AIR FORCE INSTITUTE OF TECHNOLOGY

DEPARTMENT OF ENGINEERING PHYSICS

Department Brochure

Revised: July 2019

This document is an overview of degree requirements and curricular offerings. It is not a substitute for the current issue of the Graduate Catalog, Air Force Institute of Technology, Graduate School of Engineering and Management, Wright Patterson AFB, OH.
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</tr>
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</table>
Department of Engineering Physics (Main Office, Building 640, Room 219)

Address for the Department of Engineering Physics:
AFIT/ENP, Building 640
2950 Hobson Way
Wright-Patterson AFB, Ohio 45433-7765

Phone numbers, email, and web addresses:
Voice: (937) 255-3636, plus 4-digit extension
Fax: (937) 656-6000 (located in Bldg 640, Room 219)
Department email address: enpadministration@afit.edu
(emails go to Interim Dept and Deputy Department Head)
Website: http://www.afit.edu/en/enp/index.cfm

Key Personnel

Interim Department Head: Lt Col Kenneth W. Burgi
Room: 219 B
Extension: x4696

Academic Chair:
Dr. Michael Marciniak
Room: 213 C
Extension: x4529

Deputy Head:
Lt Col Michael Dexter
Room: 203 B
Extension: x4742

Centers of Specialized Research in ENP:
Dr. Steven Fiorino, Director, Center for Directed Energy, CDE
Room: 217
Extension: x4506
Dr. Jack McCrae, Deputy Director, CDE
Room: 354 B
Extension: x4739
Lt Col Dexter, Interim Director, Center for Tech Intelligence
Room: 203 B
Extension: x4742
Studies and Research, CTISR
Dr. James Petrosky, Director, Nuclear Events Analysis and Testing
Room: 225 F
Extension: x4562
Center for Specialized Research, NEAT CSR
LTC Edward Hobbs, Deputy Director, NEAT CSR
Room: B470/R205
Extension: x4609

Doctoral Students:
Dr. David Weeks, Chair Doctoral Committee
Room: 221 B
Extension: x4561

Curricula Chairs, MS and Certificate Programs:
Lt Col Samuel Butler
Room: 223 A
Extension: x4358
Lt Col Robert Tournay
Room: 215 B
Extension: x4743
Maj Nicholas Herr
Room: 223 C
Extension: x4524
Dr. John McClory
Room: 225 B
Extension: x7308
Lt Col Samuel Butler
Room: 223 A
Extension: x4358
Dr. John McClory
Room: 225B
Extension: x7308

Class Academic Advisors, MS Programs:
Maj Daniel Emmons
Room: 221 D
Extension: x4571
Maj Omar Nava
Room: 215 A
Extension: x4518
Maj Nicholas Herr
Room: 223 C
Extension: x4524
Maj James Bevins
Room: 331 A
Extension: x4767
Maj Daniel Emmons
Room: 221 D
Extension: x4571

Office Administrative Support:
Ms. Charity Smalls, Ctr
Room: ENP Office Manager
Extension: 219
Extension: x4503
Ms. Penny Davis
Room: Business Manager
Extension: 219 D
Extension: x4751
Ms. Amy Nida, Ctr
Room: NWEPP Administrator
Extension: 225
Extension: x4706
Ms. Sara Kraft, Ctr
Room: CDE Executive Administrator
Extension: 217
Extension: x4602
Dr. Anna Bucy, Ctr
Room: Nuclear Engineering Admin
Extension: 225
Extension: x4735

Laboratory Staff:
Mr. Greg Smith
Room: Supervisor
Extension: 265
Extension: x7942
Mr. Jeffrey Sitler
Room: 214 A
Extension: x7317
Mr. Eric Taylor
Room: B470/R209
Extension: x4821
General Information

The Department of Engineering Physics provides Department of Defense (DOD)-focused graduate education and research through Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) programs in Applied Physics, Atmospheric Sciences (M.S. only), Countering Weapons of Mass Destruction (currently unavailable), Materials Science, Nuclear Engineering, and Optical Sciences and Engineering. We also offer graduate certificate programs in Countering Weapons of Mass Destruction (currently unavailable) and Nuclear Weapons Effects, Policy, and Proliferation (NWEPP). We are the Air Force’s primary provider of graduate education in physics and nuclear engineering. Military officers from sister services, DOD civilians, and DOD contractors may also qualify for admission.

Course Add/Drop Slips and Grade Change Forms: To make course changes outside of the normal enrollment period, fill out an electronic add/drop form and obtain required approvals. Forms used by the Registrar’s office can be found at https://www.afit.edu/ENER/doclib.cfm?dl=30 (click PDF titled “AFIT Registration Form”). When taking a course for letter grade and required work cannot be finished by the end of the term, the instructor may choose to give an incomplete grade. Upon completion of all the required work, a grade change form must be submitted by the instructor to assign a letter grade.

Biosafety/Chemical/Laser/Radiation/ Safety Training: Some laboratory courses or research may require special training. Training can be coordinated as the need arises; often occurring once per academic quarter. Examples of typical special training and contact person are given below.

