project has been conducted in areas of fission reactor studies, utilization of fusion devices, applied radiation research, and biomedical applications. Projects include the study of engineering aspects for both fusion and fission energy sources.
Consult M. Bucci

22.URG Undergraduate Research Opportunities Program
Prereq: None
U (Fall, IAP, Spring, Summer)
Units arranged
Can be repeated for credit.

The Undergraduate Research Opportunities Program is an excellent way for undergraduate students to become familiar with the department of Nuclear Science and Engineering. Student research as a UROP project has been conducted in areas of fission reactor studies, utilization of fusion devices, applied radiation physics research, and biomedical applications. Projects include the study of engineering aspects for fusion and fission energy sources, and utilization of radiations.
Consult M. Bucci

Graduate Subjects

22.101 Applied Nuclear Physics
Prereq: Physics II (GIR) and 18.03
G (Fall)
4-0-8 units

Provides an accelerated introduction to the basic principles of nuclear physics and its application within nuclear science and engineering. Fundamentals of quantum mechanics, nuclear properties, and nuclear structure. Origins of radioactivity and radioactive decay processes. Development of nuclear reaction theory, including cross sections, energetics, and kinematics. The interactions of photons, electrons, neutrons, and ions with matter, including the use of nuclear data and modeling tools. Basic theory of radiation and particle detection, shielding, and dosimetry. Uses of nuclear physics in energy, medicine, security, and science applications.
Z. Hartwig, M. Short

22.102 Applications of Nuclear Science and Engineering (New)
Prereq: None
G (Spring)
1-0-2 units

Provides an overview of the current research directions and application areas in the field of nuclear science and engineering. Faculty from throughout the department each present an introduction to their field of specialization, along with targeted assignments to develop awareness and cross-links between fields.
S. Kemp, M. Short

22.103 Nuclear Technology and Society (New)
Prereq: 22.01 or permission of instructor
G (Fall)
3-0-6 units
Credit cannot also be received for 22.16

Introduces the societal context and challenges for nuclear technology. Major themes include economics and valuation of nuclear power, interactions with government and regulatory frameworks, safety, quantification of radiation hazards, and public attitudes to risk. Covers policies and methods for limiting nuclear-weapons proliferation, including nuclear detection, materials security, and fuel-cycle policy.
R. Kemp

22.11 Applied Nuclear Physics
Prereq: 22.02 or permission of instructor
G (Fall; first half of term)
Not offered regularly; consult department
2-0-4 units
Can be repeated for credit.

Introduction to nuclear structure, reactions, and radioactivity. Review of quantization, the wave function, angular momentum and tunneling. Simplified application to qualitative understanding of nuclear structure. Stable and unstable isotopes, radioactive decay, decay products and chains. Nuclear reactions, cross-sections, and fundamental forces, and the resulting phenomena.
B. Yildiz

22.12 Radiation Interactions, Control, and Measurement
Prereq: 8.02 or permission of instructor
G (Fall; second half of term)
Not offered regularly; consult department
2-0-4 units
Can be repeated for credit.

The interaction, attenuation, and biological effects of penetrating radiation, especially neutrons and photons. Physical processes of radiation scattering and absorption, and their cross-sections. Outline of health physics. Biological effects of radiation, and its quantification. Principles of radiation shielding, detection, dosimetry and radiation protection.
M. Li

22.13 Nuclear Energy Systems
Prereq: 2.005, 22.01, or permission of instructor
G (Spring; first half of term)
Not offered regularly; consult department
2-0-4 units
Can be repeated for credit.

Introduction to generation of energy from nuclear reactions. Characteristics of nuclear energy. Fission cross-sections, criticality, and reaction control. Basic considerations of fission reactor engineering, thermal hydraulics, and safety. Nuclear fuel and waste characteristics. Fusion reactions and the character and conditions of energy generation. Plasma physics and approaches to achieving terrestrial thermonuclear fusion energy.
M. Bucci

22.14 Materials in Nuclear Engineering
Prereq: Chemistry (GIR) or permission of instructor
G (Spring; second half of term)
Not offered regularly; consult department
2-0-4 units
Can be repeated for credit.

