Course 22

NUCLEAR 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, 3.016, or permission of instructor
U (Fall)
4-0-8 REST
See description under subject 3.021.
M. Buehler, M. Demkowicz

22.01 Introduction to Nuclear Engineering and Ionizing Radiation
Prereq: None
U (Fall)
5-0-7 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.
D. Whyte

22.011 Seminar in Nuclear Science and Engineering
Prereq: None
U (Fall)
2-0-4
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.
M. S. Kazimi

22.012 Seminar in Fusion and Plasma Physics
Prereq: None
U (Spring)
2-0-1
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. Tour of Plasma Science and Fusion Center experimental facilities.
A. White

22.013 Applications of Radiation Science and Technology in Biomedical Research
Prereq: None
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: U (Fall)
2-0-4
Seminar lectures, led by practicing clinicians and scientists in a case presentation format, on current research topics and specific projects in the biomedical field in which radiation science and radiological engineering play an important role. Emphasis on nuclear imaging techniques such as magnetic resonance and positron emission tomography, and on radiation therapy. Term paper required. Lectures shared with freshman advisor seminar 22.010 Career Options for Biomedical Research.
B. Rosen

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 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.
P. Cappellaro

22.033 Nuclear Systems Design Project
(Subject meets with 22.33)
Prereq: None
U (Fall)
3-0-9
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 bubble 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.
M. Short

22.04 Social Problems of Nuclear Energy
(Same subject as STS.084J)
Prereq: None
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: U (Fall)
3-0-9 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.
R. S. Kemp
22.05 Neutron Science and Reactor Physics
Prereq: 22.02, 18.03
U (Fall)
3-0-7
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.

K. Smith

22.054j Materials Performance in Extreme Environments
(Same subject as 3.154j)
Prereq: 3.032, 3.044
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: U (Spring)
3-2-7
See description under subject 3.154j.
R. Ballinger

22.055 Radiation Biophysics
(Same subject as 22.55j, HST.560j)
Prereq: Permission of instructor
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: U (Spring)
3-0-9
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 (Fall)
3-0-9
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.

M. S. Kazimi, K. Shirvan

22.070 Materials for Nuclear Applications
Prereq: Permission of instructor
U (Spring)
3-0-9
Introductory subject for students who are not specializing in nuclear materials. Applications and selection of materials for use in nuclear applications. Radiation damage, radiation effects, and their effects on performance of materials in fission and fusion environments. Students taking graduate version complete additional assignments. Preference to juniors and seniors.

B. Yildiz

22.071j Electronics, Signals, and Measurement
(Same subject as 6.071j)
Prereq: 18.03
U (Spring)
3-3-6 REST
See description under subject 6.071j.
A. White

22.081j Introduction to Sustainable Energy
(Same subject as 2.650j, 10.291j)
(Same subject as 2.650j, 10.391j, 11.371j, 22.811j, ESD.166j)
Prereq: Permission of instructor
U (Fall)
3-1-8
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
(Same subject as 22.90)
Prereq: 22.02
U (Fall)
2-6-4 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.

R. C. Lanza, G. Kohse, J. Bernard

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.

D. Whyte

22.092–22.094 Special Subject in Nuclear Science and Engineering
Prereq: None
U (Fall, IAP, Spring, Summer)
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.

D. Whyte

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 [P/D/F]
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 [P/D/F]
See description under subject 2.EPW.

Staff
22.THT Undergraduate Thesis Tutorial
Prereq: 22.09
U (Fall)
1-0-2 [P/D/F]
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. 
D. Whyte

22.THU Undergraduate Thesis
Prereq: 22.THT
U (Fall, 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. 
D. Whyte

22.URG 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 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

22.09 Computational Science and Engineering
Prereq: 18.085, 22.00, or permission of instructor
Acad Year 2014–2015: G (Spring)
Acad Year 2015–2016: Not offered
3-0-9 H-LEVEL Grad Credit
Develops practical scientific computing skills with applications in radiation physics, reactor engineering and design, nuclear materials, fusion, etc. Topics include compiling/profiling/time and memory complexities/debugging, solvers of ordinary differential equations and partial differential equations, error versus stability, and pre-and post-processing. Includes a survey of visualization and parallel computing and case studies in quantum mechanics, neutron diffusion and transport, simple CFD, and radiation cascade simulations. Assignments require programming in one or several languages of choice; some MATLAB-free assignments also required.
R. S. Kemp