<table>
<thead>
<tr>
<th>Function</th>
<th>Primary</th>
<th>Alternate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical Hygiene Training:</td>
<td>Mr. Smith (x7942)</td>
<td></td>
</tr>
<tr>
<td>Laser Safety Training:</td>
<td>Maj. Herr (x4524)</td>
<td>Dr. Marciniak (x4529)</td>
</tr>
<tr>
<td>Office Safety Training:</td>
<td>Lt Col Lenyk (x4558)</td>
<td>Mr. Smith (x7924)</td>
</tr>
<tr>
<td>Radiation Safety Training:</td>
<td>Mr. Taylor (x4821)</td>
<td>Maj Bevins (x4767)</td>
</tr>
<tr>
<td>Biosafety Training:</td>
<td>Dr. Harper - ENV (x4528)</td>
<td></td>
</tr>
</tbody>
</table>

The course instructor or research advisor will direct which training is required. Additional safety training guidance and reference materials can be found at J:/ENP/Safety.

Leave Requests: MS military students must submit requests to their Branch Chief (primary approver) or Division Chief (backup approver). PhD Military students must submit requests to their Division Chief (primary approver) or Deputy Department Head (backup approver.) If any portion of the leave is during an academic term (to include thesis/dissertation research hours), a Missing Class Form needs to be attached to the leave request in LeaveWeb.

Travel (TDY): Often degree requirements or research requires travel to laboratories, conferences, or universities. Research advisors control sponsored funds and need to be consulted in order to apply funds. All travelers must have an account in the Defense Travel System (DTS) to conduct official travel. If the travel is within the continental United States, it must be submitted at least 10 days in advance; if to Canada or overseas, the coordination must be done at least 40 days in advance, as it can take up to 30 days to get the required country clearances. Civilian students who are supported as contractors must consult their contracting organization to see if travel plans must be accomplished through. In certain cases, civilian contractor students must use DTS and travel using “invitational” orders. This can be done through the research advisor.

