Physics, Nuclear and Electrical Engineering

Physics
Program Director and Professor: Shropshire
Professors: Dale, Forest, Shropshire
Research Professor: Spielman
Associate Professors: Forest, Tatar
Associate Professors: McNulty, Tatar
Assistant Professor: Stonaha
Assistant Lecturer: Bernabei
Adjunct Faculty: Franckowiak, Hoskins, Millward
Affiliate Faculty: Khandaker, Wells
Professors Emeritus: Cole, Harmon, Parker

General Objectives of Graduate Programs
The objectives of our graduate degrees, which are the Doctor of Philosophy in Applied Physics and Master of Science in Physics, are to develop a core competence in the fundamental physical science that is appropriate for the level of the degree, to develop more generalized skills of quantitative reasoning that are applicable to any discipline, and to understand the nature and influence of physics in particular, and science in general, upon our society. Additional objectives for these students include the development of (1) broad, fundamental technical skills and knowledge, (2) strong communication skills, and (3) the capability to think critically and work independently. The expectations for each of these objectives have a “level” that is appropriate for the degree.

The learning objectives of the master's degree in physics are mastery of the “core” subjects of electromagnetism, non-relativistic quantum mechanics, and theoretical methods of classical physics (principally mechanics).

The communication objectives for these degrees are writing and speaking skills that are sufficient for students to represent themselves, their projects, and their organizations at regional, national, or international scientific meetings. Our expectations are that these students will obtain critical thinking skills and an ability to work independently at a level that will require minimal or no supervision by a more senior scientist or management.

The educational objectives of the doctoral degree in applied physics include all of those of the master's degree program, plus mastery of additional graduate-level classes of the student’s choosing, plus completion of an original doctoral research thesis project with the objective of mastery of planning, executing, and publishing original research in physics at the highest level of the discipline. The communication objectives at this level are writing and speaking skills that are sufficient to teach in higher education, attract interest and funding to their projects, and to represent themselves, their projects and their organizations at regional, national, or international scientific meetings. Our expectations are that these students will develop critical thinking skills and an ability to work independently such that they are capable of initiating and leading their own scientific projects, and can work at a level that requires no supervision.

Nuclear Engineering and Health Physics
Program Director and Professor: Pope
Professors: Brey, Imel, Jacobsen, Kunze
Associate Professors: Burgett, Dunzik-Gougar

Certificate Program in Applied Nuclear Energy
This program provides bachelor's degree graduates who do not have recent experience or education in the nuclear energy field with historical insights, information on basic concepts, regulatory requirements, and economic and environmental considerations. This program is not intended to lead to a master's or doctoral program in the areas of Nuclear Science and Engineering. The Certificate is granted upon completion of fourteen (14) credit hours of class work, consisting of nine credit hours of required courses, a three-credit elective course and participation in two semesters of a one-credit graduate seminar. Up to six credits of appropriate graduate course work taken at another university may be applied toward the certificate program subject to approval by the student’s certificate committee. With appropriate pre-planning, some of these credits could be applied to a master’s degree.

Master of Science in Nuclear Science and Engineering
The master’s degree program in Nuclear Science and Engineering prepares the student for advanced placement in the nuclear industry in commercial, research, or development areas. It provides in-depth studies and advanced design concepts in several areas of modern nuclear science and engineering. It is also an excellent program of study for entering the doctoral program in Nuclear Science and Engineering.

Goals
• Enhance the knowledge of graduates in the physics and engineering of nuclear reactors, the nuclear fuel cycle, and other aspects of the study of nuclear engineering. At Idaho State University, while our emphasis is on advanced reactors and the science and technology of nuclear fuel recycling, we allow the flexibility to build programs on other aspects, which can include systems studies and simulations including policy aspects, radiation shielding and detection, medical applications of radiation, and the economics and safety of all of these applications.

• Increase the ability of graduates to synthesize and apply these advanced concepts to develop realistic nuclear engineering designs and to solve identified problems, designing strategies for implementing them safely, ethically, and effectively.

• Enhance the ability of graduates to effectively communicate these concepts both in oral and written formats.

Master of Science in Health Physics
The Nuclear Engineering and Health Physics Program additionally offers the master’s option in Health Physics. Health Physics, an applied science, is concerned with the protection of humans and their environment from the possible harmful effects of radiation while providing for its beneficial uses. It is a multi-disciplined profession that incorporates aspects of both the physical and biological sciences. The master's program in Health Physics is accredited by the Applied Sciences Accreditation Commission of ABET, http://www.abet.org. The Idaho State University Health Physics programmatic educational objectives have been developed in close collaboration of faculty and the Idaho State University Health Physics Program Advisory Board.

The educational objectives of the ISU Health Physics program are to produce health physicists with...
1. broad, fundamental technical knowledge;
2. written and verbal communication skills;
3. professional judgment and capability to think critically;
4. practical experience in solving applied health physics problems;
5. the ability to work independently;
6. a professional ethic of magnitude sufficient for them to productively and successfully work in a variety of health physics settings.

The graduate program has two additional educational objectives:

1. An ability to conduct research;
2. Professional tools and experience above that expected for the baccalaureate program.

Students may enter the master's program in health physics from several undergraduate majors including health physics, physics, chemistry, biology, and other science or engineering majors. Additional course work to correct deficiencies may be necessary.

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

This program combines the atomic nuclear aspects of engineering and science. Research areas range from the more traditional nuclear engineering disciplines (reactor physics, thermal hydraulics, and reactor design) to cross-discipline topics in the fields of radiation detection and measurement, nuclear fuels, and materials development, nuclear fuel cycle systems studies and radioactive waste management.

**Goals**

- Prepare graduates to conduct and disseminate independent scholarly research.
- Prepare graduates for careers in academia or industry.

**Objectives**

- Increase the knowledge of graduates in their specialized field: chemistry, engineering (all disciplines), geosciences, mathematics, and physics.
- Enhance the ability of graduates to contribute to their chosen field.
- Enhance effective written and oral communication skills of graduates.

**Electrical Engineering**

Program Director and Professor: Chiu

Professors: Mousavinezhad

Associate Professors: Chiu, Ellis, Kantabutra

Adjunct Faculty: Baldwin, Alsaraj

**Master of Science in Measurement and Control Engineering**

The master’s degree program in Measurement and Control Engineering is designed to provide advanced study (analytically, computationally, and experimentally) in measurements, modeling, simulation, robotics, and adaptive, intelligent, nonlinear, optimal, and robust control. This program prepares the student for advanced placement in the measurement and control engineering field in industry, research, or development areas. Additionally, this program provides a suitable base for entrance into a doctoral program in a field related to electrical or mechanical engineering. The program is offered both at the Pocatello and the Idaho Falls campuses, primarily through the use of telecommunications/distance learning, which includes partial in-class instruction.

**Goals**

- Enhance the knowledge of graduates in advanced concepts of measurement, control, signal processing, engineering mathematics, computation and other related areas.
- Increase the ability of graduates to synthesize and apply these advanced concepts to develop realistic measurement and control engineering designs and to solve identified problems, designing strategies for implementing them safely, ethically, and effectively.
- Enhance the ability of graduates to effectively communicate these concepts both in oral and written formats.