Introduces the fundamental phenomena of materials science with special attention to radiation and harsh environments. Materials lattices and defects and the consequent understanding of strength of materials, fatigue, cracking, and corrosion. Coulomb collisions of charged particles; their effects on structured materials; damage and defect production, knock-ons, transmutation, cascades and swelling. Materials in fission and fusion applications: cladding, waste, plasma-facing components, blankets.
J. Li

22.15 Essential Numerical Methods
Prereq: 12.010 or permission of instructor
G (Spring; first half of term)
Not offered regularly; consult department
2-0-4 units
Can be repeated for credit.

Introduces computational methods for solving physical problems in nuclear applications. Ordinary and partial differential equations for particle orbit, and fluid, field, and particle conservation problems; their representation and solution by finite difference numerical approximations. Iterative matrix inversion methods. Stability, convergence, accuracy and statistics. Particle representations of Boltzmann's equation and methods of solution such as Monte-Carlo and particle-in-cell techniques.
N. Louriero, I. Hutchinson, H. Wainwright

22.16 Nuclear Technology and Society
Prereq: 22.01 or permission of instructor
G (Fall)
Not offered regularly; consult department
2-0-4 units
Can be repeated for credit. Credit cannot also be received for 22.103

Introduces the societal context and challenges for nuclear technology. Major themes include economics and valuation of nuclear power, interactions with government and regulatory frameworks, safety, quantification of radiation hazards, and public attitudes to risk. Covers policies and methods for limiting nuclear-weapons proliferation, including nuclear detection, materials security, and fuel-cycle policy.
R. S. Kemp

Nuclear Reactor Physics

22.211 Nuclear Reactor Physics I
Prereq: 22.05
G (Spring)
3-0-9 units

Provides an overview of reactor physics methods for core design and analysis. Topics include nuclear data, neutron slowing down, homogeneous and heterogeneous resonance absorption, calculation of neutron spectra, determination of group constants, nodal diffusion methods, Monte Carlo simulations of reactor core reload design methods.
B. Forget

22.212 Nuclear Reactor Analysis II
Prereq: 22.211
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-2-7 units

Addresses advanced topics in nuclear reactor physics with an additional focus towards computational methods and algorithms for neutron transport. Covers current methods employed in lattice physics calculations, such as resonance models, critical spectrum adjustments, advanced homogenization techniques, fine mesh transport theory models, and depletion solvers. Also presents deterministic transport approximation techniques, such as the method of characteristics, discrete ordinates methods, and response matrix methods.
B. Forget

22.213 Nuclear Reactor Physics III
Prereq: 22.211
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-0-9 units

Covers numerous high-level topics in nuclear reactor analysis methods and builds on the student's background in reactor physics to develop a deep understanding of concepts needed for time-dependent nuclear reactor core physics, including coupled non-linear feedback effects. Introduces numerical algorithms needed to solve real-world time-dependent reactor physics problems in both diffusion and transport. Additional topics include iterative numerical solution methods (e.g., CG, GMRES, JFNK, MG), nonlinear accelerator methods, and numerous modern time-integration techniques.
B. Forget

22.251 Systems Analysis of the Nuclear Fuel Cycle
Subject meets with 22.051
Prereq: 22.05
Acad Year 2024-2025: G (Fall)
Acad Year 2025-2026: Not offered
3-2-7 units

Study of the relationship between the technical and policy elements of the nuclear fuel cycle. Topics include uranium supply, enrichment, fuel fabrication, in-core reactivity and fuel management of uranium and other fuel types, used fuel reprocessing and waste disposal. Principles of fuel cycle economics and the applied reactor physics of both contemporary and proposed thermal and fast reactors are presented. Nonproliferation aspects, disposal of excess weapons plutonium, and transmutation of long lived radioisotopes in spent fuel are examined. Several state-of-the-art computer programs relevant to reactor core physics and heat transfer are provided for student use in problem sets and term papers. Students taking graduate version complete additional assignments.
K. Shirvan