Thesis Preparation: An M.S. thesis preparation course (PHYS 598, 1 cr hr) is offered in the spring quarter each year for students in the Department of Engineering Physics. A thesis template is provided by AFIT for consistency. It is to be followed. The AFIT Thesis Processing Center staff will contact graduating students with instructions for thesis completion and approvals. The student and thesis advisor are responsible for all content, quality, accuracy, and formatting.
<table>
<thead>
<tr>
<th>Rank</th>
<th>Name</th>
<th>Specialty</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Professor</strong></td>
<td>Larry W. Burggraf</td>
<td>Computational/ materials chemistry, optical/nuclear spectroscopy, exotic particles</td>
</tr>
<tr>
<td></td>
<td>Steven T. Fiorino</td>
<td>Atmospheric physics, microwave remote sensing; Director of CDE</td>
</tr>
<tr>
<td></td>
<td>Nancy C. Giles</td>
<td>Experimental solid state physics, photoluminescence, absorption, electron paramagnetic resonance spectroscopy</td>
</tr>
<tr>
<td></td>
<td>Michael A. Marciniak</td>
<td>Optical/infrared signatures, electro-optics</td>
</tr>
<tr>
<td></td>
<td>Glen P. Perram</td>
<td>Laser physics, chemical kinetics, molecular spectroscopy</td>
</tr>
<tr>
<td></td>
<td>James C. Petrosky</td>
<td>Nuclear engineering, radiation, Director of NEAT CSR</td>
</tr>
<tr>
<td></td>
<td>Heidi R. Ries</td>
<td>Nonlinear optical materials, electron paramagnetic resonance spectroscopy, laser processing of materials; Dean for Research</td>
</tr>
<tr>
<td></td>
<td>David E. Weeks</td>
<td>Computational chemical physics</td>
</tr>
<tr>
<td></td>
<td>Paul J. Wolf</td>
<td>Atomic, molecular, and optical physics; Associate Dean for Academic Affairs</td>
</tr>
<tr>
<td><strong>Associate Professor</strong></td>
<td>John W. McClory</td>
<td>Nuclear engineering, Director of NWEPP</td>
</tr>
<tr>
<td></td>
<td>Anil K. Patnaik</td>
<td>Combustion spectroscopy, laser-based sensing</td>
</tr>
<tr>
<td></td>
<td>Ronald F. Tuttle</td>
<td>Measurement and signature intelligence; NWEPP course instruction</td>
</tr>
<tr>
<td><strong>Assistant Professor</strong></td>
<td>Maj James B. Bevins</td>
<td>Optimization, neutron spectroscopy, nuclear effects, post-detonation forensics, radiation detector development, and nuclear policy</td>
</tr>
<tr>
<td></td>
<td>Abigail A. Bickley</td>
<td>Research faculty; nuclear chemistry, nuclear engineering, nuclear forensics</td>
</tr>
<tr>
<td></td>
<td>Santasri Bose-Pillai</td>
<td>Research faculty; laser beam propagation and imaging through atmosphere, partially coherent sources, laser communications</td>
</tr>
<tr>
<td>Rank</td>
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<td>Specialty</td>
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</tr>
<tr>
<td>Lt Col</td>
<td>Kenneth W. Burgi</td>
<td>Fourier optics, statistical optics; Interim Department Head</td>
</tr>
<tr>
<td>Lt Col</td>
<td>Samuel D. Butler</td>
<td>Optical Physics</td>
</tr>
<tr>
<td></td>
<td>Michael J. Caylor</td>
<td>Research faculty; space systems</td>
</tr>
<tr>
<td></td>
<td>Justin A. Clinton</td>
<td>Nuclear engineering, NWEPP course instruction</td>
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<tr>
<td>Lt Col</td>
<td>Michael L. Dexter</td>
<td>Nuclear weapons effects; Interim Director of CTISR</td>
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<tr>
<td>Maj</td>
<td>Daniel J. Emmons</td>
<td>Plasma physics, space physics</td>
</tr>
<tr>
<td></td>
<td>Manuel R. Ferdinandus</td>
<td>Optics, fast-pulse lasers, non-linear optics</td>
</tr>
<tr>
<td>Lt Col</td>
<td>Anthony Franz</td>
<td>Optics, laser dynamics, space weather</td>
</tr>
<tr>
<td></td>
<td>Michael R. Hawks</td>
<td>Research faculty; optics, remote sensing</td>
</tr>
<tr>
<td>Maj</td>
<td>Nicholas C. Herr</td>
<td>Laser/materials interactions; materials</td>
</tr>
<tr>
<td>LTC</td>
<td>Edward L. Hobbs</td>
<td>Radiation Transport; Deputy Director of NEAT CSR</td>
</tr>
<tr>
<td></td>
<td>Darren E. Holland</td>
<td>Research faculty; nuclear engineering</td>
</tr>
<tr>
<td>CDR</td>
<td>Royce W. James</td>
<td>Plasma physics, emphasis in fusion, energy, space, and environmental applications</td>
</tr>
<tr>
<td>Lt Col</td>
<td>Christopher A. Lenyk</td>
<td>Material physics, nuclear weapon effects, wide-band gap oxides, laser materials, point effect characterization</td>
</tr>
<tr>
<td></td>
<td>Robert D. Loper</td>
<td>Quantum scattering, computational physics</td>
</tr>
<tr>
<td></td>
<td>Jesse J. Lutz</td>
<td>Research faculty; quantum chemistry, quantum physics, modeling solid state defects</td>
</tr>
<tr>
<td></td>
<td>Jack E. McCrae</td>
<td>Research faculty; directed energy weapons systems</td>
</tr>
<tr>
<td>Maj</td>
<td>Omar A. Nava</td>
<td>Atmospheric Science</td>
</tr>
<tr>
<td></td>
<td>Michael V. Pak</td>
<td>Research faculty, quantum computing and quantum information systems</td>
</tr>
<tr>
<td></td>
<td>Christopher A. Rice</td>
<td>Research faculty; image processing, laser development, remote sensing, rare-gas lasers</td>
</tr>
<tr>
<td>Rank</td>
<td>Name</td>
<td>Specialty</td>
</tr>
<tr>
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</tr>
<tr>
<td>Adjunct Faculty</td>
<td>John R. Bruzzese</td>
<td>Lasers, photonics (AFRL)</td>
</tr>
<tr>
<td></td>
<td>Xiaofeng Frank Duan</td>
<td>Computational chemistry and materials science (HPC)</td>
</tr>
<tr>
<td></td>
<td>Michel T. Eismann</td>
<td>Hyperspectral imaging (AFRL)</td>
</tr>
<tr>
<td></td>
<td>Kevin C. Gross</td>
<td>Molecular spectroscopy; remote sensing</td>
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<tr>
<td></td>
<td>F. Kenneth Hopkins</td>
<td>Directed energy, photonics devices (AFRL)</td>
</tr>
<tr>
<td></td>
<td>Gary S. Kedziora</td>
<td>Computational chemistry (HPC)</td>
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<tr>
<td></td>
<td>Tony D. Kelly</td>
<td>Nuclear engineering (AFTAC)</td>
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<td>Maj C. David Lewis II</td>
<td>Computational physics</td>
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<td>Joseph Meola</td>
<td>Hyperspectral imaging (AFRL)</td>
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<td>COL Buckley E. O’Day</td>
<td>Nuclear engineering; radiation health physics</td>
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<tr>
<td></td>
<td>Gregory A. Pitz</td>
<td>Diode pumped alkali laser, hollow core gas-filled fiber lasers, laser spectroscopy (AFRL)</td>
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<td>Mark Spencer</td>
<td>Adaptive optics, directed energy</td>
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<tr>
<td></td>
<td>Augustine M. Urbas</td>
<td>Metamaterials (AFRL)</td>
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<tr>
<td>Professor Emeritus</td>
<td>William F. Bailey</td>
<td>Plasma physics, space physics</td>
</tr>
<tr>
<td></td>
<td>Robert L. Hengehold</td>
<td>Experimental solid state physics</td>
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<tr>
<td></td>
<td>Kirk A. Mathews</td>
<td>Computational nuclear engineering</td>
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<tr>
<td>Rank</td>
<td>Name</td>
<td>Specialty</td>
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<tr>
<td>Adjunct Faculty</td>
<td>Professor Emeritus</td>
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</tr>
<tr>
<td></td>
<td>Adib J. Samin</td>
<td>Nuclear engineering, nuclear materials</td>
</tr>
<tr>
<td></td>
<td>LTC Michael B. Shattan</td>
<td>Nuclear engineering</td>
</tr>
<tr>
<td></td>
<td>Bryan J. Steward</td>
<td>EO/IR, remote sensing, OPIR, data exploitation, physical modeling</td>
</tr>
<tr>
<td></td>
<td>Lt Col Robert C. Tournay</td>
<td>Atmospheric science, land surface interaction, ML/AI forecasting</td>
</tr>
<tr>
<td></td>
<td>Gaiven Varshney</td>
<td>Research faculty; nuclear engineering</td>
</tr>
<tr>
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</tbody>
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8
Facilities