**Doctor of Philosophy in Applied Physics**

**Program Goals**

- Prepare graduates to conduct and disseminate independent scholarly research in applied physics.
- Prepare graduates for careers in academia, industry, or government.

**Program Objectives**

- Increase the knowledge of graduates in their chosen field of applied physics.
- Enhance the ability of graduates to contribute to their chosen field of applied physics.
- Enhance effective written and oral communication skills of graduates.

The Ph.D. program in Applied Physics is an interdisciplinary program offered by that allows for a broad range of research topics. Areas of emphasis in the department include: nuclear physics applications, radiation effects in materials, accelerator physics and applications, materials science, homeland security applications, and other areas of applied nuclear science.

To attain a degree in this program, a student must demonstrate scholarly achievement and ability for independent investigation. The program will normally require approximately five years of full-time study beyond the bachelor’s degree (or three years beyond the master’s degree), including class work, research, and preparation of the dissertation.

**Admission Requirements**

All applicants must meet Idaho State University Graduate School admission requirements for doctoral programs. In addition, applicants must have attained a minimum of a bachelor’s degree in physics, or a closely related field (engineering, applied physics, chemistry, etc.). The student’s course of study will be determined by consultation with the department chair or the department’s graduate advising committee. Students may be required to complete any missing course material that is required for the B.S. degree in physics at Idaho State University. Continued enrollment in the program is contingent upon maintaining a 3.0 grade point average, and upon making satisfactory progress toward the degree.

A complete graduate application for classified status in the Idaho State University Physics Department Ph.D. program consists of:

1. GRE scores (normally, a minimum of 50th percentile on verbal, quantitative, or analytical is required for classified students);
2. An Idaho State University Graduate School application form, fee, and official copies of transcripts;
3. Three letters of recommendation;
4. A resume or CV;
5. A statement of career goals.

General Requirements

The Ph.D. degree requires completion of at least 84 credits at the 500-course or greater. Of these, at least 32 credits, but no more than 44 credits, must be doctoral dissertation credits (PHYS 8850 Doctoral Dissertation). At least 4 must be graduate seminar (or equivalent, as determined by the department). The remaining required credits consist of electives and the required courses listed below. Students entering the program with a master’s degree may receive credit for up to 30 credits toward the Ph.D., subject to the department chair’s approval. Students should complete the required courses as listed below (or their equivalent, as determined by the department), at Idaho State University.

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>PHYS 5525</td>
<td>Nuclear and Particle Physics I</td>
<td>3</td>
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<tr>
<td>PHYS 5526</td>
<td>Nuclear and Particle Physics II</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 6602</td>
<td>Theoretical Methods of Physics</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 6611</td>
<td>Electricity and Magnetism</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 6621</td>
<td>Classical Mechanics</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 6624</td>
<td>Quantum Mechanics</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 6649</td>
<td>Graduate Seminar (4 credits total)</td>
<td>1</td>
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Program of Study

A departmental advisory committee consisting of graduate faculty will guide each student in establishing his or her program of course and laboratory study based upon the student’s background and research interest. The advisory committee has the responsibility of ensuring that the student has adequate knowledge to support research in his or her area of research.

At the beginning of a full-time student's second year, the student will sit for a written Qualifying Examination. Exceptions to this schedule may be made when a student has academic deficits to make up, in which case the student will have an additional year. The student may take the exam as often as it is offered, but the student must pass the exam by the end of their second year of enrollment. The student will be admitted to candidacy upon passing the qualifying examination.

A dissertation committee of four departmental members and a Graduate Faculty Representative (GFR), chaired by the candidate’s major professor, must be appointed within six months of passing the qualifying examination. Within one year of passing the qualifying exam, the full-time candidate, with guidance from the major professor, must satisfactorily complete the Preliminary Examination, which consists of an oral presentation and defense of a written proposal for dissertation research to the student’s dissertation committee.

The research and dissertation preparation must be done under the close supervision of the committee and must include at least one full year of work performed under the supervision of a Idaho State University graduate faculty.

Dissertation Examination approval requires a public presentation of the dissertation and a satisfactory oral defense to the dissertation committee. Doctoral oral examinations are open to all regular members of the graduate faculty as observers. Further, oral presentations are open to the public until questioning by the dissertation committee begins.

Doctor of Philosophy in Engineering and Applied Science

A doctoral program in Engineering and Applied Science, administered through the College of Science and Engineering, is available to Physics students. The complete program description is provided in the Engineering and Applied Science (http://coursecat.isu.edu/graduate/engineering/ engineeringandappliedscience) section of the Graduate Catalog.

Master of Science Programs

Admission Requirements

The student must apply to, and meet all criteria for, admission to the Graduate School. In addition to the general requirements of the Graduate School, the student must comply with departmental requirements.

A complete graduate application for classified status in the Idaho State University Physics Department consists of:

1. GRE aptitude scores;
2. An Idaho State University Graduate School Application form, fees, and official copies of transcripts;
3. Three letters of recommendation;
4. A resume or CV;
5. A brief statement of career goals.

Applications must hold the degree of Bachelor of Science or Bachelor of Arts in Physics, or a closely related field. The student’s course of study will be determined by consultation with the chair and the student’s major advisor. In some circumstances, a placement examination will be given. Students will normally be required to complete as deficiencies any courses required for the B.S. in Physics at Idaho State University which they have not already taken. Continued enrollment in the program is contingent upon maintaining a 3.0 grade point average and upon making satisfactory progress toward the degree.

Master of Science

Thesis Option:

A satisfactory score on physics examination(s) may be required before admission to candidacy. A total of 30 credits are required for the Master of Science Degree.

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<td>3</td>
</tr>
<tr>
<td>PHYS 6650</td>
<td>Thesis</td>
<td>6</td>
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</tbody>
</table>

Additional graduate level credits approved by the student’s advisor, department chair and the Graduate School

Total Credits 36

A public presentation of the thesis is required, along with a satisfactory oral defense to the thesis committee consisting of two departmental members and one GFR.
Master of Science

Non-Thesis Option:

There are two mechanisms by which a student may attain a non-thesis M.S. degree. First, students in the Ph.D. program who do not pass the qualifying examination at the Ph.D. level after two attempts may complete a non-thesis M.S. degree. The required core courses for the non-thesis M.S. degree are the same as those for the Ph.D., i.e. those listed above. In addition, a non-thesis M.S. student must pass the qualifying examination at a level appropriate for the M.S., and he or she must complete an oral presentation and defense of a written proposal for research project to the student’s graduate committee.

Second, students in the Ph.D. program who have completed all required courses for the Ph.D. and have passed both their qualifying examination and their oral presentation and defense of a written proposal for research project are eligible for a non-thesis M.S. degree.

Nuclear Engineering and Health Physics

Certificate Program in Applied Nuclear Energy

Admission Requirements

The student must apply to, and meet, all criteria for admission to the Graduate School. GRE scores are not required if an earned grade point average of at least 3.0 or higher was achieved for all upper division credits taken at the undergraduate level, regardless of the institution at which the credits were earned.