Nuclear Reactor Engineering

22.312 Engineering of Nuclear Reactors
Prereq: (2.001 and 2.005) or permission of instructor
G (Fall)
3-0-9 units

Engineering principles of nuclear reactors, emphasizing power reactors. Power plant thermodynamics, reactor heat generation and removal (single-phase as well as two-phase coolant flow and heat transfer), and structural mechanics. Engineering considerations in reactor design.
J. Buongiorno

22.313[J] Thermal Hydraulics in Power Technology
Same subject as 2.59[J], 10.536[J]
Prereq: 2.006, 10.302, 22.312, or permission of instructor
G (Fall)
3-2-7 units

Emphasis on thermo-fluid dynamic phenomena and analysis methods for conventional and nuclear power stations. Kinematics and dynamics of two-phase flows. Steam separation. Boiling, instabilities, and critical conditions. Single-channel transient analysis. Multiple channels connected at plena. Loop analysis including single and two-phase natural circulation. Subchannel analysis.
E. Baglietto, M. Bucci

22.315 Applied Computational Fluid Dynamics and Heat Transfer
Prereq: Permission of instructor
G (Spring)
3-0-9 units

Focuses on the application of computational fluid dynamics to the analysis of power generation and propulsion systems, and on industrial and chemical processes in general. Discusses simulation methods for single and multiphase applications and their advantages and limitations in industrial situations. Students practice breaking down an industrial problem into its modeling challenges, designing and implementing a plan to optimize and validate the modeling approach, performing the analysis, and quantifying the uncertainty margin.
E. Baglietto

22.33 Nuclear Engineering Design
Subject meets with 22.033
Prereq: 22.312
G (Fall)
3-0-15 units

Group design project involving integration of nuclear physics, particle transport, control, heat transfer, safety, instrumentation, materials, environmental impact, and economic optimization. Provides opportunity to synthesize knowledge acquired in nuclear and non-nuclear subjects and apply this knowledge to practical problems of current interest in nuclear applications design. Past projects have included using a fusion reactor for transmutation of nuclear waste, design and implementation of an experiment to predict and measure pebble flow in a pebble bed reactor, and development of a mission plan for a manned Mars mission including the conceptual design of a nuclear powered space propulsion system and power plant for the Mars surface. Students taking graduate version complete additional assignments.
Z. Hartwig, M. Short

22.38 Probability and Its Applications To Reliability, Quality Control, and Risk Assessment
Prereq: Permission of instructor
Acad Year 2024-2025: G (Spring)
Acad Year 2025-2026: Not offered
3-0-9 units

Interpretations of the concept of probability. Basic probability rules; random variables and distribution functions; functions of random variables. Applications to quality control and the reliability assessment of mechanical/electrical components, as well as simple structures and redundant systems. Elements of statistics. Bayesian methods in engineering. Methods for reliability and risk assessment of complex systems, (event-tree and fault-tree analysis, common-cause failures, human reliability models). Uncertainty propagation in complex systems (Monte Carlo methods, Latin hypercube sampling). Introduction to Markov models. Examples and applications from nuclear and other industries, waste repositories, and mechanical systems. Open to qualified undergraduates.
Staff

22.39 Integration of Reactor Design, Operations, and Safety
Subject meets with 22.039
Prereq: 22.211 and 22.312
G (Fall)
3-2-7 units

Integration of reactor physics and engineering sciences into nuclear power plant design focusing on designs that are projected to be used in the first half of this century. Topics include materials issues in plant design and operations, aspects of thermal design, fuel depletion and fission-product poisoning, and temperature effects on reactivity. Safety considerations in regulations and operations such as the evolution of the regulatory process, the concept of defense in depth, general design criteria, accident analysis, probabilistic risk assessment, and risk-informed regulations. Students taking graduate version complete additional assignments.
E. Baglietto, K. Shirvan