22.10 Advanced Computational Methods for Nuclear Engineering
Prereq: 18.085, 22.00, or permission of instructor
G (Spring; first half of term)
2-0-4 H-LEVEL Grad Credit
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.
I. Hutchinson

22.11 Applied Nuclear Physics
Prereq: 22.02 or permission of instructor
G (Fall; first half of term)
2-0-4 H-LEVEL Grad Credit
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, 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 H-LEVEL Grad Credit
Can be repeated for credit
D. Whyte

22.13 Nuclear Energy Systems
Prereq: 22.01, 2.005, or permission of instructor
G (Spring; first half of term)
2-0-4 H-LEVEL Grad Credit
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. Short

22.14 Materials in Nuclear Engineering
Prereq: Chemistry (GIR) or permission of instructor
G (Spring; first half of term)
2-0-4 H-LEVEL Grad Credit
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.
M. Short

22.15 Essential Numerical Methods
Prereq: 12.010 or permission of instructor
G (Fall; first half of term)
2-0-4 H-LEVEL Grad Credit
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.
I. Hutchinson

22.16 Nuclear Technology and Society
Prereq: 22.01 or permission of instructor
G (Spring; second half of term)
2-0-4 H-LEVEL Grad Credit
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
### Nuclear Reactor Physics

#### 22.211 Nuclear Reactor Physics I
Prereq: 22.05  
G (Spring)  
3-0-9 H-LEVEL Grad Credit

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 H-LEVEL Grad Credit

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 (New)
Prereq: 22.211  
Acad Year 2014–2015: G (Spring)  
Acad Year 2015–2016: Not offered  
3-0-9 H-LEVEL Grad Credit

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 read-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, B. Forget

#### 22.251 Systems Analysis of the Nuclear Fuel Cycle
Prereq: 22.05  
Acad Year 2014–2015: Not offered  
Acad Year 2015–2016: G (Fall)  
3-2-7 H-LEVEL Grad Credit

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.  
K. Smith

### Nuclear Reactor Engineering

#### 22.312 Engineering of Nuclear Reactors
Prereq: 2.001, 2.005; or permission of instructor  
G (Fall)  
3-0-9 H-LEVEL Grad Credit

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

#### 22.313J Thermal Hydraulics in Power Technology
(Subject meets with 22.033)  
Prereq: 2.006, 10.302, 22.312, or permission of instructor  
Acad Year 2014–2015: Not offered  
Acad Year 2015–2016: G (Spring)  
3-2-7 H-LEVEL Grad Credit

E. Baglietto

#### 22.314J Structural Mechanics in Nuclear Power Technology
(Same subject as 1.56J, 2.084J)  
Prereq: 2.001 or permission of instructor  
Acad Year 2014–2015: G (Spring)  
Acad Year 2015–2016: Not offered  
3-0-9 H-LEVEL Grad Credit

Structural components in nuclear power plant systems, their functional purposes, operating conditions, and mechanical/structural design requirements. Combines mechanics techniques with models of material behavior to determine adequacy of component design. Considerations include mechanical loading, brittle fracture, inelastic behavior, elevated temperatures, neutron irradiation, vibrations and seismic effects.  
M. S. Kazimi, O. Buyukozturk

#### 22.315 Applied Computational Fluid Dynamics and Heat Transfer
Prereq: Permission of instructor  
Acad Year 2014–2015: G (Spring)  
Acad Year 2015–2016: Not offered  
3-0-9 H-LEVEL Grad Credit

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
Prereq: 22.312  
G (Fall)  
3-0-9 H-LEVEL Grad Credit

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.
Radiation Interactions and Applications

22.51 Quantum Theory of Radiation Interactions
Prereq: 22.101, 22.105
G (Fall)
3-0-9 H-LEVEL Grad Credit

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

22.55j Radiation Biophysics
(Same subject as HST.560j)
(Subject meets with 22.055)
Prereq: Permission of instructor
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Spring)
3-0-9 H-LEVEL Grad Credit

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.

A. Jasanoff

22.561J Magnetic Resonance Analytic, Biochemical, and Imaging Techniques
(Same subject as HST.584j)
Prereq: Permission of instructor
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Spring)
3-0-12 H-LEVEL Grad Credit

See description under subject HST.584j.