The Department of Engineering Physics is one of six academic departments in the Graduate School of Engineering and Management of the Air Force Institute of Technology (AFIT) located on Wright-Patterson Air Force Base (WPAFB), Ohio. The AFIT campus is comprised primarily of a series of interconnected buildings in Area B of WPAFB. The Department of Engineering Physics is located in Building 640 with in-residence courses taught primarily in Building 640 and the adjoining Building 646.

In addition to department offices and classrooms, the Department of Engineering Physics utilizes laboratories in Buildings 640, 644, and 470. The laboratories in Building 640 consist primarily of instructional laboratories, as well as research facilities dedicated to semiconductor characterization, photoluminescence excitation and emission, and image-based bi-directional reflectance distribution functions. Building 640 also houses a modeling and simulation facility devoted to research analysis of naturally occurring electrically charged gases (also known as geoplasmas) in the outer reaches of the Earth’s atmosphere. Research in this field is of growing concern to military operations. Faculty and students have acquired many of the leading space weather models within the DOD and scientific communities, along with the supporting data and software necessary to pursue publishable research.

Building 644 is a 29,914 gross square foot engineering research laboratory connected to the southeast corner of the Building 640. The Department of Engineering Physics operates laboratories within this facility to support faculty and student research at the M.S. and Ph.D. levels in laser spectroscopy, optics, solid state physics, Mossbauer spectroscopy, nuclear radiation detection, nuclear effects, and environmental engineering. The instructional laboratories complement courses of study in engineering physics, optical observables, nuclear radiation detection and instrumentation; nuclear and environmental engineering; space weather, optics, and lasers and optical diagnostics. Equipment is continually updated to remain abreast of the state-of-the-art in engineering physics, optical engineering, space weather, and nuclear engineering. There also exists a suite of three environmental science laboratories that provide research in remediation technologies, environmental sampling, remote sensing, and microbiology in support of the department’s research in nuclear proliferation and combating weapons of mass destruction.

Building 644 contains a clean room suite (class 1000) that enables the fabrication of microelectromechanical systems (MEMS), and micro- and opto-electronic devices; and integrated systems. The Clean Room supports basic research on advanced electronic and photonic materials. Coupled with the Clean Room is the Electronic Devices and Materials (Microelectronics) Laboratory, which contains an array of integrated circuit fabrication equipment and cutting edge diagnostic instrumentation. The fabrication facilities encompass complete photolithography, mask printing, thermal oxidation, dopant diffusion, and metallization capabilities. The diagnostic facilities include a sub-micron probe station, scanning electron microscope, atomic force microscope, cathodoluminescence, profilometer, and probe station.

Building 470, located apart from the AFIT complex, houses teaching and research laboratories that support our nuclear engineering program. These laboratories have up-to-date equipment for detecting and measuring sources of alpha, beta, gamma, and neutron radiation. These capabilities are updated constantly. Areas of focus include neutron and gamma-ray spectroscopy, gamma imaging, detection of nuclear fuels in trace quantities, and studies of radiation effects on materials and electronics. Data acquisition and analysis are carried out with a network of high-end PCs, complete with multi-channel analyzer software interfaced to computer-controlled nuclear electronics components. This system provides advanced data acquisition and data sharing between measurement stations. A radio-chemistry laboratory and radio nuclide storage facility support these laboratories. In addition, excellent equipment for nuclear analytical measurements is available, and a complete range of semiconductor characterization tools is available for studies of radiation effects on electronics.
Master of Science Programs

Introduction
The Master of Science (M.S.) programs in the Department of Engineering Physics are typically 6 quarters in length (18 months) and consist of a minimum of 48 credit hours. These 48 credit hours are divided between 36 credit hours of coursework and 12 credit hours of independent study. A Master of Science thesis is the result of the independent study. Most courses are 4 cr hrs (on the quarter system), with some laboratory and seminar courses of 2 cr hrs or 1 cr hr each.

While 48 credit hours is the requirement for the M.S. degree, almost all students will complete more. Courses required for a particular program may have prerequisites that the student may not have completed previously. Also, military students must take at least 12 credit hours per quarter for the 6 quarter duration of the program resulting in 72 credit hours. Each program is tailored to the “customer”. For military students, the gaining unit will expect a certain breadth of knowledge in your degree area that will require more than 36 credit hours of coursework. Your academic advisor will help you tailor your course plan so that you can fit in any additional electives.

Our department’s philosophy is to offer an exceptional graduate program of study by providing a broad foundation in the core topics of a degree program, complemented with the mathematical and applications courses, and culminating in a research activity. For many of our military students, the degree is a terminal Master’s degree, providing them with the extensive knowledge and technical expertise needed to successfully pursue their AF or Army careers. Therefore, the typical program of study far exceeds the minimal degree requirements of 48 cr hrs for military students.