22.40[J] Fundamentals of Advanced Energy Conversion
Same subject as 2.62[J], 10.392[J]
Subject meets with 2.60[J], 10.390[J]
Prereq: 2.006, (2.051 and 2.06), or permission of instructor
G (Spring)
4-0-8 units

See description under subject 2.62[J].
A. F. Ghoniem, W. Green

Radiation Interactions and Applications

22.51[J] Quantum Technology and Devices
Same subject as 8.751[J]
Subject meets with 22.022
Prereq: 22.11
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units

Examines the unique features of quantum theory to generate technologies with capabilities beyond any classical device. Introduces fundamental concepts in applied quantum mechanics, tools and applications of quantum technology, with a focus on quantum information processing beyond quantum computation. Includes discussion of quantum devices and experimental platforms drawn from active research in academia and industry. Students taking graduate version complete additional assignments.
P. Cappellaro

22.52 Quantum Theory of Materials Characterization
Subject meets with 22.052
Prereq: 8.511 or permission of instructor
G (Fall)
3-0-9 units

Holistic theoretical foundation of characterization techniques with photons, electrons, and neutron probes in various spaces. Techniques for assessing real space, reciprocal space, energy space, and time space utilizing microscopy, diffraction, spectroscopy, and time-domain methods. Elucidation of microscopic interaction mechanisms of materials. Practical assessment of what each characterization measures, methods for linking experimental features to microscopic materials information, state of the art methods for combining information, and machine learning aids. Students taking graduate version complete additional assignments.
M. Li

22.54[J] Biomedical Systems: Modeling and Inference
Same subject as 6.4800[J]
Prereq: (6.3100 and (18.06 or 18.C06[J])) or permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Fall)
4-4-4 units

See description under subject 6.4800[J].
E. Adalsteinsson, T. Heldt, C. M. Stultz, J. K. White

22.55[J] Radiation Biophysics
Same subject as HST.560[J]
Subject meets with 22.055
Prereq: Permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-0-9 units

Provides a background in sources of radiation with an emphasis on terrestrial and space environments and on industrial production. Discusses experimental approaches to evaluating biological effects resulting from irradiation regimes differing in radiation type, dose and dose-rate. Effects at the molecular, cellular, organism, and population level are examined. Literature is reviewed identifying gaps in our understanding of the health effects of radiation, and responses of regulatory bodies to these gaps is discussed. Students taking graduate version complete additional assignments.
Staff

22.561[J] Magnetic Resonance Analytic, Biochemical, and Imaging Techniques
Same subject as HST.584[J]
Prereq: Permission of instructor
Acad Year 2024-2025: G (Spring)
Acad Year 2025-2026: Not offered
3-0-12 units

See description under subject HST.584[J].
L. Wald, B. Bilgic

Plasmas and Controlled Fusion

22.611[J] Introduction to Plasma Physics I
Same subject as 8.613[J]
Prereq: (6.2300 or 8.07) and (18.04 or *Coreq: 18.075*)
G (Fall)
3-0-9 units

Introduces plasma phenomena relevant to energy generation by controlled thermonuclear fusion and to astrophysics. Elementary plasma concepts, plasma characterization. Motion of charged particles in magnetic fields. Coulomb collisions, relaxation times, transport processes. Two-fluid hydrodynamic and MHD descriptions. Plasma confinement by magnetic fields, simple equilibrium and stability analysis. Wave propagation in a magnetic field; application to RF plasma heating. Introduction to kinetic theory; Vlasov, Boltzmann and Fokker-Planck equations; relation of fluid and kinetic descriptions. Electron and ion acoustic plasma waves, Landau damping.
N. Loureiro, I. Hutchinson

22.612[J] Introduction to Plasma Physics II
Same subject as 8.614[J]
Prereq: 22.611[J]
Acad Year 2024-2025: G (Spring)
Acad Year 2025-2026: Not offered
3-0-9 units

