NUCLEAR SCIENCE AND ENGINEERING (COURSE 22)

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, 3.016, or permission of instructor
U (Spring)
4-0-8 units. REST

See description under subject 3.021.
M. Buehler, R. Gomez-Bombarelli

22.01 Introduction to Nuclear Engineering and Ionizing Radiation
Prereq: None
U (Fall)
4-1-7 units. REST

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

22.011 Seminar in Nuclear Science and Engineering
Prereq: None
U (Fall)
2-0-4 units

Surveys the range of diverse subjects in nuclear science and engineering covered by the department. Topics include quantum computing, energy and power, radiation effects-stem cells and DNA, BNCT, nuclear space applications, fusion, airport security, accelerators, magnetic resonance imaging, non-proliferation, risk assessment, safety, biology and medicine. A demonstration of the MIT Reactor as a research tool is given as well as a tour of the MIT Tokomak fusion machine and accelerators used in research.
A. White

22.012 Seminar in Fusion and Plasma Physics
Prereq: None
U (Spring)
2-0-4 units

Lectures and discussion introducing the range of topics relevant to plasma physics and fusion engineering. Introductory discussion of the economic and ecological motivation for the development of fusion power. Contemporary magnetic confinement schemes, theoretical questions, and engineering considerations are presented by expert guest lecturers. Includes visit to Plasma Science and Fusion Center experimental facilities.
D. Whyte, Z. Hartwig

22.014 Ethics for Engineers
Engineering School-Wide Elective Subject.
Offered under: 1.082, 2.900, 6.904, 10.01, 22.014
Subject meets with 6.9041
Prereq: None
U (Fall, Spring)
2-0-4 units

See description under subject 10.01.
D. Doneson, B. L. Trout

22.02 Introduction to Applied Nuclear Physics
Prereq: Physics II (GIR), Calculus II (GIR); 8.03 or permission of instructor
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
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. Bucci, K. Shirvan

22.044[J] Social Problems of Nuclear Energy
Same subject as STS.084[J]
Prereq: None
U (Spring)
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

22.055 Radiation Biophysics
Subject meets with 22.55[J], HST.560[J]
Prereq: Permission of instructor
Acad Year 2018-2019: U (Spring)
Acad Year 2019-2020: Not offered
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)
3-0-9 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

22.054[J] Materials Performance in Extreme Environments
Same subject as 3.154[J]
Prereq: 3.032, 3.044
Acad Year 2018-2019: Not offered
Acad Year 2019-2020: U (Spring)
3-2-7 units

See description under subject 3.154[J].
R. Ballinger

22.05 Neutron Science and Reactor Physics
Prereq: 18.03, 22.01, 22.06
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
22.071 Electronics, Signals, and Measurement  
Prereq: 18.03  
U (Spring)  
3-3-6 units. REST  
Provides the knowledge necessary for reading schematics and designing, building, analyzing, and testing fundamental analog and digital circuits. Students construct interactive examples and explore the practical uses of electronics in engineering and experimental science, including signals and measurement fundamentals. Uses state-of-the-art hardware and software for data acquisition, analysis, and control. Suitable for students with little or no previous background in electronics. Limited to 20.  
A. White

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  
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)  
2-6-4 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.  
M. Short

22.S092-22.S094 Special Subject in Nuclear Science and Engineering  
Prereq: None  
U (Fall, IAP, Spring, Summer)  
Not offered regularly; consult department  
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.  
M. Short

22.EPE UPOP Engineering Practice Experience  
Engineering School-Wide Elective Subject.  
Offered under: 1.EPE, 2.EPE, 3.EPE, 6.EPE, 10.EPE, 16.EPE, 22.EPE  
Prereq: 2.EPW or permission of instructor  
U (Fall, Spring)  
0-0-1 units  
See description under subject 2.EPE.  
Staff

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: None  
U (Fall, IAP)  
1-0-0 units  
See description under subject 2.EPW. Enrollment limited.  
Staff
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.
N. Louriero

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.
M. Short

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.
M. Short

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.
M. Short

Graduate Subjects

22.11 Applied Nuclear Physics
Prereq: 22.02 or permission of instructor
G (Fall; first half of term)
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)
2-0-4 units
Can be repeated for credit.