Note: All military M.S. students will be required to take PHYS 598, Engineering Physics Seminar (1 cr hr) once during the MS program of study. This course introduces Department and School rules on thesis preparation and prepares students on how to complete the thesis document. All military M.S. students are also required to take PHYS 798, Department Seminar (1 cr hr) each quarter. Neither of these hours count in the required 48 hrs for the degree. Civilian students are encouraged to attend, but must not register for these two courses. During the last quarter of study, all M.S. students must register for 12 cr hrs of TENP 799. The grade assigned to the TENP 799 registration is the official thesis grade.

General Degree Requirements
All M.S. programs in the Department of Engineering Physics have the following general degree requirements, as detailed in the Graduate School of Engineering and Management Operating Instruction 36-135 (ENOI 36-135).

- The M.S. student must have obtained a bachelor’s degree with a major field of study appropriate to the program, or the equivalent, at least three quarters prior to the date of graduation.
- The M.S. student must have 48 credit hours of coursework and independent study combined in a program previously approved by the department. Thirty-six of these 48 credit hours must be in residence. Transfer credits may be accepted up to 12 credit hours.
- The M.S. student must have completed at least 12 credit hours of independent study. The independent study is an investigation into a problem of interest to the Department of Defense with the results presented to the department as a formal thesis. This thesis will be assigned a letter grade for 12 credit hours regardless of the larger number of independent study credit hours that may have been accumulated.
- For full-time DOD-sponsored students (quota students), all program requirements must be completed no later than five years after their initial planned graduation date, except as specified in ENOI 36-135.
- The M.S. student must have been recommended for the degree by the Faculty Council Academic Standards Committee of the Graduate School of Engineering and Management.
Admission Requirements - General
Mathematics: Ordinary differential equations is required for all department M.S. degree programs.

Test Required: GRE (general exam only; subject test not required); scores of 153 verbal and 148 quantitative (or 500 verbal and 600 quantitative for GREs taken prior to 1 August 2012).

Undergraduate GPA Required: Overall – 3.0; Mathematics – 3.0; Major – 3.0

Waivers to the above criteria may be granted on a case-by-case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply and allow the department to perform an academic evaluation.

Admission Requirements - Undergraduate Preparation
Applied Physics: An undergraduate degree in physics or a major with at least 24 semester hours of physics. US Air Force Academy graduates with Engineering Mechanics or Engineering Science are also eligible. Undergraduate majors in Engineering, Meteorology, Astronomy, or Chemistry may be approved by department review.

Atmospheric Science: An undergraduate degree in Atmospheric Sciences or Meteorology.

Countering Weapons of Mass Destruction: A Bachelor’s degree in a technical area (Engineering, Math, or Science) or one with sufficient technical content (e.g., USAFA or USMA core). Example technical degrees include Physics, Biology, Chemistry, Industrial Hygiene, or a medical field related to Physiology, Epidemiology, or Health Sciences.

Materials Science: An undergraduate degree in Materials Science, Mechanical Engineering, Chemistry, Physics, or related Engineering disciplines. The following courses are required: Introduction to Materials, Physical Chemistry, and Strength of Materials. Waivers may be approved by department review.

Nuclear Engineering: An undergraduate degree in Nuclear, Mechanical, Electrical, or Chemical Engineering or Physics. Some other Engineering and Math majors may also be approved by departmental review. Our master’s degree program in Nuclear Engineering is accredited by the Engineering Accreditation Commission of ABET. ABET accreditation is assurance that a college or university program meets the quality standards established by the profession for which it prepares its students. Thus, our accredited nuclear engineering program meets the quality standards set by the nuclear engineering profession. Therefore, while the AFIT graduate nuclear engineering program is unique, the program maintains a level of quality consistent with the broader nuclear engineering profession. ABET accreditation is a significant achievement, and we have worked hard to ensure that our program meets the quality standards set by the profession. Furthermore, because accreditation requires comprehensive, periodic evaluations, ABET accreditation demonstrates our continuing commitment to the quality of our program – both now and in the future. In addition to the academic criteria, this program also requires the ability to obtain a SECRET security clearance and appropriate certification to need to know. Interested civilian students should contact the Department of Engineering Physics for details.

Optical Sciences and Engineering: An undergraduate degree in Physics, or degree in Engineering or Physical Science with approval from the department.
**Summary of Important Dates for MS Students**  
*(for students carrying out thesis research in Department of Engineering Physics)*

<table>
<thead>
<tr>
<th>Event</th>
<th>Deadline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presentation of topics to students</td>
<td>1st and 2nd quarters</td>
</tr>
<tr>
<td>Selection of topics by students</td>
<td>No later than the 5th week of the 3rd quarter</td>
</tr>
<tr>
<td>Student submits prospectus</td>
<td>No later than Tuesday of the 10th week of the 3rd quarter</td>
</tr>
<tr>
<td>Student begins independent study</td>
<td>No later than the 4th quarter</td>
</tr>
<tr>
<td>Student concentrates on thesis work</td>
<td>5th quarter (typically)</td>
</tr>
<tr>
<td>Student submits progress reports and portions of draft</td>
<td>As required by the advisor</td>
</tr>
<tr>
<td>Student submits grading copy to advisor and committee</td>
<td>No later than Monday of the 2nd week of the final quarter</td>
</tr>
</tbody>
</table>