Follow-up to 22.611[J] provides in-depth coverage of several fundamental topics in plasma physics, selected for their wide relevance and applicability, from fusion to space- and astro-physics. Covers both kinetic and fluid instabilities: two-stream, Weibel, magnetorotational, parametric, ion-temperature-gradient, and pressure-anisotropy-driven instabilities (mirror, firehose). Also covers advanced fluid models, and drift-kinetic and gyrokinetic equations. Special attention to dynamo theory, magnetic reconnection, MHD turbulence, kinetic turbulence, and shocks.
N. Loureiro

22.615 MHD Theory of Fusion Systems
Prereq: 22.611[J]
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units

Discussion of MHD equilibria in cylindrical, toroidal, and noncircular configurations. MHD stability theory including the Energy Principle, interchange instability, ballooning modes, second region of stability, and external kink modes. Description of current configurations of fusion interest.
N. Louriero

22.617 Plasma Turbulence and Transport
Prereq: Permission of instructor
G (Spring)
Not offered regularly; consult department
3-0-9 units

Introduces plasma turbulence and turbulent transport, with a focus on fusion plasmas. Covers theory of mechanisms for turbulence in confined plasmas, fluid and kinetic equations, and linear and nonlinear gyrokinetic equations; transport due to stochastic magnetic fields, magnetohydrodynamic (MHD) turbulence, and drift wave turbulence; and suppression of turbulence, structure formation, intermittency, and stability thresholds. Emphasis on comparing experiment and theory. Discusses experimental techniques, simulations of plasma turbulence, and predictive turbulence-transport models.
Staff

22.62 Fusion Energy
Prereq: 22.611[J]
G (Spring)
3-0-9 units

Basic nuclear physics and plasma physics for controlled fusion. Fusion cross sections and consequent conditions required for ignition and energy production. Principles of magnetic and inertial confinement. Description of magnetic confinement devices: tokamaks, stellarators and RFPs, their design and operation. Elementary plasma stability considerations and the limits imposed. Plasma heating by neutral beams and RF. Outline design of the ITER "burning plasma" experiment and a magnetic confinement reactor.
J. Hare

22.63 Engineering Principles for Fusion Reactors
Prereq: Permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units

Fusion reactor design considerations: ignition devices, engineering test facilities, and safety/environmental concerns. Magnet principles: resistive and superconducting magnets; cryogenic features. Blanket and first wall design: liquid and solid breeders, heat removal, and structural considerations. Heating devices: radio frequency and neutral beam.
D. Whyte, Z. Hartwig

22.64[J] Ionized Gases
Same subject as 16.55[J]
Prereq: 8.02 or permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-0-9 units

See description under subject 16.55[J].
C. Guerra Garcia

22.67[J] Principles of Plasma Diagnostics
Same subject as 8.670[J]
Prereq: 22.611[J]
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
4-4-4 units

Introduction to the physical processes used to measure the properties of plasmas, especially fusion plasmas. Measurements of magnetic and electric fields, particle flux, refractive index, emission and scattering of electromagnetic waves and heavy particles; their use to deduce plasma parameters such as particle density, pressure, temperature, and velocity, and hence the plasma confinement properties. Discussion of practical examples and assessments of the accuracy and reliability of different techniques.
J. Hare, A. White

Nuclear Materials

22.71[J] Modern Physical Metallurgy
Same subject as 3.40[J]
Subject meets with 3.14
Prereq: (3.20 and 3.22) or permission of instructor
G (Fall)
3-0-9 units

See description under subject 3.40[J].
R. Freitas

22.72 Corrosion: The Environmental Degradation of Materials
Subject meets with 22.072
Prereq: None
G (Fall)
Not offered regularly; consult department
3-0-9 units

Applies thermodynamics and kinetics of electrode reactions to aqueous corrosion of metals and alloys. Application of advanced computational and modeling techniques to evaluation of materials selection and susceptibility of metal/alloy systems to environmental degradation in aqueous systems. Discusses materials degradation problems in marine environments, oil and gas production, and energy conversion and generation systems, including fossil and nuclear.
Staff

22.73[J] Defects in Materials
Same subject as 3.33[J]
Prereq: 3.21 and 3.22
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-0-9 units

