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 the 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 course work (9 credit hours for Masters 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)

<table>
<thead>
<tr>
<th>Course</th>
<th>Hrs</th>
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<tbody>
<tr>
<td>Core courses</td>
<td>13.0</td>
</tr>
<tr>
<td>Elective core courses</td>
<td>12.0</td>
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<tr>
<td>Additional elective courses</td>
<td>3.0</td>
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<tr>
<td>Nuclear Science and Engineering Seminar</td>
<td>2.0</td>
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<tr>
<td><strong>Total Semester Hrs</strong></td>
<td><strong>30.0</strong></td>
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Master of Science (MS)

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<tr>
<th>Course</th>
<th>Hrs</th>
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<tbody>
<tr>
<td>Core courses</td>
<td>13.0</td>
</tr>
<tr>
<td>Elective core courses</td>
<td>6.0</td>
</tr>
<tr>
<td>Nuclear Science and Engineering Seminar</td>
<td>2.0</td>
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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)

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<tr>
<th>Course</th>
<th>Hrs</th>
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<tbody>
<tr>
<td>Core courses</td>
<td>13.0</td>
</tr>
<tr>
<td>Elective core courses</td>
<td>12.0</td>
</tr>
<tr>
<td>Additional elective courses</td>
<td>3.0</td>
</tr>
<tr>
<td>Nuclear Science and Engineering Seminar</td>
<td>4.0</td>
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<tr>
<td>Graduate research (minimum)</td>
<td>24.0</td>
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<tr>
<td>Graduate research or elective courses</td>
<td>16.0</td>
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<tr>
<td><strong>Total Semester Hrs</strong></td>
<td><strong>72.0</strong></td>
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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; and
- 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 a MS). The core electives consist of the following:

- **MTGN593** NUCLEAR MATERIALS SCIENCE AND ENGINEERING 3.0
- **PHGN504** RADIATION DETECTION AND MEASUREMENT 3.0
- **CHGN511** RISK AND RELIABILITY ENGINEERING ANALYSIS AND DESIGN 3.0
- **NUGN506** NUCLEAR FUEL CYCLE 3.0
- **NUGN590** COMPUTATIONAL REACTOR PHYSICS 3.0
- **PHGN422** NUCLEAR PHYSICS 3.0
- **Total Semester Hrs** 13.0

Additionally, a 400- or 500-level Nuclear Physics class counts towards the credits required to fulfill core elective requirements. This is optional for Masters 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 of 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.

### Nuclear Engineering Combined Degree Program Option

Students enrolled in Mines’ combined undergraduate/graduate program may double count up to six 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 (Ph.D). 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 Ph.D 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** APPLIED RADIOCHEMISTRY 3.0
  or **MTGN598** SPECIAL TOPICS IN METALLURGICAL AND MATERIALS ENGINEERING 3.0
- **Total Semester Hrs** 12.0

#### Nuclear Detection

- **PHGN422** NUCLEAR PHYSICS 3.0
- **NUGN510** INTRODUCTION TO NUCLEAR REACTOR PHYSICS 3.0
- **PHGN504** RADIATION DETECTION AND MEASUREMENT 3.0
- **NUGN580** NUCLEAR REACTOR LABORATORY 3.0
- **Total Semester Hrs** 12.0
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. Prerequisite: graduate 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.

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 transfer 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.
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
Mark Jensen, Jerry and Tina Grandey University Chair in Nuclear Science and Engineering, Department of Chemistry

Department of Chemistry
Mark Jensen, Professor and Jerry and Tina Grandey University Chair in Nuclear Science and Engineering

Thomas Albrecht-Schönzart, Distinguished University Professor, Nuclear Science and Engineering Center Director

Jenifer Shafer, Professor

Department of Economics and Business
Roderick Eggert, Professor

Department of Mechanical Engineering
Mark Deinert, Associate Professor

Andrew Osborne, Assistant Professor

Department of Metallurgical and Materials Engineering
Kip Findley, Professor

Jeffrey King, Professor

Ivar Reimanis, Professor, Department Head and Herman F. Coors Distinguished Professor of Ceramic Engineering

Haitao Dong, Radiation Safety Officer

Department of Physics
Uwe Greife, Professor

Kyle Leach, Associate Professor

Frederic Sarazin, Professor