Nuclear Engineering

Degrees Offered

- Master of Engineering (Nuclear Engineering)
- Master of Science (Nuclear Engineering)
- Doctor of Philosophy (Nuclear Engineering)

Program Description

The Nuclear Science and Engineering program at Colorado School of Mines is interdisciplinary in nature and draws contributions from departments across the university. While delivering a traditional Nuclear Engineering course core, the School of Mines program in Nuclear Science and Engineering emphasizes the nuclear fuel life cycle. Faculty bring to the program expertise in all aspects of the nuclear fuel life cycle: fuel exploration and processing, nuclear power systems production, design and operation, fuel recycling, storage and waste remediation, radiation detection, and radiation damage as well as the policy issues surrounding each of these activities. Related research is conducted through the Nuclear Science and Engineering Center.

Students in all three Nuclear Engineering degrees are exposed to a broad systems overview of the complete nuclear fuel cycle as well as obtaining detailed expertise in a particular component of the cycle. Breadth is assured by requiring all students to complete a rigorous set of core courses. The core consists of a 13-credit hour course sequence. The remainder of the course and research work is obtained from the multiple participating departments, as approved for each student by the student's advisor and the student's thesis committee (as appropriate).

The Master of Engineering degree is a non-thesis graduate degree intended to supplement the student's undergraduate degree by providing the core knowledge needed to prepare the student to pursue a career in the nuclear energy field. The master of science and doctor of philosophy degrees are thesis-based degrees that emphasize research.

In addition, students majoring in allied fields may complete a minor degree through the Nuclear Science and Engineering Program, consisting of 12 credit hours of coursework (9 credit hours for master's students). The Nuclear Science and Engineering Minor programs are designed to allow students in allied fields to acquire and then indicate, in a formal way, specialization in a nuclear-related area of expertise.

Program Requirements

The Nuclear Science and Engineering Program offers programs of study leading to three graduate degrees:

Master of Engineering (ME)

Core courses	13.0
Elective core courses	12.0
Additional elective courses	3.0
Nuclear Science and Engineering Seminar	2.0
Total Semester Hrs	**30.0**

Master of Science (MS)

Core courses	13.0
Elective core courses	6.0
Nuclear Science and Engineering Seminar	2.0
Graduate research (minimum)	6.0
Graduate research or elective courses	3.0
Total Semester Hrs	**30.0**

MS students must complete and defend a research thesis in accordance with this Graduate catalog and the Nuclear Science and Engineering Thesis Procedures. The student must complete the preparation and defense of a thesis proposal as described by the Nuclear Science and Engineering Proposal Procedures at least one semester before the student defends his or her MS thesis.

Doctor of Philosophy (PhD)

Core courses	13.0
Elective core courses	12.0
Additional elective courses	3.0
Nuclear Science and Engineering Seminar	4.0
Graduate research (minimum)	24.0
Graduate research or elective courses	16.0
Total Semester Hrs	**72.0**

PhD students must successfully complete the program's quality control process.

The PhD quality control process includes the following:

- Prior to admission to candidacy, the student must complete all of the Nuclear Engineering required core and elective core classes.
- Prior to admission to candidacy, the student must pass a qualifying examination in accordance with the Nuclear Science and Engineering Qualifying Exam Procedures.
- A PhD thesis proposal must be presented to, and accepted by, the student's thesis committee in accordance with the Nuclear Science and Engineering Proposal Procedures.
- The student must complete and defend a PhD thesis in accordance with this Graduate catalog and the Nuclear Science and Engineering Thesis Procedures.

Thesis Committee Requirements

The student's thesis committee must meet the general requirements listed in the Graduate Bulletin section on Graduate Degrees and Requirements. In addition, the student's advisor or co-advisor must be an active faculty member of Mines Nuclear Science and Engineering Program. For MS students, at least two, and for PhD students, at least three, committee members must be faculty members of the Nuclear Science and Engineering Program and must come from at least two different departments. At least one member of the PhD committee must be a faculty member from outside the Nuclear Science and Engineering Program.