<table>
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<tr>
<th>Code</th>
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<tbody>
<tr>
<td>NSEN 6615</td>
<td>Introduction to Practical Nuclear Engineering</td>
<td>3</td>
</tr>
<tr>
<td>NSEN 6617</td>
<td>Applications of Nuclear Energy</td>
<td>3</td>
</tr>
<tr>
<td>ENGR 6651</td>
<td>Seminar (2 credits minimum)</td>
<td>1</td>
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Electives

Select one of the following: 3 credits

- ENGR 6606 Environmental Law and Regulations
- HPHY 6610 Radiation Regulations
- NSEN 6618 Radioactive Waste Management
- NSEN 6619 Materials Science of Radwaste

Approved NE, NSEN, ENGR, ENVE or PHYS 55xx/66xx elective course.

Master of Science in Nuclear Science and Engineering

Admission Requirements

The student must apply to, and meet, all criteria for admission to the Graduate School and hold a BS degree in a physical science or engineering.

General Requirements

The basic program requirements are 32 credits, of which 15 credits must be at the 6600-course level. Six of the eighteen required credits may be thesis. Students who are prepared with some education and experience in health physics will likely not need all of the elective health physics courses. Therefore, the student’s program will be determined in consultation with the student’s advisor and committee and can include electives to meet his/her needs. An oral examination in defense of the thesis is required for the thesis option.

Thesis Option in Engineering Master’s Programs

All students entering with less than two years of industrial experience as determined by Engineering are required to complete six credits of thesis in their related field. Students who are planning to continue their education beyond the master level are strongly encouraged to choose this option. After the completion of the course work and the thesis, an oral defense of the thesis will be required. No more than six credits of Thesis (ENGR 6650 Thesis, 1-9 credits) will be allowed on the student’s final Program of Study.

Non-Thesis Option in Engineering Master’s Programs

All students entering with a minimum of two years industrial experience in the related area as determined by the School of Engineering are eligible to choose this option. In the non-thesis program students will be required to take an additional 3-credit course, to complete a 3-credit Special Project (ENGR 6660 Special Project, 1-9 credits) in the related field and submit a written report. After completion of the course work and the Special Project, students are required to take a two-hour oral exam on their Special Project and other courses in the MS program. No more than three credits of special Project will be allowed on the student’s final Program of Study.

Master of Science in Health Physics

Admission Requirements

For admission, the student must apply to, and meet all criteria for, admission to the Graduate School, including a baccalaureate degree in a physical or biological science or engineering.

General Requirements

The basic program requirements are 33 credits, of which 15 credits must be at the 6600-course level. Six of the eighteen required credits may be thesis. Students who are prepared with some education and experience in health physics will likely not need all of the elective health physics courses. Therefore, the student’s program will be determined in consultation with the student’s advisor and committee and can include electives to meet his/her needs. An oral examination in defense of the thesis is required for the thesis option. A non thesis option is also available.

Doctor of Philosophy in Nuclear Science and Engineering

Admission Requirements

All applicants must meet Idaho State University Graduate School admission requirements for doctoral programs. Additionally, applicants must have attained a master’s degree in engineering, physics, chemistry, geosciences, mathematics, or a closely related field. Applicants must submit a one-page (only) statement of research interests, a one-page (only) statement of career interests, a resume, and at least 2 letters of reference along with their applications. In some special cases, a student with exceptional undergraduate academic record and aptitude for research, but without an M.S. degree, may be directly admitted to the Ph.D. program with the approval of the Ph.D. program committee.

General Requirements

The doctoral degree requires completion of at least 84 credits consisting of 32 credits for the master’s degree, 18 credits of additional course work (at least 50% of the credits should be at 6600 level), 4 credits of graduate seminar and 32 credits of dissertation research. Six credits of core courses are required for each emphasis area. At least 9 of the 18 credits of course work must be in collateral areas as designated by the student’s advisor. Additional dissertation research credits may be required by the student’s dissertation committee.
**Program of Study**

An advisor, a Graduate Faculty member from the student's parent department, will be identified for each student upon entering the program. The advisor will guide the student in establishing his or her program of course work and laboratory study based upon the student's background and research interest. The advisor has the responsibility of ensuring that the student has adequate knowledge to support research in his or her chosen area of interest.

At the end of the first year, the student will take an 8-hour written, comprehensive qualifying examination covering the relevant information addressed in a nuclear engineering B.S. curriculum (including nuclear physics, reactor physics, reactor engineering and nuclear fuel cycle.) A student taking the comprehensive qualifying exam needs to be prepared to take an oral examination conducted by the examination committee. The oral exam needs to focus primarily on material in the written exam that was not adequately answered. However, the examination committee, at its discretion, may excuse a student from taking the oral examination if the student excels in the written examination. The student will be allowed two attempts to pass the comprehensive examination, and the second attempt must be within one-half year after the first attempt. The student will be admitted to candidacy upon passing the comprehensive qualifying examination.

A dissertation committee is formed with a minimum of 5 members consisting of a major professor, 2 members from the student's parent department, a member from other relevant department, and a Graduate Faculty Representative. The major advisor chairs the dissertation committee. Within six months of passing the comprehensive qualifying examination, the candidate, with guidance from the major advisor, will satisfactorily complete an oral presentation and defense of a proposal for dissertation research to the dissertation committee. The research and dissertation preparation must be conducted under the close supervision of the committee and must include at least one full year of work performed under Idaho State University graduate faculty. The candidate can submit the final dissertation anytime after six months from the date of acceptance of the research proposal.

Dissertation approval requires a public presentation of the dissertation and a satisfactory oral defense to the dissertation committee. Doctoral oral examinations are open to all regular members of the faculty as observers. Further, oral presentations are open to the public until questioning by the dissertation committee begins.

**Electrical Engineering**

**Master of Science in Measurement and Control Engineering**

Program Director: Ken Bosworth

**Admission Requirements**

The student must meet all criteria for admission and then apply to the Graduate School. In addition, official Graduate School record Examination (GRE) score reports are required for all applicants, with a score equal or above the upper 65th percentile on the Quantitative Reasoning area being required for admission.

**General Requirements**

With the assistance of the Mechanical Engineering and/or Electrical Engineering faculty, the student shall select an initial advisor during the first semester of residence to help in planning a program of studies and research. The student must also complete a Plan of Study and form a complete advisory committee by the time six credits of course work have been completed.

30 credit hours are required to complete the M.S. degree (at least 50% of the credits should be at the 6600 level). Approximately half of the credits are engineering and technical electives, subject to the approval of the student’s advisory committee. The Thesis or Special Project should consist of study and research that complements the course work selected.

**Required Courses (30 credits)**

The following courses are required of every student receiving the master's degree in Measurement and Control Engineering covered by the abbreviated list.