A. Danagoulian

22.13 Nuclear Energy Systems
Prereq: 22.01, 2.005, or permission of instructor
G (Spring; second half of term)
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; first half of term)  
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 (Fall; first half of term)  
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*

### 22.16 Nuclear Technology and Society
Prereq: 22.01 or permission of instructor  
G (Spring)  
2-0-4 units  
Can be repeated for credit.

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*

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### 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  
G (Fall)  
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.  
*K. Smith*

#### 22.213 Nuclear Reactor Physics III
Prereq: 22.211  
Acad Year 2018-2019: Not offered  
Acad Year 2019-2020: G (Spring)  
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 nonlinear 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.  
*K. Smith*
22.251 Systems Analysis of the Nuclear Fuel Cycle
Prereq: 22.05
Acad Year 2018-2019: G (Fall)
Acad Year 2019-2020: 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.

C. Forsberg

Nuclear Reactor Engineering

22.312 Engineering of Nuclear Reactors
Prereq: 2.001, 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
Acad Year 2018-2019: Not offered
Acad Year 2019-2020: G (Fall)
3-2-7 units


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.

M. Short, A. White
22.38 Probability and Its Applications To Reliability, Quality Control, and Risk Assessment
Prereq: Permission of instructor
G (Spring)
3-0-9 units
Staff

22.39 Integration of Reactor Design, Operations, and Safety
Prereq: 22.211, 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.
E. Baglietto, K. Shirvan

Same subject as 2.62[J], 10.392[J]
Subject meets with 2.60[J], 10.390[J]
Prereq: 2.006, or 2.051 and 2.06, or permission of instructor
Acad Year 2018-2019: G (Spring)
Acad Year 2019-2020: Not offered
4-0-8 units
See description under subject 2.62[J].
A. F. Ghoniem, W. Green

Radiation Interactions and Applications

22.51 Quantum Theory of Radiation Interactions
Prereq: 22.11
G (Fall)
3-0-9 units
Introduces elements of applied quantum mechanics and statistical physics. Starting from the experimental foundation of quantum mechanics, develops the basic principles of interaction of electromagnetic radiation with matter. Introduces quantum theory of radiation, time-dependent perturbation theory, transition probabilities and cross sections. Applications are to controlling coherent and decoherent dynamics with examples from quantum information processing.
P. Cappellaro

22.55[J] Radiation Biophysics
Same subject as HST.560[J]
Subject meets with 22.055
Prereq: Permission of instructor
Acad Year 2018-2019: G (Spring)
Acad Year 2019-2020: Not offered
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

Same subject as HST.584[J]
Prereq: Permission of instructor
Acad Year 2018-2019: Not offered
Acad Year 2019-2020: G (Spring)
3-0-12 units
See description under subject HST.584[J].
L. Wald, K. Setsompop
Plasmas and Controlled Fusion

22.611[J] Introduction to Plasma Physics I
Same subject as 8.613[J]
Prereq: 6.013 or 8.07; 18.04 or Coreq: 18.075
G (Fall)
3-0-9 units


I. Hutchinson

22.612[J] Introduction to Plasma Physics II
Same subject as 8.614[J]
Prereq: 8.613[J]
G (Spring)
3-0-9 units

See description under subject 8.614[J].

Staff

22.615 MHD Theory of Fusion Systems
Prereq: 22.611[J] or 8.613[J]
Acad Year 2018-2019: G (Spring)
Acad Year 2019-2020: Not offered
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

22.616 Plasma Transport Theory
Prereq: 22.615
Acad Year 2018-2019: G (Fall)
Acad Year 2019-2020: Not offered
3-0-9 units

The Fokker-Planck operator for Coulomb collisions, including the Landau and Rosenbluth potential forms, is derived, expanded to obtain useful limits, and used to define characteristic times. Classical collisional transport in an arbitrary magnetic field is developed first, and then the high (Pfirsch-Schluter), low (banana), and intermediate (plateau) collisionality regimes of tokamak transport are examined with emphasis on the banana regime where bootstrap current is most pronounced. Gyrokinetics and zonal flow is discussed.