*(There will be a grade penalty for late submission to the committee unless previous approval has been given by the Department Head)*

<table>
<thead>
<tr>
<th>Event</th>
<th>Deadline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group oral presentations</td>
<td>As scheduled by the department (typically late Jan/early Feb)</td>
</tr>
<tr>
<td>Student defense of thesis to the committee</td>
<td>Scheduled by students and their thesis research committees</td>
</tr>
<tr>
<td>Thesis committee returns grading copy to student</td>
<td>No later than the Friday of the 5th week of the final quarter</td>
</tr>
<tr>
<td>Student submits final thesis document to Advisor/dept rep (may be library staff) for final review and approval</td>
<td>Monday of the 9th week of the final quarter</td>
</tr>
<tr>
<td>Thesis returned to student</td>
<td>COB Wednesday of the 9th week of the final quarter</td>
</tr>
<tr>
<td>Student submits approved final thesis</td>
<td>Monday of the 10th week of the final quarter</td>
</tr>
</tbody>
</table>
Applied Physics

Program Description
The Applied Physics program provides each student with a broad, graduate-level foundation in applied physics with degree requirements in the areas of mathematics, foundational physics, applications, laboratory work, and capstone courses. Analytic and numerical mathematics are important and students often take courses in both. Additionally, computational methods are used in many courses. Courses in electrodynamics, quantum mechanics, and thermal/statistical physics provide foundational physics. A course in classical dynamics is also available. Applications courses build on the foundational physics as well as other courses and provide breadth to the curriculum. Air Force organizations that employ our graduates consistently value the ability of the graduate to apply their knowledge to problems of interest to the organization. These problems change as the graduate moves to new Air Force organizations so they value graduates with breadth. One application course will typically be the start of specialized study in preparation for the student’s thesis research and two other application courses provide this breadth. Also, a graduate laboratory course is required. Rather than follow specific prescribed steps, graduate labs have students make decisions about what to measure to reach a goal, design the experiment, collect and analyze data, assess the results, and communicate results through papers and talks. Finally, students take a capstone course that integrates material from other courses in the program and is focused on a specific Air Force mission, problem area, or relevant technology.

The research experience is the culmination of graduate education. All students are required to complete and defend a thesis. Many students take other coursework to increase depth and prepare them for thesis research.

Students will take one of two educational tracks: engineering physics or space physics. Both tracks begin with the same foundation but the curriculum diverges with applications courses and beyond. The Engineering Physics track requires three applications courses designed to achieve an educational breadth, for example: plasma physics, solid state physics, and laser physics. The Space Physics track provides breadth across the ionosphere, magnetosphere and solar atmosphere.

Flexibility in the program is maintained to take full advantage of the varied backgrounds and abilities of the students. The specific courses in the curriculum vary depending on the specialization pursued and, in the case of an Air Force officer, the requirements associated with the officer’s assigned Air Force academic specialty code or follow-on assignment. Also, for students who need more preparation, we offer pre-requisite courses.

Concentration in the two tracks is described below:

**Engineering Physics:** a broad range of applied physics topics, including the areas of laser physics, infrared systems, remote sensing, solid state physics, and plasma physics. Emphasis is placed on the application of basic physics to a variety of engineering areas, such as directed energy weapons, remote sensing, molecular dynamics, photonics, surveillance, and countermeasures.

**Space Physics:** encompasses the variations in the Earth’s magnetosphere, ionosphere, and subsequent effects of the space environment on the propagation of electromagnetic waves, communication, space operations, and manned space flight. An understanding of solar effects on the near-earth environment and ramifications on military operation is achieved.

In both tracks, emphasis is placed on applying basic physical principles together with current state-of-the-art computational and experimental techniques to address Air Force and DoD problems.
Program Educational Objectives (PEOs)
The PEOs of the Applied Physics program identify desired capabilities and anticipated activities of our graduates three years after graduation:
1. Direct or perform research; conduct and evaluate design and analysis; and communicate their work clearly, working independently and in groups, with a focus on applications of interest to the commands to which they are assigned after graduation.
2. Learn program details and technologies in their new areas of responsibility and apply the skills and tools learned at the Air Force Institute of Technology.
3. Apply knowledge and skills to solve problems that arise in the technical work they conduct or supervise.
4. Study an issue, identify, and evaluate alternative actions, propose appropriate courses of action, and identify optimal choices.
5. Develop and implement programs, working within their organizations, to implement the chosen solution.
6. Write, edit, and/or supervise the preparation by contractors or subordinates of written reports, journal articles, military briefings, and professional presentations that clearly communicate their work and support the needs of decision makers; present their ideas effectively and defend them appropriately.
7. Develop and implement, or sustain and improve, programs that entail multidisciplinary research, simulation, modeling, engineering design, production, and/or fielding of engineered systems.

Program Outcomes (POs)
The POs of the Applied Physics program identify desired capabilities and anticipated activities of our graduates upon degree completion:
1. Apply advanced concepts in mathematics and physics, including analytic & computational methods, electrodynamics, quantum mechanics, and statistical physics, to applications in the areas of laser/optics technology, materials physics, plasma physics, space physics, nuclear physics, and atmospheric science which support AF and DOD mission requirements.
2. Perform research, design, and analysis, working independently and in groups, with a focus on applications of interest to the Commands for which they are assigned after graduation.
3. Understand and critically evaluate technical communications in the form of journal articles, research proposals, and conference presentations and contribute and communicate their results and understanding in these same forums.