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<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>MATH 5521</td>
<td>Advanced Engineering Mathematics I</td>
<td>3</td>
</tr>
<tr>
<td>MCE 6642</td>
<td>Advanced Control Systems</td>
<td>3</td>
</tr>
<tr>
<td>MCE 6643</td>
<td>Advanced Measurement Methods</td>
<td>3</td>
</tr>
<tr>
<td>Approved Engineering Electives</td>
<td>6</td>
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<tr>
<td>Approved Technical Electives</td>
<td>9</td>
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<tr>
<td>ENGR 6650</td>
<td>Thesis</td>
<td>6</td>
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<tr>
<td>OR One additional elective course</td>
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<tr>
<td>AND ME 6660</td>
<td>Special Project</td>
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</table>

Total Credits: 30

1 Students desiring to do the non-thesis option must have a minimum of two years industry experience. In place of the 6-credit thesis, the non-thesis option consists of a 3-credit Special Project in addition to a 3-credit course. At the completion of the Special Project, the student will be required to present an oral presentation/defense of the Project.

**Electrical Engr Courses**

**EE 5513 Techniques of Computer-Aided Circuit Analysis and Design: 3 semester hours.**

Automatic formulation of equations and fundamental programming techniques pertinent to computer-aided circuit analysis, design, modeling. May include sensitivity calculations, system analogies, optimization. PREREQ: EE 3340 and EE 3342.

**EE 5516 Applied Engineering Methods: 3 semester hours.**

Applied discrete and continuous probability, random variables, probability distributions, sampling, data description, parameter estimation, hypothesis testing, inference, correlation and linear and multiple regression. PREREQ: EE 3345.

**EE 5517 Probabilistic Signals and Systems: 3 semester hours.**


**EE 5518 Communication Systems: 3 semester hours.**

Basic principles of analysis and design of modern analog and digital communication systems, including transmission and reception. PREREQ: EE 3329 and EE 3345.

**EE 5525 Mechatronics: 3 semester hours.**

Basic kinematics, sensors, actuators, measurements, electronics, microprocessors, programmable logic controllers, feedback control, robotics and intelligent manufacturing. Equivalent to ME 5525. PREREQ: MATH 3360, EE 3342, and EE 3340.
EE 5526 Computer Architecture and Organization: 3 semester hours.
Design, implementation, and performance evaluation of modern computer systems; instruction sets; datapath and control optimizations; single-cycle, multiple-cycle, and pipelined processors; hazard detection and resolution; memory hierarchies; peripheral devices. Specific, evaluated graduate-level activities and/or performances are identified in the course syllabus. PREREQ: EE 2274 and EE 2275 or equivalent.

EE 5527 Embedded Systems Engineering: 2 semester hours.
Integration of algorithms, software and hardware to design real-time and embedded systems for signal processing and control. PREREQ: CS 4475 or CS 5575. COREQ: EE 5572L.

EE 5527L Embedded Systems Engineering Laboratory: 1 semester hour.
Lab activities include the complete process of design and implementation of embedded signal processing and control systems through the integration of algorithms, software, and hardware. COREQ: EE 5527.

EE 5529 Advanced Electronics: 2 semester hours.
Introduction to operational amplifiers and their applications, current mirrors, active loads, differential amplifiers, feedback and stability, filters, oscillators, Schmitt triggers, power amplifiers and voltage regulators. COREQ: EE 5529L.
PREREQ: EE 3329 and EE 3345.

EE 5529L Advanced Electronics Laboratory: 1 semester hour.
Laboratory course emphasizing transistor biasing, amplifiers and other basic analog circuit designs. COREQ: EE 5529.

EE 5532 Introduction to VLSI Design: 3 semester hours.
Photolithography, CMOS fabrication, MOSFET operation, CMOS passive elements, design rules and layout, CAD tools for IC design, invertors, static logic and transmission gates, dynamic logic. PREREQ: EE 3329.

EE 5533 Mixed Signal Design: 3 semester hours.
Analog IC design. Passive components, parasitic elements, component matching, IC layout techniques, amplifiers, current sources, comparators, op amps, noise, switched capacitor circuits. Includes lab work using design tools. PREREQ: EE 4432 or EE 5532.

EE 5572 Electrical Machines and Power: 3 semester hours.
Theory and application of electrical machinery and transformers. Power and energy relationships in power systems. Includes 1 credit lab component. COREQ: EE 5572L. PREREQ: EE 3340, EE 3342, and MATH 3360.

EE 5572L Electrical Machines and Power Laboratory: 1 semester hour.
Laboratory course emphasizing an experimental study of the fundamental physical phenomena and characteristics of transformers, induction motors, synchronous and direct current machines. COREQ: EE 5572.

EE 5573 Automatic Control Systems: 3 semester hours.
Study of continuous-time and control systems using both frequency-domain and state-space techniques; topics include design methodology, performance specifications, analysis and design techniques. PREREQ: EE 3345, ME 5505 or ME 4405.

EE 5574 Advanced Circuit Theory: 3 semester hours.
Methods of analog electrical circuit analysis and synthesis. Topics include signal flow graphs, multi-port networks, simulation techniques, and topological methods for formulation of network equations. PREREQ: EE 3340.

EE 5575 Digital Signal Processing: 3 semester hours.
Discrete, fast Fourier and Z-transforms, correlation, convolution, finite and infinite impulse response digital filter design, spectral analysis and adaptive digital filters. COREQ: EE 4484 or EE 5584. PREREQ: EE 3345.

EE 5576 Semiconductor Processing and Fabrication: 3 semester hours.
Silicon semiconductor processing and basic integrated circuit fabrication. Physics, chemistry, and technology in basic processing steps in production of integrated circuits. PREREQ: PHYS 2211, PHYS 2212, and MATH 1170 or equivalent.

EE 5578 Semiconductor Devices: 3 semester hours.
Operating principles of basic building blocks of modern silicon-based semiconductor devices to include p-n junctions, field effect transistors and bipolar junction transistors. PREREQ: PHYS 2212 or equivalent.

EE 5579 Advanced Semiconductor Devices: 3 semester hours.
Review of semiconductor band theory. Opto-electronics, quantum mechanics, hetero junctions, power and microwave semiconductor devices. PREREQ: EE 5578 or equivalent.

EE 5582 Principles of Power Electronics: 3 semester hours.
Introduction to steady state converter modeling and analysis. Principles of converter dynamics and control including controller design. COREQ: EE 5573.
PREREQ: EE 3329.

EE 5584 Signal Processing Laboratory: 1 semester hour.
Design finite and infinite response digital filters in digital signal processing system applications. COREQ: EE 5575.

EE 5592 Digital Control Systems: 3 semester hours.
Design of advanced control algorithms topics include: observers and state estimation, linear quadratic regulator, frequency-domain techniques for robust control, and an introduction to multivariable and nonlinear control. PREREQ: EE 5573 or EE 4473.

EE 5599 Experimental Course: 1-6 semester hours.
This is an experimental course. The course title and number of credits are noted by course section and announced in the class schedule by the scheduling department. Experimental courses may be offered no more than three times. May be repeated.

EE 6699 Experimental Course: 1-6 semester hours.
This is an experimental course. The course title and number of credits are noted by course section and announced in the class schedule by the scheduling department. Experimental courses may be offered no more than three times. May be repeated.