Required Curriculum

In order to be admitted to the Nuclear Science and Engineering Graduate Degree Program, students must meet the following minimum requirements:

- Baccalaureate degree in a science or engineering discipline from an accredited program
- Mathematics coursework up to and including differential equations

- Coursework in thermodynamics
- ENGY475 (or equivalent).

Students who do not meet these minimum requirements may be admitted with specified coursework to be completed in the first semesters of the graduate program. These introductory courses will be selected in consultation with the student's graduate advisor.

All degree offerings within the Nuclear Science and Engineering program are based on a set of required and elective core courses. The required core classes are:

NUGN510	INTRODUCTION TO NUCLEAR REACTOR PHYSICS	3.0
NUGN520	INTRODUCTION TO NUCLEAR REACTOR THERMAL-HYDRAULICS	3.0
NUGN580	NUCLEAR REACTOR LABORATORY (taught in collaboration with the USGS)	3.0
NUGN585 & NUGN586	NUCLEAR REACTOR DESIGN I and NUCLEAR REACTOR DESIGN II	4.0
Total Semester Hrs		**13.0**

Additionally, students pursuing a Nuclear Engineering graduate degree must take a certain number of courses from the elective core (four for a ME or PhD, two for an MS). The core electives consist of the following:

MTGN593	NUCLEAR MATERIALS SCIENCE AND ENGINEERING	3.0
PHGN504	RADIATION DETECTION AND MEASUREMENT	3.0
CHGN511	APPLIED RADIOCHEMISTRY	3.0
MEGN592	RISK AND RELIABILITY ENGINEERING ANALYSIS AND DESIGN	3.0
NUGN506	NUCLEAR FUEL CYCLE	3.0
NUGN590	COMPUTATIONAL REACTOR PHYSICS	3.0
PHGN598	SPECIAL TOPICS	0-6

Additionally, a 500-level Nuclear Physics class counts toward the credits required to fulfill core elective requirements. This is optional for Master's degrees but required for a PhD degree.

Students will select additional coursework in consultation with their graduate advisor and their thesis committee (where applicable). Through these additional courses, students gain breadth and depth in their knowledge the Nuclear Engineering industry.

Students seeking MS and PhD degrees are required to complete the minimum research credit requirements ultimately leading to the completion and defense of a thesis. Research is conducted under the direction of a member of Mines Nuclear Science and Engineering faculty and could be tied to a research opportunity provided by industry partners.

Graduate Seminar

Full-time graduate students in the Nuclear Science and Engineering Program are expected to maintain continuous enrollment in Nuclear Science and Engineering Seminar. Students who are concurrently enrolled in a different degree program that also requires seminar attendance may have this requirement waived at the discretion of the program director.

Mines' Combined Undergraduate/Graduate Degree Program

Students enrolled in Mines’ combined undergraduate/graduate program may double count up to 6 credits of graduate coursework to fulfill requirements of both their undergraduate and graduate degree programs. These courses must have been passed with B- or better, not be substitutes for required coursework, and meet all other university, department, and program requirements for graduate credit.

Students are advised to consult with their undergraduate and graduate advisors for appropriate courses to double count upon admission to the combined program.

Minor Degree Programs

Students majoring in allied fields may choose to complete minor degree programs through the Nuclear Science and Engineering Program indicating specialization in a nuclear-related area of expertise. Minor programs require completion of 9 credits of approved coursework (masters degree), or 12 credits of approved coursework (PhD). Existing minors and their requirements are as follows, with the first three courses listed being required for a masters degree, and the last being an additional requirement for a PhD degree:

Nuclear Engineering

NUGN510	INTRODUCTION TO NUCLEAR REACTOR PHYSICS	3.0
NUGN520	INTRODUCTION TO NUCLEAR REACTOR THERMAL-HYDRAULICS	3.0
NUGN580	NUCLEAR REACTOR LABORATORY	3.0
MTGN598	SPECIAL TOPICS IN METALLURGICAL AND MATERIALS ENGINEERING (Nuclear Materials Politics and Public Policy)	3.0
Total Semester Hrs		**12.0**

Nuclear Materials Processing

NUGN510	INTRODUCTION TO NUCLEAR REACTOR PHYSICS	3.0
MTGN593	NUCLEAR MATERIALS SCIENCE AND ENGINEERING	3.0
NUGN506	NUCLEAR FUEL CYCLE	3.0
CHGN511 or MTGN598	APPLIED RADIOCHEMISTRY SPECIAL TOPICS IN METALLURGICAL AND MATERIALS ENGINEERING	3.0
Total Semester Hrs		**12.0**

Nuclear Detection

NUGN510	INTRODUCTION TO NUCLEAR REACTOR PHYSICS	3.0
PHGN504	RADIATION DETECTION AND MEASUREMENT	3.0
NUGN580	NUCLEAR REACTOR LABORATORY	3.0
PHGN598	SPECIAL TOPICS	6.0
Total Semester Hrs		**15.0**

Courses

NUGN505. NUCLEAR SCIENCE AND ENGINEERING SEMINAR. 1.0 Semester Hr.
(I, II) The Nuclear Science and Engineering Seminar provides a forum for Nuclear Engineering graduate students to present their research projects, participate in seminars given by Nuclear Science and Engineering professionals, and develop an enhanced understanding of the breadth of the nuclear engineering discipline. Prerequsite: gradaute standing. 1 hour seminar; 1 semester hour. Repeatable; maximum 2 hours granted towards M.S./M.E. Degree Requirements and 4 hours maximum granted towards Ph.D. Requirements.

NUGN506. NUCLEAR FUEL CYCLE. 3.0 Semester Hrs.
(I) An introduction to nuclear energy emphasizing the science, engineering, and policies underlying the systems and processes involved in energy production by nuclear fission. Students will acquire a broad understanding of nuclear energy systems framed in the context of the fuel used to power nuclear reactors. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- Use Segré chart to determine properties of various nuclides
- Describe the components of various nuclear fuel cycles and their interrelation
- Determine the cost of nuclear fuel under a variety of economic and technical conditions
- Distinguish between various fissile nuclides and their importance as reactor fuel or nuclear explosives
- Perform and apply basic power reactor calculations such as isotope production rates, average flux, reactor power, capacity factor, fuel burnup, efficiency of multibatch cores.
- . Recount the basic chemical and engineering considerations in the milling of uranium bearing ores and the reprocessing of used nuclear fuel
- Describe major regulations affecting nuclear waste disposal in the US and their impact on disposal strategies
- Describe the major features of a waste repository and consider how they intersect with the requirements imposed by the composition of used nuclear fuel.

NUGN510. INTRODUCTION TO NUCLEAR REACTOR PHYSICS. 3.0 Semester Hrs.
Bridges the gap between courses in fundamental nuclear physics and the neutronic design and analysis of nuclear reactors. Review of neutron energetics and reactions; nuclear cross sections; neutron induced fission; neutron life cycle, multiplication, and criticality; nuclear reactor kinetics and control; the diffusion approximation for neutron transport; simple reactor geometries and compositions; modeling and simulation of reactors. Prerequisite: ENGY475, MEGN475 or equivalent.

NUGN520. INTRODUCTION TO NUCLEAR REACTOR THERMAL-HYDRAULICS. 3.0 Semester Hrs.
Bridges the gap between fundamental courses in thermodynamics, fluid flow, and heat transer and the thermal-hydraulic design and analysis of nuclear reactors. Provides a comprehensive introduction to the thermal-hydraulics of each of the major classes of nuclear reactors. Introduces the major thermal-hydraulic computational tools, passively safe reactor design, thermal-hydraulic transient analysis, and severe nuclear reactor accident analysis. Prerequisite: ENGY475, MEGN475 or equivalent.