USAF Academic Specialty Codes supported by this degree
4KDY, Engineering Physics; 8FDD, Ionospheric Environment; 8FDY, Solar and Space Sciences (21 month); 8HCG, Lasers, Atomic and Molecular Physics; 8HCX, Atomic and Molecular Physics, Other; 8HCY, Atomic and Molecular Physics; 8HEY, Electromagnetism; 8HFG, Physics, Semiconductor Devices; 8HFX, Physics, Electronics, Other; 8HFY, Electronics; 8HY, Engineering Physics; 8HKY, Nuclear Effects Physics; 8HLB, Nuclear Physics, Detectors; 8HLC, Nuclear Physics, Neutrons; 8HLH, Radioactive Material and Isotopes; 8HLY, Nuclear Physics; 8HMA, Atmosphere and Space Optics; 8HMH, Infrared Phenomena; 8HMI, Lasers; 8HMY, Optics; 8HNI, Plasma Physics; 8HOS, Semiconductors; 8HOX, Solid State Physics, Other; 8HOY, Solid State Physics; 8HOZ, Space Physics; 8HYY, Physics, General
Requirements for Masters of Science in Applied Physics

A student in the Applied Physics program is required to complete at least 48 graduate credit hours for the M.S. degree. The 48 credit hours include:

- 4 credit hours  Mathematics at the 500 or higher level
- 12 credit hours  Foundational Physics
- 12 credit hours  Applications Courses
- 4 credit hours  Graduate Laboratory
- 4 credit hours  Capstone Course
- 12 credit hours  Independent Study (research)

Specific courses are determined by track, the student’s academic specialty code (AF officer only), previous background, and area of specialization. Education plans are approved by the academic advisor prior to enrollment in courses. Most students will take additional courses beyond the 48 hour requirement to meet prerequisite requirements, to satisfy knowledge requirements specific to the needs of their sponsors or research topic, to develop the breadth of experience to lead a rich and varied career, and to satisfy the student’s intellectual curiosity.

One mathematics course is required (though interested students usually take two), typically chosen from:

- MATH 504  Differential Equations of Mathematical Physics
- MATH 508  Applied Numerical Methods
- MATH 511  Methods of Applied Mathematics I
- MATH 521  Applied Linear Algebra

Foundational physics courses establish the foundation for application, capstone, and other specialization courses. The required 12 credit hours are satisfied with:

- PHYS 601  Electrodynamics I
- PHYS 635  Thermal Physics
- PHYS 655  Quantum Mechanics

Well prepared students may substitute any of the following for the respective 600 level course:

- PHYS 730  Electrodynamics II
- PHYS 735  Statistical Physics
- PHYS 755  Quantum Mechanics II

The applications requirements are met through courses specific to the educational track and research specialization. Examples of available application courses include:

(a) Engineering Physics Track. Three of:
- NENG 605  Physics of Nuclear Explosives
- NENG 660  Radiation Effects on Electronics
- OENG 620  Laser Engineering
- OENG 650  Optical Radiometry and Detection
- PHYS 650  Kinetic Theory of Plasmas
- PHYS 661  Atomic and Molecular Spectroscopy
- PHYS 670  Introduction to Solid State Physics
- PHYS 757  Quantum Computing

(b) Space Physics Track. All of:
- PHYS 775  Ionospheric Physics and Chemistry
- PHYS 776  Structure and Dynamics of the Magnetosphere
- PHYS 777  The Solar Atmosphere
Students will take one graduate laboratory course from the following:

- NENG 612  Nuclear Engineering Laboratory
- NENG 664  Radiation Effects on Electronics Laboratory
- OENG 616  Electro-Optical Systems Laboratory
- OENG 651  Optical Diagnostics Laboratory
- PHYS 792  Space Weather Laboratory

The capstone course is chosen from one of the following courses:

- NENG 791  Non-Proliferation of Nuclear Weapons and Technologies
- OENG 647  Hyperspectral Remote Sensing
- OENG 720  Laser Devices and Applications
- OENG 775  Introduction to Photonic Devices
- OENG 780  Infrared Technology
- PHYS 791  Operational Assessments in Space Sciences

Beyond these requirements, complementary courses are selected for each student depending upon the academic specialty code assigned, requirements from the follow-on unit, and/or the student’s interests and needs. These courses provide more depth, assistance to underprepared students, or satisfy a student’s interest and desire to learn. Complementary courses are normally derived from the lists above and below, but others are available:

- CHEM 675  Upper Atmospheric Chemistry
- CHEM 720  Kinetics of Fast Reactions
- MATL 525  Thermodynamics and Kinetics of Materials
- MATL 672  Optical Properties of Materials
- METG 610  Radiative Transfer
- NENG 651  Nuclear Physics
- OENG 644  Linear Systems and Fourier Optics
- OENG 660  Introduction to Non-Linear Optical Devices
- PHYS 519  The Space Environment
- PHYS 531  Electromagnetism
- PHYS 542  Optics Laboratory
- PHYS 556  Introduction to Quantum Physics
- PHYS 600  Dynamics
- PHYS 640  Optics
- PHYS 740  Optics II
- PHYS 781  Laser Spectroscopy
- MATH 5XX or 6XX  Additional mathematics
- STAT 5XX or 6XX  Courses in statistics and/or probability

All full-time military students are required to enroll in PHYS 798, Departmental Seminar, each quarter and are required to take PHYS 598, Engineering Physics Thesis Seminar.