EE 8850 Doctoral Dissertation: 1-24 semester hours.

Health Physics Courses

HPHY 5511 Accelerator Health Physics: 3 semester hours.
Fundamentals of particle accelerator design and operation. Examination of the potential radiation environment associated with accelerators and health and safety issues of their operation. PREREQ: Senior standing in Health Physics or permission of instructor.

HPHY 5512 Environmental Health Physics: 3 semester hours.
State-of-the-art applied mathematical techniques for estimating the release, transport, and fate of contaminants in multimedia environmental pathways (air, groundwater, terrestrial). Both radiological and non-radiological contaminants will be addressed, with emphasis on radiological contaminants. PREREQ: Permission of instructor.

HPHY 5513 Fundamentals of Industrial Hygiene: 3 semester hours.
Overview on the recognition, evaluation, and control of hazards arising from physical agents in the occupational environment. The exposure consequences associated with agents of major occupational health concerns are considered. PREREQ: Permission of instructor.
HPHY 5516 Introduction to Nuclear Measurements: 3 semester hours.
Lecture/laboratory course emphasizing practical measurement techniques in nuclear physics. PREREQ: CHEM 1112 and PHYS 1111 and PHYS 1113 or PHYS 2211 and PHYS 2213 or equivalent or permission of instructor.

HPHY 5516L Radiation Detect/Measure Lab: 0 semester hours.
Laboratory course emphasizing practical measurement techniques in nuclear physics.

HPHY 5517 Industrial and Aerosol Physics: 3 semester hours.
This course focuses on two distinct subject areas: an elaboration on the details of the ACGIH method of local exhaust-system design, and a study of applied aerosol physics based upon trajectory analysis. PREREQ: Permission of instructor.

HPHY 5518 Non-ionizing Radiation Protection: 3 semester hours.
Occupational safety and health issues of human exposure to non-ionizing radiation. Topics include health concerns and safety strategies developed for extremely low frequency, microwave, ratio-frequency, ultraviolet, infrared, laser radiation, and soundwaves. PREREQ: Permission of instructor.

HPHY 5519 Radiological Emergency Planning: 3 semester hours.
Radiological emergency planning for facilities ranging from reactors and other major nuclear facilities to transportation accidents and smaller-scale nuclear accidents. Topics include planning, coordination, "exercises," exposure pathways, modeling, measurement, control, decontamination, and recovery. PREREQ: Permission of instructor.

HPHY 5520 Reactor Health Physics: 3 semester hours.
Introduction to reactor physics; nuances peculiar to reactor health physics; reactor designs. Critiques of exposure pathways accidents, decommissioning, contamination control, and emergency planning examine radiation safety approaches within the nuclear fuel cycle. PREREQ: Permission of instructor.

HPHY 5531 Radiation Physics I: 3 semester hours.
Atomic and nuclear structure, series and differential-equation descriptions of radioactive decay, physical theory of the interaction of radiation with matter suitable for the discipline of Health Physics. PREREQ: Permission of instructor.

HPHY 5532 Radiation Physics II: 3 semester hours.
Continuation of HPHY 5531 considering dosimetric quantities/units, theory and technology of radiation detection and measurement, and radiobiology important to an advanced understanding of radiation protection. PREREQ: HPHY 5531 or permission of instructor.

HPHY 5533 External Dosimetry: 3 semester hours.
A lecture course emphasizing external radiation protection including study of point kernel techniques, monte carlo modeling, and NCRP-49 methods. Also discussed are external dosimetry measurement techniques. PREREQ: HPHY 5532 or permission of instructor.

HPHY 5534 Internal Dosimetry: 3 semester hours.
A lecture course emphasizing internal radiation protection including studies of ICRP-2, ICRP-26&30, ICRP-60&66, and MIRD methods of internal dosimetry. PREREQ: HPHY 5533 or permission of instructor.

HPHY 5555 Topics in Health Physics I: 2 semester hours.
A lecture/senior course covering special topics in Health Physics such as state and federal regulations, waste disposal methodology, and emergency procedures. PREREQ: HPHY 5532 or permission of instructor.

HPHY 5556 Topics in Health Physics II: 2 semester hours.
A continuation of HPHY 5555. A lecture/senior course covering special topics in Health Physics such as state and federal regulations, waste disposal methodology, and emergency procedures. PREREQ: HPHY 5532 or permission of instructor.

HPHY 5558 Advanced Radiobiology: 3 semester hours.
An advanced-level class covering aspects of molecular radiobiology, teratogenesis, oncogenesis, and acute radiation illnesses. It also considers nonstochastic radiation effects and the epidemiology of radiation exposures. Equivalent to BIOL 5588. PREREQ: Permission of instructor.

HPHY 5590 ABHP Review: 3 semester hours.
A course for practicing professionals aimed at the development and improvement of skills. May be graded S/U. PREREQ: Permission of the instructor.

HPHY 5599 Experimental Course: 1-6 semester hours.
This course is not described in the catalog. The course title and number of credits are announced in the class schedule by the scheduling department. Experimental courses may be offered no more than three times with the same title and content.

HPHY 6605 Radiological Environmental Monitoring and Surveillance: 3 semester hours.
Advanced considerations in the design of monitoring programs. Sampling and analytical measurement programs for specific radionuclides and sources with emphasis in quality assurance.

HPHY 6610 Radiation Regulations: 3 semester hours.
Covers regulation of ionizing and non-ionizing radiation. Historical, biological, and legal foundations; federal regulations; state regulations; nuclear fuel cycle; emergency response; academic and medical facilities; transportation; accelerators; NORM/NARM; non-ionizing radiation. PREREQ: Permission of instructor.

HPHY 6650 Thesis: 1-12 semester hours.
Thesis. 1-12 credits. May be repeated. Graded S/U.

HPHY 6699 Experimental Course: 1-6 semester hours.
This course is not described in the catalog. The course title and number of credits are announced in the class schedule by the scheduling department. Experimental courses may be offered no more than three times with the same title and content.

HPHY 8850 Doctoral Dissertation: 1-12 semester hours.
Research toward and completion of the dissertation. 1-12 credits. May be repeated. Graded S/U.

Measurement/Control Engr Courses

MCE 5599 Experimental Course: 1-6 semester hours.
This is an experimental course. The course title and number of credits are noted by course section and announced in the class schedule by the scheduling department. Experimental courses may be offered no more than three times. May be repeated.

MCE 6640 System Modeling Identification and Simulation: 3 semester hours.
Model development, off-line and on-line identification methods for engineering systems, diagnostic tests and model validation and analog and digital simulation methods. PREREQ: ME/EE 5573 or equivalent.

MCE 6642 Advanced Control Systems: 3 semester hours.
State space analysis and design to include stability, controllability, observability, realizations, state feedback and estimation. PREREQ: ME 5573/EE 5573 or ME 4473/EE 4473.

MCE 6643 Advanced Measurement Methods: 3 semester hours.
Instrumentation systems used in detection and signal conditioning of thermal-hydraulic process variables, radiation including lasers, and electrical and mechanical properties of materials. PREREQ: ME 5505 or ME 4405.