NUGN535. INTRODUCTION TO HEALTH PHYSICS. 3.0 Semester Hrs.
(I) Health physics evaluates effects of ionizing radiation on biological systems for the safe use of radiation and control of potential health hazards. The core concept is dosimetry, which relates the radiation absorbed externally and internally to a quantitative estimate of health effects. Other areas in health physics such as protection standards, regulations, and radiation diagnosis and therapy are all constructed on dosimetric methods.

NUGN570. MATHEMATICAL METHODS IN NUCLEAR SCIENCE AND ENGINEERING. 1.0 Semester Hr.
This is a 1 credit course in the applied mathematics of nuclear engineering. Students will be instructed in how to solve systems of coupled ODEs and PDEs describing neutron transport and burnup. Students will also learn how to use adjoint perturbation theory to investigate stability in nuclear reactors, and how to use Python to formulate numerical solutions to neutron transport and burnup equations. Examples will be drawn specifically from nuclear reactor physics and nuclear thermal hydraulics.
Course Learning Outcomes

- Use matrix exponentials and Laplace transforms to solve linear modified burnup equations
- Identify linear PDEs and ODEs that come up in modeling nuclear reactors
- Use Python for numerical solutions of the neutron diffusion equation
- Use Python for the coupled solution of neutron diffusion and burnup equations in a 1-D reactor
- Understand the derivation of the modified Bateman equations used to model burnup in a nuclear reactor
- Solve the time dependent neutron diffusion equation in 1-3 dimensions
- Use perturbation theory to understand stability in the non-linear neutron diffusion equation
- Define and solve adjoint equations

NUGN580. NUCLEAR REACTOR LABORATORY. 3.0 Semester Hrs.
Provides hands-on experience with a number of nuclear reactor operations topics. Reactor power calibration; gamma spectroscopy; neutron activation analysis; reactor flux and power profiles; reactor criticality; control rod worth; xenon transients and burnout; reactor pulsing. Taught at the USGS TRIGA reactor. Prerequisite: NUGN510. 3 hours laboratory; 3 semester hours.

NUGN585. NUCLEAR REACTOR DESIGN I. 2.0 Semester Hrs.
Provides a basic understanding of the nuclear reactor design process, including: key features of nuclear reactors; nuclear reactor design principles; identification of design drivers; neutronic and thermal-hydraulic design of nuclear reactors; reactor safety considerations; relevant nuclear engineering computer codes. Prerequisite: NUGN510, NUGN520.

NUGN586. NUCLEAR REACTOR DESIGN II. 2.0 Semester Hrs.
Builds on the design experience obtained in NUGN586 to provide an in-depth understanding of the nuclear reactor design process. Prerequisites: NUGN585 (taken in the same academic year). 2 hours lecture; 2 semester hours.

NUGN590. COMPUTATIONAL REACTOR PHYSICS. 3.0 Semester Hrs.
(I) This course will provide an introduction to computational nuclear reactor physics. Students will understand the physics driving neutron cross sections and how they determined, and how neutron transport calculations are completed using Monte Carlo and finite difference methods. Students will learn how to write modular code using professional software engineering practices, and will have an introduction

to the Serpent and MCNP family of transport codes. 3 hours lecture; 3 semester hours.

Course Learning Outcomes

- Students should understand the physics driving reactor operation and implement this understanding to address nuclear engineering challenges.

NUGN598. SPECIAL TOPICS. 6.0 Semester Hrs.

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

NUGN599. INDEPENDENT STUDY IN NUCLEAR ENGINEERING. 0.5-6 Semester Hr.

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

NUGN698. SPECIAL TOPICS. 6.0 Semester Hrs.

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

NUGN699. INDEPENDENT STUDY IN NUCLEAR ENGINEERING. 0.5-6 Semester Hr.

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

NUGN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.

(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

Program Director

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