Staff

22.617 Plasma Turbulence and Transport
Prereq: 22.616 or permission of instructor
Acad Year 2018-2019: G (Spring)
Acad Year 2019-2020: Not offered
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.

I. Hutchinson
22.63 Engineering Principles for Fusion Reactors
Prereq: Permission of instructor
Acad Year 2018-2019: G (Fall)
Acad Year 2019-2020: Not offered
3-0-9 units
D. Whyte, Z. Hartwig

22.67 Principles of Plasma Diagnostics
Prereq: 8.613[J] or 22.611[J]
Acad Year 2018-2019: Not offered
Acad Year 2019-2020: G (Fall)
3-0-9 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.
A. White

Nuclear Materials

22.71[J] Modern Physical Metallurgy
Same subject as 3.40[J]
Subject meets with 3.14
Prereq: 3.022, 3.032
G (Fall)
3-0-9 units
See description under subject 3.40[J].
C. Tasan

22.72[J] Corrosion: The Environmental Degradation of Materials
Same subject as 3.54[J]
Prereq: 3.012
Acad Year 2018-2019: G (Spring)
Acad Year 2019-2020: Not offered
3-0-9 units
See description under subject 3.54[J].
R. G. Ballinger

22.73[J] Defects in Materials
Same subject as 3.33[J]
Prereq: 3.21, 3.22
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]
Prereq: 22.14, 3.21, or permission of instructors
G (Fall)
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.
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
**22.78 Principles of Nuclear Chemical Engineering and Waste Management**
Prereq: Permission of instructor
Acad Year 2018-2019: Not offered
Acad Year 2019-2020: G (Spring)
3-0-9 units

Introduces scientific and engineering aspects of chemical engineering and waste management applied to reactors and the fuel cycle. Includes chemical behavior in reactors (normal and accident), spent nuclear fuel aging, separation processes in reprocessing (aqueous, pyro, and molten salt), and waste treatment processes. Addresses management of radioactive wastes, including waste forms, classification, fundamental principles, governing equations for radionuclide transport in the environment, performance assessment of geological waste disposal systems, and implications of advanced fuel cycles.
C. Forsberg

**Systems, Policy, and Economics**

**22.812 Managing Nuclear Technology**
Prereq: Permission of instructor
G (Spring)
Not offered regularly; consult department
3-0-9 units

Examines current economic, management, and policy issues concerning nuclear power and its fuel cycle. Introduces methods for analyzing private and public policy alternatives, including techniques in economic and financial analysis. Application to specific problem areas, including nuclear waste management, weapons proliferation, and the economic competitiveness of nuclear power. Other topics include deregulation and restructuring in the electric power industry.
R. K. Lester

**22.813[J] Energy Technology and Policy: From Principles to Practice**
Same subject as 5.00[J], 6.929[J], 10.579[J]
Prereq: None
G (Spring)
Not offered regularly; consult department
3-0-6 units

See description under subject 5.00[J]. Limited to 100.
J. Deutch

Same subject as 17.474[J]
Prereq: None
G (Fall)
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
22.90 Nuclear Science and Engineering Laboratory
Subject meets with 22.09
Prereq: permission of instructor
G (Fall)
2-6-4 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. A. Bernard

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, I. Hutchinson, P. Cappellaro

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, I. Hutchinson, P. Cappellaro

22.921 Nuclear Power Plant Dynamics and Control
Prereq: None
G (IAP)
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 Experience in Nuclear Science & Engineering
Prereq: Permission of department
G (Fall, Spring, Summer)
Units arranged

For qualified graduate students interested in teaching as a career.
Classroom, laboratory, or tutorial teaching under the supervision
of a faculty member. 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.
D. Whyte

22.94 Research in Nuclear Science and Engineering
Prereq: Permission of research supervisor
G (Fall, Spring, Summer)
Units arranged [P/D/F]
Can be repeated for credit.

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

22.902-22.905 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. 22.905 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