MCE 6644 Measurements and Controls Laboratory: 3 semester hours.
Work with measuring systems for a variety of process variables. Investigation of characteristics of various process control components and systems; Transient and stationary conditions will be included. PREREQ: MCE 6642 and MCE 6643.
MCE 6645 Advanced Control Theory and Applications: 3 semester hours.
Topics selected from advanced control theory and applications, depending upon the interest of students and faculty. May be repeated for credit when topics vary. PREREQ: MCE 6642 or permission of instructor.

MCE 6646 Intelligent Control Systems: 3 semester hours.
Analysis and design of systems using intelligent techniques such as neural networks, fuzzy logic, genetic algorithms, and artificial intelligence. PREREQ: Permission of instructor.

MCE 6647 Nonlinear Control Systems: 3 semester hours.
Phase plane analysis. Lyapunov stability. Describing functions. Singular perturbation and feedback linearization. PREREQ: MCE 6642 or permission of instructor.

MCE 6649 Robotics and Automation: 3 semester hours.
Robotic manipulator kinematics, dynamics, trajectory planning, sensors, programming and control. The application concepts of robotics in industry will be briefly introduced. PREREQ: MCE 6642.

MCE 6650 Thesis: 1-9 semester hours.
Thesis research must be approved by the student's advisory committee. Six credits may be used to satisfy the research requirements for the degree. Graded S/U.

MCE 6652 Special Problems: 1-3 semester hours.
Special experimental, computational, or theoretical investigation leading to development of proficiency in some area of engineering. Formal report required. PREREQ: PRIO Project Approval Required by an Engineering Faculty. May be graded S/U. May be repeated.

MCE 6653 Optimal Control Systems: 3 semester hours.

MCE 6654 Adaptive Control Systems: 3 semester hours.

MCE 6656 Robust Control Systems: 3 semester hours.
Analyze and design basic robust controllers using methods for robustness investigation such as nu-analysis and H infinity control algorithms. PREREQ: MCE 6642 or permission of instructor.

MCE 6660 Special Project: 1-9 semester hours.
A significant project, involving engineering applications, toward the completion of M.S. program with non-thesis option. Includes a report and oral examination. Graded S/U. May be repeated.

MCE 6699 Experimental Course: 1-6 semester hours.
This is an experimental course. The course title and number of credits are noted by course section and announced in the class schedule by the scheduling department. Experimental courses may be offered no more than three times. May be repeated.

MCE 8850 Doctoral Dissertation: 1-24 semester hours.

Nuclear Engr Courses

NE 5519 Energy Systems and Nuclear Power: 3 semester hours.
Fundamentals of conventional and renewable energy systems. Energy sources, distribution, use and environmental effects. Nuclear power plant "balance of plant" design. Specific, evaluated graduate-level activities and/or performances are identified in the course syllabus. PREREQ: ME 3307 and MATH 3360 or instructor permission.

NE 5521 Mathematical Methods in Nuclear Engineering: 3 semester hours.
First and second order ordinary differential equations (ODEs), generalization to systems of ODEs, Laplace transforms, series solutions to second order ODEs, special functions and Sturm-Liouville systems; partial differential equations by separation of variables. Examples will emphasize practical problems of interest to nuclear engineers. PHYS 6602 may be substituted for this course. PREREQ: MATH 3360.

NE 5543 Thermal Fluids Laboratory: 1 semester hour.
Measurement of thermal and fluid properties, experiments on fluid flow and heat transfer systems. Equivalent to ME 5543. PREREQ: ME 3341 and NE 5576 or NE 4476.

NE 5545 Reactor Physics: 3 semester hours.
Neutron balance equations in reacting systems, diffusion and diffusion-perturbation theory, introductory reactor kinetics, the multi-group energy approach, neutron slowing down and thermalization, introductory concepts in reactor systems. PREREQ: NE 3302 or NSEN 6685, and NE 5521 or equivalent.

NE 5546 Nuclear Fuel Cycle Systems: 3 semester hours.
Uranium mining, milling, conversion; enrichment technology including cascade analysis; fuel fabrication, criticality safety in the nuclear fuel cycle, introduction to ORIGEN and Monte-Carlo methods and codes, reactor fuel management, waste management (LLW, HLW, TRU waste). PREREQ: NE 3302 or NSEN 6684 or equivalent.

NE 5548 Design Control and Use of Radiation Systems: 3 semester hours.
Generation detection and measurement systems design for control and use of neutrons and gamma rays in industrial and medical applications. Radiation protection, regulations, environmental and economic considerations. COREQ: ENGR 5545.

NE 5551 Nuclear Seminar: 1 semester hour.
Current topics in nuclear science and engineering. Specific, evaluated graduate-level activities and/or performances are identified in the course syllabus. PREREQ: Graduate student status in NSEN or HPHY program.

NE 5558 Monte Carlo Methods and Applications: 3 semester hours.
Basics of the application of stochastic methods to calculate the transport of neutrons, photons, and other sub-atomic particles. Includes introduction to the MCNP code, and sample application problems in both nuclear reactor design and in applications such as radiation beams used for cancer therapy.

NE 5576 Heat Transfer: 3 semester hours.

NE 5578 Reliability and Risk Assessment: 3 semester hours.
Methods of evaluating process and equipment reliability. Probabilistic methods applied to analysis and design. Setting probabilistic design objectives and calculating probabilistic performance. Specific, evaluated graduate-level activities and/or performances are identified in the course syllabus. PREREQ: MATH 3360 and EE 4416 or permission of instructor.
Applied Nuclear Energy.
Applications of engineering and physics, principles, particularly nuclear science, to medicine. Covers radioisotopes, x-ray imaging, magnetic resonance and ultrasound imaging, radiation protection, codes and standards. PREREQ: MATH 3360 and PHYS 2212.

NE 5599 Experimental Course: 1-6 semester hours.
This is an experimental course. The course title and number of credits are noted by course section and announced in the class schedule by the scheduling department. Experimental courses may be offered no more than three times. May be repeated.

NE 6699 Experimental Course: 1-6 semester hours.
This is an experimental course. The course title and number of credits are noted by course section and announced in the class schedule by the scheduling department. Experimental courses may be offered no more than three times. May be repeated.

NE 8850 Doctoral Dissertation: 1-24 semester hours.

Nuclear Sci and Engr Courses

NSEN 5599 Experimental Course: 1-6 semester hours.
This is an experimental course. The course title and number of credits are noted by course section and announced in the class schedule by the scheduling department. Experimental courses may be offered no more than three times. May be repeated.

NSEN 6601 Nuclear Engineering Experiments: 3 semester hours.
Experimental verification of theoretical models will be stressed. Kinetic behavior, neutron spatial distribution, perturbation, and other characteristic equations will be investigated. PREREQ: NE 5545, NE 4445, or equivalent.

NSEN 6603 Thermal Hydraulics: 3 semester hours.
Advanced studies of both fluid flow and heat transfer in nuclear reactor cores. Conservation equations constitutive relations formulation and solution approaches for complete equation set. PREREQ: ME 3341 and ME/NE 5576 or ME 4476.