See description under subject 3.33[J].
J. Li

22.74[J] Radiation Damage and Effects in Nuclear Materials
Same subject as 3.31[J]
Subject meets with 22.074
Prereq: 3.21, 22.14, or permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units

Studies the origins and effects of radiation damage in structural materials for nuclear applications. Radiation damage topics include formation of point defects, defect diffusion, defect reaction kinetics and accumulation, and differences in defect microstructures due to the type of radiation (ion, proton, neutron). Radiation effects topics include detrimental changes to mechanical properties, phase stability, corrosion properties, and differences in fission and fusion systems. Term project required. Students taking graduate version complete additional assignments.
M. Short, B. Yildiz

22.75[J] Properties of Solid Surfaces
Same subject as 3.30[J]
Prereq: 3.20, 3.21, or permission of instructor
G (Spring)
3-0-9 units

Covers fundamental principles needed to understand and measure the microscopic properties of the surfaces of solids, with connections to structure, electronic, chemical, magnetic and mechanical properties. Reviews the theoretical aspects of surface behavior, including stability of surfaces, restructuring, and reconstruction. Examines the interaction of the surfaces with the environment, including absorption of atoms and molecules, chemical reactions and material growth, and interaction of surfaces with other point defects within the solids (space charges in semiconductors). Discusses principles of important tools for the characterization of surfaces, such as surface electron and x-ray diffraction, electron spectroscopies (Auger and x-ray photoelectron spectroscopy), scanning tunneling, and force microscopy.
B. Yildiz

22.76[J] Ionics and Its Applications
Same subject as 3.55[J]
Prereq: None
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-0-9 units

Discusses valence states of ions and how ions and charge move in liquid and solid states. Introduces molten salt systems and how they are used in nuclear energy and processing. Addresses corrosion and the environmental degradation of structural materials. Examines the applications of ionics and electrochemistry in industrial processing, computing, new energy technologies, and recycling and waste treatment.
J. Li, B. Yildiz

22.78[J] Nuclear Energy and the Environment: Waste, Effluents, and Accidents
Same subject as 1.878[J]
Subject meets with 1.098[J], 22.078[J]
Prereq: Permission of instructor
G (Spring)
3-0-9 units

Introduces the essential knowledge for understanding nuclear waste management. Includes material flow sheets for nuclear fuel cycle, waste characteristics, sources of radioactive wastes, compositions, radioactivity and heat generation, chemical processing technologies, geochemistry, waste disposal technologies, environmental regulations and the safety assessment of waste disposal. Covers different types of wastes: uranium mining waste, low-level radioactive waste, high-level radioactive waste and fusion waste. Provides the quantitative methods to compare the environmental impact of different nuclear and other energy-associated waste. Students taking graduate version complete additional assignments.
H. Wainwright

Systems, Policy, and Economics

22.811[J] Sustainable Energy
Same subject as 1.818[J], 2.65[J], 10.391[J], 11.371[J]
Subject meets with 2.650[J], 10.291[J], 22.081[J]
Prereq: Permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-1-8 units

Assessment of current and potential future energy systems. Covers resources, extraction, conversion, and end-use technologies, with emphasis on meeting 21st-century regional and global energy needs in a sustainable manner. Examines various energy technologies in each fuel cycle stage for fossil (oil, gas, synthetic), nuclear (fission and fusion) and renewable (solar, biomass, wind, hydro, and geothermal) energy types, along with storage, transmission, and conservation issues. Emphasizes analysis of energy propositions within an engineering, economic and social context. Students taking graduate version complete additional assignments.
M. W. Golay

22.814[J] Nuclear Weapons and International Security
Same subject as 17.474[J]
Prereq: None
Acad Year 2024-2025: G (Spring)
Acad Year 2025-2026: Not offered
4-0-8 units

Examines the historical, political, and technical contexts for nuclear policy making, including the development of nuclear weapons by states, the evolution of nuclear strategy, the role nuclear weapons play in international politics, the risks posed by nuclear arsenals, and the policies and strategies in place to mitigate those risks. Equal emphasis is given to political and technical considerations affecting national choices. Considers the issues surrounding new non-proliferation strategies, nuclear security, and next steps for arms control.
R. S. Kemp, V. Narang

General

22.90 Nuclear Science and Engineering Laboratory
Subject meets with 22.09
Prereq: Permission of instructor
G (Fall)
1-5-9 units

See description under subject 22.09.
A. Danagoulian, G. Kohse

22.901 Independent Project in Nuclear Science and Engineering
Prereq: Permission of instructor
G (Fall, Spring, Summer)
Units arranged
Can be repeated for credit.