22.562 Spatial Aspects of Nuclear Magnetic Resonance Spectroscopy
Prereq: 18.03, 8.05
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Fall)
3-0-9 H-LEVEL Grad Credit

Discusses the theory and application of nuclear magnetic resonance spectroscopy to questions of the spatial distribution of spins. Covers NMR imaging, localized spectroscopy, and local geometries as determined by diffusive processes. The theory is discussed in terms of the density operator and reciprocal space (for both imaging and motional studies). Describes applications to rapid imaging, dynamic imaging, microscopy, and localized spectroscopy. Instrumentation and experimental constraints are also described.

L. Wald, K. Setsompop

Plasmas and Controlled Fusion

22.611J Introduction to Plasma Physics I
(Same subject as 6.651J, 6.813J)
Prereq: 6.013, 8.07, or 22.105; 18.04 or Coreq: 18.075
G (Fall)
3-0-9 H-LEVEL Grad Credit


A. White
22.612J Introduction to Plasma Physics II
(Same subject as 6.652J, 8.614J)
Prereq: 6.651J, 8.613J, or 22.611J
G (Spring)
3-0-9 H-LEVEL Grad Credit
See description under subject 8.614J.
Staff

22.615 MHD Theory of Fusion Systems
Prereq: 22.611J, 6.651J, or 8.613J
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Spring)
3-0-9 H-LEVEL Grad Credit
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.
J. P. Freidberg

22.616 Plasma Transport Theory
Prereq: 22.615
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Fall)
3-0-9 H-LEVEL Grad Credit
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 2014–2015: G (Spring)
Acad Year 2015–2016: Not offered
3-0-9 H-LEVEL Grad Credit
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
G (Spring)
3-0-9 H-LEVEL Grad Credit
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 2014–2015: G (Spring)
Acad Year 2015–2016: Not offered
3-0-9 H-LEVEL Grad Credit
D. Whyte

22.67 Principles of Plasma Diagnostics
Prereq: 6.651J, 8.613J, or 22.611J
Acad Year 2014–2015: G (Fall)
Acad Year 2015–2016: Not offered
3-0-9 H-LEVEL Grad Credit
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.
I. Hutchinson

Nuclear Materials

22.71J Modern Physical Metallurgy
(Same subject as 3.40J)
(Subject meets with 3.14)
Prereq: 3.022, 3.032
G (Fall)
3-0-9 H-LEVEL Grad Credit
See description under subject 3.40J.
J. Li

22.72J Corrosion: The Environmental Degradation of Materials
(Same subject as 3.54J)
Prereq: 3.012
Acad Year 2014–2015: G (Spring)
Acad Year 2015–2016: Not offered
3-0-9 H-LEVEL Grad Credit
See description under subject 3.54J.
R. G. Ballinger

22.74 Radiation Damage and Effects in Nuclear Materials (New)
Prereq: 22.14, 3.21, or permission of instructors
G (Fall)
3-0-9 H-LEVEL Grad Credit
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

22.76 Nuclear Chemical Engineering
Prereq: Permission of instructor
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Fall)
3-1-8 H-LEVEL Grad Credit
Staff
22.78 Principles of Nuclear Chemical Engineering and Waste Management
Prereq: Permission of instructor
Acad Year 2014–2015: G (Spring)
Acad Year 2015–2016: Not offered
3-0-9 H-LEVEL Grad Credit
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, 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

22.811J Sustainable Energy
(Same subject as 1.818J, 2.65J, 10.391J, 11.371J, ESD.166J)
(Subject meets with 2.650J, 10.291J, 22.081J)
Prereq: Permission of instructor
G (Fall)
3-1-8 H-LEVEL Grad Credit
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

22.812J Managing Nuclear Technology
(Same subject as ESD.163J)
Prereq: Permission of instructor
Acad Year 2014–2015: G (Fall)
Acad Year 2015–2016: Not offered
3-0-9 H-LEVEL Grad Credit
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

22.814 Nuclear Non-Proliferation
Prereq: None
G (Spring)
4-0-8
Examines the historical development of nuclear weapons, the policies and technical strategies currently in place to secure and control the movement of nuclear materials, and the short- and long-term effects of weapons utilized under different scenarios. Considers issues such as how to restrict the global proliferation of nuclear weapons, whether nuclear energy can be made proliferation-proof and what has changed in the wake of the Cold War, as well as lessons to be learned from past experience. Emphasizes advanced approaches to both production and detection of nuclear materials.
R. C. Lanza

22.90 Nuclear Science and Engineering Laboratory
(Subject meets with 22.09)
Prereq: 22.101
G (Fall)
2-6-4 H-LEVEL Grad Credit
See description under subject 22.09.
R. C. Lanza, G. Kohse, J. Bernard