NSEN 6604 Dynamic Behavior of Nuclear Systems: 3 semester hours.
Kinetic behavior of nuclear reactors including feedback effects of power transients, fuel burn up, coolant perturbations, etc. Mathematical models developed to predict both short and long term behavior. PREREQ: NE 4445 or NE 5545.

NSEN 6605 Nuclear Reactor Design: 3 semester hours.
Detailed treatment of current, advanced nuclear power reactor designs. Emphasis on the inherent and engineered safety features and on advantages and disadvantages of each design. PREREQ: NE 5545 or NE 4445.

NSEN 6608 Radiation Transport: 3 semester hours.
Advanced treatment of radiation transport and shielding concepts; interaction and attenuation of neutral particles, including photons. Use of deterministic and Monte Carlo computer codes. PREREQ: NE 5521 or NE 4421.

NSEN 6609 Radiation Detection Measurement and Applications: 3 semester hours.
Advanced treatment of radiation detectors, measurement techniques, data acquisition, and signal processing. Emphasis on applications in science, industry, and medicine. PREREQ: NE 5545, NE 4445 or NSEN 6608.

NSEN 6615 Introduction to Practical Nuclear Engineering: 3 semester hours.

NSEN 6616 Special Applications of Nuclear Energy: 3 semester hours.
Isotopic power systems for remote applications, nuclear propulsion for space vehicles, process heat and space heat reactors, maritime nuclear power plants, medical and industrial applications of nuclear radiation. PREREQ: Acceptance in Certificate Program in Applied Nuclear Energy.

NSEN 6617 Applications of Nuclear Energy: 3 semester hours.
Continued study of nuclear power plant design, operation, and safety analysis of present plants, proposed future concepts. Examination of biological effects of radiation and nuclear medicine, food irradiation and waste heat applications. PREREQ: NSEN 6615 and acceptance in Certificate Program in Applied Nuclear Energy.

NSEN 6618 Radioactive Waste Management: 3 semester hours.
Overview of historical, legal, political and social aspects of radioactive waste management; radwaste across the nuclear fuel cycle; waste definition and classification, treatment and disposal; design and assessment of repositories and radionuclide migration. PREREQ: NSEN 6684 and NSEN 6685 or equivalent.

NSEN 6619 Materials Science of Radwaste: 3 semester hours.
Materials chemistry and fabrication of waste glasses, ceramics and cements; waste form development and characterization; waste form degradation; radionuclide release and migration. PREREQ: ENGR 3350 and NE 5546 or equivalent.

NSEN 6631 Computational Transport Theory: 3 semester hours.
Study of advanced theories used in the calculation of nuclear reactor parameters including such topics as the Boltzman transport equation with energy and space dependence multi-group, multi-region diffusion for reflected systems, perturbation theory, etc. Special emphasis will be given to the application of digital computers in nuclear reactor design problems. PREREQ: NSEN 6608.

NSEN 6651 Nuclear Engineering Seminar: 1 semester hour.
Current topics in nuclear engineering and health physics. Invited speakers will be used when possible. Student presentations required. May be taken a maximum of four times. Graded S/U. PREREQ: Permission of instructor.

NSEN 6678 Probabilistic Risk Assessment: 3 semester hours.
Probabilistic methods applied to analysis and design. Setting probabilistic design objectives and calculating probabilistic performance emphasized. PREREQ: NSEN 6605.

NSEN 6684 Nuclear Engineering Basics: 3 semester hours.
For BS physical science graduates with little or no nuclear background. Lecture, laboratory each semester. Nuclear science; reactor physics, kinetics and thermal hydraulics; nuclear fuel cycle. PREREQ: Permission of NE Department Chair.

NSEN 6685 Nuclear Engineering Basics: 3 semester hours.
For BS physical science graduates with little or no nuclear background. Lecture, laboratory each semester. Nuclear science; reactor physics, kinetics and thermal hydraulics; nuclear fuel cycle. PREREQ: Permission of NE Department Chair.

NSEN 6686 Modeling Experimentation and Validation: 3 semester hours.
Two-week summer course. Provides early career nuclear engineers with advanced studies in integrated modeling, experimentation, and validation. The course emphasis rotates yearly among thermal-hydraulics, reactor physics, fuels and materials, and simulations. PREREQ: Permission of the NE Department Chair.

NSEN 6699 Experimental Course: 1-6 semester hours.
This is an experimental course. The course title and number of credits are noted by course section and announced in the class schedule by the scheduling department. Experimental courses may be offered no more than three times. May be repeated.

NSEN 8850 Doctoral Dissertation: 1-24 semester hours.
Physics Courses

**PHYS 5503 Advanced Modern Physics: 3 semester hours.**
Study of the elementary principles of quantum mechanics and an introduction to atomic, solid state and nuclear physics. Quantum mechanics will be used as much as possible. PREREQ: MATH 3360 and PHYS 3301.

**PHYS 5504 Advanced Modern Physics: 3 semester hours.**
Study of the elementary principles of quantum mechanics and an introduction to atomic, solid state and nuclear physics. Quantum mechanics will be used as much as possible. PREREQ: PHYS 5503.

**PHYS 5505 Advanced Laboratory: 2 semester hours.**
Experiments in radiation detection and measurement, nuclear spectroscopy including x-ray and gamma spectroscopies, neutron activation and beam methods. Available to Geology, Engineering, Health Physics, and Physics majors. PREREQ: Permission of instructor.

**PHYS 5510 Science in American Society: 2 semester hours.**
Observational basis of science; technology's historical influences on scientific developments; perceptions of science in contemporary America; tools/strategies for teaching science. Equivalent to GEOL 5510. PREREQ: Permission of instructor.

**PHYS 5514 Electronic Instrumentation and Measurement: 3 semester hours.**
Lecture course with laboratory requirements. Topics include: DC and AC electrical circuits, Analog pulses, Bipolar Transistors, Field Effect Transistors, Operational amplifiers. PREREQ: PHYS 2212, PHYS 2214, and MATH 3360.

**PHYS 5515 Statistical Physics: 3 semester hours.**
Topics covered may include kinetic theory, elementary statistical mechanics, random motion and the theory of noise. Choice of topics will depend upon the interest of the students and instructor. PREREQ: PHYS 2212 and MATH 3360.

**PHYS 5516 Radiation Detection and Measurement: 3 semester hours.**
Lecture/laboratory course emphasizing practical measurement techniques in nuclear physics. PREREQ: CHEM 1111, CHEM 1111L, CHEM 1112, CHEM 1112L, and either PHYS 1111 and PHYS 1113, or PHYS 2211 and PHYS 2213.

**PHYS 5516L Radiation Detect/Measure Lab: 0 semester hours.**

**PHYS 5521 Electricity and Magnetism I: 3 semester hours.**
Intermediate course in fundamental principles of electrical and magnetic theory. Free use will be made of vector analysis and differential equations. PREREQ: PHYS 2212 and MATH 3360.

**PHYS 5522 Electricity and Magnetism: 3 semester hours.**
Intermediate course in fundamental principles of electrical and magnetic theory. Free use will be made of vector analysis and differential equations. PREREQ: PHYS 5521.