For graduate students who wish to conduct a one-term project of theoretical or experimental nature in the field of nuclear engineering, in close cooperation with individual staff members. Topics and hours arranged to fit students' requirements. Projects require prior approval.
J. Li

22.911 Seminar in Nuclear Science and Engineering
Prereq: None
G (Fall)
2-0-1 units
Can be repeated for credit.

Restricted to graduate students engaged in doctoral thesis research.
C. Forsberg, J. Hare, M. Li

22.912 Seminar in Nuclear Science and Engineering
Prereq: None
G (Spring)
2-0-1 units
Can be repeated for credit.

Restricted to graduate students engaged in doctoral thesis research.
C. Forsberg, J. Hare, M. Li

22.921 Nuclear Power Plant Dynamics and Control
Prereq: None
G (IAP)
Not offered regularly; consult department
1-0-2 units

Introduction to reactor dynamics, including subcritical multiplication, critical operation in absence of thermal feedback effects and effects of xenon, fuel and moderator temperature, etc. Derivation of point kinetics and dynamic period equations. Techniques for reactor control including signal validation, supervisory algorithms, model-based trajectory tracking, and rule-based control. Overview of light-water reactor start-up. Lectures and demonstrations with use of the MIT Research Reactor. Open to undergraduates with permission of instructor.
J. A. Bernard

22.93 Teaching and Technical Communication Experience in Nuclear Science & Engineering
Prereq: Permission of department
G (Fall, Spring, Summer)
Units arranged [P/D/F]
Can be repeated for credit.

For qualified graduate students interested in teaching as a career or other technical communication intensive careers. Classroom, laboratory, or tutorial teaching under the supervision of a faculty member or instructor. Students selected by interview. Credits for this subject may not be used toward master's or engineer's degrees. Enrollment limited by availability of suitable teaching assignments and NSE communication lab capacity.
Consult NSE Academic Office

22.94 Research in Nuclear Science and Engineering
Prereq: None
G (IAP)
Not offered regularly; consult department
Units arranged [P/D/F]
Can be repeated for credit.

For academic research activities in Nuclear Science and Engineering for students who have not completed the NSE doctoral qualifying exam. Hours arranged with and approved by the research advisor. Units may not be used towards advanced degree requirements.
J. Li

22.95 Internship in Nuclear Science and Engineering
Prereq: None
G (IAP, Summer)
0-1-0 units
Can be repeated for credit.

For Nuclear Science and Engineering students participating in research or curriculum-related off-campus experiences. Before enrolling, students must have an offer from a company or organization. Upon completion, the student must submit a final report or presentation to an approved MIT internship experience advisor, usually the student's thesis advisor or a member of the thesis committee. Subject to departmental approval. Consult the NSE Academic Office for details on procedures and restrictions. Limited to students participating in internships consistent with NSE policies relating to research-related employment.
Consult NSE Academic Office

22.S902-22.S905 Special Subject in Nuclear Science and Engineering
Prereq: Permission of instructor
G (Spring)
Units arranged
Can be repeated for credit.

Seminar or lecture on a topic in nuclear science and engineering that is not covered in the regular curriculum. 22.S905 is graded P/D/F.
J. Li

22.THG Graduate Thesis
Prereq: Permission of instructor
G (Fall, IAP, Spring, Summer)
Units arranged
Can be repeated for credit.

Program of research, leading to the writing of an SM, NE, PhD, or ScD thesis; to be arranged by the student and an appropriate MIT faculty member. Consult department graduate office.
J. Li