22.911 Seminar in Nuclear Science and Engineering
Prereq: None
G (Fall)
2-0-1 [P/D/F]
Can be repeated for credit
22.912 Seminar in Nuclear Science and Engineering
Prereq: None
G (Spring)
2-0-1 [P/D/F]
Can be repeated for credit
Restricted to graduate students engaged in doctoral thesis research.
C. Forsberg, D. Whyte

22.921 Nuclear Power Plant Dynamics and Control
Prereq: None
G (IAP)
1-0-2
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. Bernard

22.93 Teaching Experience in Nuclear Science and Engineering
Prereq: Permission of department
G (Fall, Spring, Summer)
Units arranged H-LEVEL Grad Credit
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.
R. K. Lester

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.
M. S. Kazimi

22.5902–22.5905 Special Subject in Nuclear Science and Engineering
Prereq: Permission of instructor
G (Fall, IAP, Spring, Summer)
Units arranged H-LEVEL Grad Credit
Can be repeated for credit
Seminar or lecture on a topic in nuclear science and engineering that is not covered in the regular curriculum. 22.5905 is graded P/D/F.
M. S. Kazimi
Bachelor of Science in Nuclear Science and Engineering/Course 22

General Institute Requirements (GIRs)  
Subjects | Subjects  
---|---  
Science Requirement 6  
Humanities, Arts, and Social Sciences Requirement [can be satisfied by 22.04J in the Departmental Program] 8  
Restricted Electives in Science and Technology (REST) Requirement [can be satisfied from among 8.03; 18.03 or 18.034; 22.01; 22.02; and 22.071J, in the Departmental Program] 2  
Laboratory Requirement [can be satisfied by 22.09 in the Departmental Program] 1  
Total GIR Subjects Required for SB Degree 17

Communication Requirement  
The program includes a Communication Requirement of 4 subjects:  
2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and  
2 subjects designated as Communication Intensive in the major (CI-M).

PLUS Departmental Program  
Subject names below are followed by credit units, and by prerequisites, if any (corequisites in italics)  
Units | Units  
---|---  
Basic Requirements 84  
2.005 Thermal-Fluids Engineering I, 12; REST, Calculus II (GIR), Calculus II (GIR), 8.03  
6.0001 Introduction to Computer Science Programming in Python, 6  
6.0002 Introduction to Computational Thinking and Data Science, 6; 6.0001*(i) or 12.010 Computational Methods of Scientific Programming, 12; Calculus II (GIR), Physics I (GIR) 8.03  
Physics III, 12; REST, Physics II (GIR), Calculus II (GIR) 18.03  
Differential Equations, 12; REST, Calculus II (GIR) 18.06  
Linear Algebra, 12; REST, Calculus II (GIR) 22.01 Introduction to Nuclear Engineering and Ionizing Radiation, 12; REST 22.071J Electronics, Signals, and Measurement, 12; REST, 18.03

Required Nuclear Science and Engineering Core Subjects 72  
22.02 Introduction to Applied Nuclear Physics, 12; REST, Calculus II (GIR), Calculus II (GIR), 8.03*  
22.03 Nuclear Systems Design Project, 12  
22.05 Neutron Science and Reactor Physics, 12; 18.03, 22.02  
22.09 Principles of Nuclear Radiation Measurement and Protection, 12, LAB, CI-M; 22.02

Choose two of the following:  
22.04J Social Problems of Nuclear Energy, 12; HASS-S, CI-M 22.055 Radiation Biophysics, 12; permission of instructor 22.06 Engineering of Nuclear Systems, 12; 2.005 22.070 Materials for Nuclear Applications, 12; permission of instructor

Required Undergraduate Nuclear Science and Engineering Thesis 12  
22.THGT Undergraduate Thesis Tutorial (minimum of 3 units); 22.09  
22.THGU Undergraduate Thesis (minimum of 9 units), CI-M; 22.THGT

Departmental Program Units That Also Satisfy the GIRs (48)  
Unrestricted Electives 60

Total Units Beyond the GIRs Required for SB Degree 180

No subject can be counted both as part of the 17-subject GIRs and as part of the 192 units required beyond the GIRs. Every subject in the student’s departmental program will count toward one or the other, but not both.

Notes
*(i) Alternate prerequisites and corequisites are listed in the subject description.  
(1) The combination of 6.0001 and 6.0002 counts as a REST subject.  
For an explanation of credit units, or hours, please refer to the online help in the MIT Subject Listing & Schedule, http://student.mit.edu/catalog/index.cgi.