**PHYS 5525 Nuclear and Particle Physics I: 3 semester hours.**
A course in Nuclear and Particle Physics with emphasis on structural models, radioactivity, nuclear reactions, particle interactions, fission and fusion, the standard model of particle physics, symmetries and conservation laws. PREREQ: Knowledge of elementary quantum mechanics and differential equations or permission of instructor.

**PHYS 5526 Nuclear and Particle Physics II: 3 semester hours.**
A course in Nuclear and Particle Physics with emphasis on structural models, radioactivity, nuclear reactions, particle interactions, fission and fusion, the standard model of particle physics, symmetries and conservation laws.

**PHYS 5542 Solid State Physics: 3 semester hours.**
Introduction to the field of solid state physics emphasizing the fundamental concepts. Topics usually covered are crystal structure, X-ray diffraction, crystal binding energies, free electron theory of solids, energy bands. PREREQ: PHYS 3301, PHYS 5583, and MATH 3360 or permission of instructor.

**PHYS 5552 Intermediate Optics: 3 semester hours.**
Wave theory, e/m waves, production of light, measurement of light, reflection, refraction, interference, diffraction, polarization, optical systems, matrix methods, Jones vectors, Fourier optics, propagation of e/m waves in materials, atmospheric optics. COREQ: MATH 3360. PREREQ: PHYS 2212.

**PHYS 5553 Topics in Astrophysics: 2 semester hours.**
Application of physics to astronomy or cosmology. May include lab exercise. PREREQ: Permission of instructor.

**PHYS 5561 Introduction to Mathematical Physics I: 3 semester hours.**
Introduction to the mathematics most commonly used in physics with applications to, and practice in, solving physical problems; includes vector analysis, ordinary and partial differential equations. PREREQ: PHYS 2212 and MATH 3360.

**PHYS 5562 Introduction to Mathematical Physics: 3 semester hours.**
Introduction to the mathematics most commonly used in physics with applications to, and practice in, solving physical problems; includes vector analysis, ordinary and partial differential equations. PREREQ: PHYS 5561.

**PHYS 5583 Theoretical Mechanics: 4 semester hours.**
Basic constituents of the standard model, experimental methods, particle interactions: weak, gravitational, strong and electromagnetic, conservation laws, hadron structure and interactions, unification of interactions, physics beyond the standard model. PREREQ: PHYS 6624 or permission of instructor.

**PHYS 6603 Particle Physics: 3 semester hours.**
Basic constituents of the standard model, experimental methods, particle interactions: weak, gravitational, strong and electromagnetic, conservation laws, hadron structure and interactions, unification of interactions, physics beyond the standard model. PREREQ: PHYS 6624 or permission of instructor.

**PHYS 6609 Advanced Nuclear Physics: 3 semester hours.**
Nucleon-nucleon interaction, bulk nuclear structure, microscopic models of nuclear structure, collective models of nuclear structure, nuclear decays and reactions, electromagnetic interactions, weak interactions, strong interactions, nucleon structure, nuclear applications. current topics in nuclear physics. PREREQ: PHYS 6624 or permission of instructor.

**PHYS 6611 Electricity and Magnetism: 3 semester hours.**
Maxwell's equations and methods of solution, plane wave propagation and dispersion, wave guides, antennas and other simple radiating systems, relativistic kinematics and dynamics, classical interaction of charged particles with matter, classical radiation production mechanisms.
**PHYS 6612 Advanced Electricity and Magnetism: 3 semester hours.**
Advanced topics in application of Maxwell's equations to wave guides, antennas and other simple radiating systems. Particular emphasis upon the relativistic interaction of charged particles with matter, energy loss, and classical radiation production and absorption mechanisms. PREREQ: PHYS 6611 or permission of instructor.

**PHYS 6615 Activation Analysis: 3 semester hours.**
Theory and use of neutron activation methods for quantitative chemical analysis of natural and synthetic materials. Applications in geologic systems will be emphasized. PREREQ: Permission of instructor.

**PHYS 6621 Classical Mechanics: 3 semester hours.**
Lagrange equations, small vibrations; Hamilton's canonical equations; Hamilton's principal, least action; contact transformation; Hamilton-Jacobi equation, perturbation theory; nonlinear mechanics. PREREQ: PHYS 5583, PHYS 5561 and PHYS 5562, or permission of instructor.

**PHYS 6624 Quantum Mechanics: 3 semester hours.**
Schrödinger wave equation, stationary state solution; operators and matrices; perturbation theory, non-degenerate and degenerate cases; WKB approximation, non-harmonic oscillator, etc.; collision problems. Born approximation, method of partial waves. PREREQ: PHYS 5561, PHYS 5562, and PHYS 6621 or permission of instructor.

**PHYS 6625 Quantum Mechanics: 3 semester hours.**
Schrödinger wave equation, stationary state solution; operators and matrices; perturbation theory, non-degenerate and degenerate cases; WKB approximation, non-harmonic oscillator, etc.; collision problems. Born approximation, method of partial waves. PREREQ: PHYS 6624 or permission of instructor.

**PHYS 6626 Advanced Quantum Mechanics: 3 semester hours.**
Elementary quantum field theory and practical applications. Emphasis upon non-relativistic and relativistic quantum electrodynamics, radiative processes, bremsstrahlung, pair-production, scattering, photo-electric effect, emission and absorption. PREREQ: PHYS 6625 or permission of instructor.

**PHYS 6630 Accelerator Physics: 3 semester hours.**
The physics of direct voltage accelerators, betatrons, synchrotrons, linear induction acceleration; high current accelerators; electromagnetic particle optics, free electron lasers and synchrotron light sources. PREREQ: PHYS 6612, and PHYS 6624 or equivalent.

**PHYS 6631 Accelerator Technology: 3 semester hours.**
Topics will include high voltage and pulsed power techniques, wave guide and R.F. structures, ion and electron beam sources and beam measurements as applied to particle beam machines. PREREQ: PHYS 6612 or equivalent.

**PHYS 6632 Particle Beam Laboratory: 1-4 semester hours.**
Laboratory projects in particle beam and ion optics, radiation detectors, ion source operation, etc. May be repeated up to 4 credits. PREREQ: Permission of instructor.

**PHYS 6640 Statistical Mechanics: 3 semester hours.**
Statistical ensembles; the Maxwell-Boltzmann law; approach to equilibrium, quantum statistical mechanics; application of statistical mechanics to thermodynamic processes. PREREQ: PHYS 5515 and PHYS 6621.

**PHYS 6641 Field Theory Particles and Cosmology I: 3 semester hours.**
Topics may include Dirac theory, group theory, Feynman diagrams, superstrings, supergravity, relativity and cosmology. PREREQ: Permission of instructor.

**PHYS 6642 Field Theory Particles and Cosmology II: 3 semester hours.**
A continuation of PHYS 6641. Topics may include Dirac theory, group theory, Feynman diagrams, superstrings, super gravity, relativity and cosmology. PREREQ: Permission of instructor.