All students are required to satisfy the 12-credit-hour (minimum) research requirement by enrolling in PHYS 799, Thesis Research, in quarters as directed by their academic and research advisors. Registration for a total of 12 credit hours of TENP 799 must be accomplished in the quarter they defend their thesis, typically the last quarter. This course is an administrative place holder used to assign the thesis grade and does not represent extra credit hours taken in the quarter.
To clearly identify how certain academic specialty codes are serviced in the different tracks, the following table is provided. For each program track below, some academic specialty codes and three (or more) typical courses satisfying the academic specialty are listed as examples.

**Engineering Physics:**
- 8HKY, Nuclear Effects Physics
  - NENG 605, NENG 631, NENG 635
- 8HLY, Nuclear Physics
  - NENG 605, NENG 650, NENG 651
- 8HMJ, Lasers
  - OENG 620, OENG 651, OENG 720
- 8HMY, Optics
  - OENG 620, OENG 644, OENG 650
- 8HYY, General Physics
  - PHYS 601, PHYS 635, PHYS 655

**Space Physics**
- 8FDD, Ionospheric Environment
  - CHEM 675, PHYS 650, PHYS 775
- 8FDY, Solar Environment
  - CHEM 675, PHYS 775, PHYS 776, PHYS 777
- 8HOZ, Space Physics
  - CHEM 675, PHYS 775, PHYS 776, PHYS 777

Two sample curricula are show on the next two pages, one for each track. A student’s actual coursework will be determined by the factors listed previously and will be codified in an Education Plan after the student meets with their academic advisor before they start taking classes.
### Engineering Physics Track
**(Sample Curriculum)**

Short Term Review Session (4 weeks) includes: Calculus and Differential Equations, Physics, and Computational Review

Typical program shown below is for a full-time resident student under DOD sponsorship; minimum required registration each quarter is 12 credit hours.

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Course Code</th>
<th>Course Title</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Quarter, Fall</td>
<td>MATH 504</td>
<td>Differential Equations of Math Physics</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>PHYS 601</td>
<td>Electrodynamics I</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>PHYS 640</td>
<td>Optics</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>PHYS 655</td>
<td>Quantum Mechanics</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>PHYS 798</td>
<td>Departmental Seminar</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>17</strong></td>
</tr>
<tr>
<td>2nd Quarter, Winter</td>
<td>MATH 508</td>
<td>Applied Numerical Methods</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>PHYS 635</td>
<td>Thermal Physics</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>PHYS 661</td>
<td>Atomic &amp; Molecular Spectroscopy</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>PHYS 798</td>
<td>Departmental Seminar</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>13</strong></td>
</tr>
<tr>
<td>3rd Quarter, Spring</td>
<td>OENG 620</td>
<td>Laser Engineering</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>PHYS 542</td>
<td>Optics Laboratory</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>PHYS 598</td>
<td>Engineering Physics Thesis Seminar</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>PHYS 650</td>
<td>Kinetic Theory of Plasmas</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>PHYS 670</td>
<td>Solid State Physics</td>
<td>4</td>
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<tr>
<td></td>
<td>PHYS 798</td>
<td>Departmental Seminar</td>
<td>1</td>
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<td></td>
<td></td>
<td></td>
<td><strong>16</strong></td>
</tr>
<tr>
<td>4th Quarter, Summer</td>
<td>OENG 651</td>
<td>Optical Diagnostics Laboratory</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>PHYS 798</td>
<td>Departmental Seminar</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>PHYS 799</td>
<td>Thesis Research</td>
<td>4</td>
</tr>
<tr>
<td></td>
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</tr>
<tr>
<td>5th Quarter, Fall</td>
<td>PHYS 798</td>
<td>Departmental Seminar</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>PHYS 799</td>
<td>Thesis Research</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>13</strong></td>
</tr>
<tr>
<td>6th Quarter, Winter</td>
<td>PHYS 798</td>
<td>Departmental Seminar</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>PHYS 799</td>
<td>Thesis Research (as needed)</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>TENP 799</td>
<td>ENP Thesis (required for thesis grade, does not count as extra hours)</td>
<td>12*</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Two courses typically chosen from:</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>OENG 650 Radiometry and Detection</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>OENG 720 Laser Devices and Applications</td>
<td></td>
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<td></td>
<td></td>
<td>OENG 775 Photonics</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PHYS 600 Dynamics</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PHYS 740 Optics II</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>13</strong></td>
</tr>
</tbody>
</table>
Space Physics Track  
(Sample Curriculum, 21 months)

Short Term Review Session (4 weeks) includes: Calculus and Differential Equations, Physics, and Computational Review

Typical program shown below is for a full-time resident student under DOD sponsorship; minimum required registration each quarter is 12 cr hrs.

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Course Code</th>
<th>Course Title</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Quarter, Summer</td>
<td>MATH 511</td>
<td>Methods of Applied Mathematics I</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>PHYS 531</td>
<td>Electromagnetism</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>PHYS 556</td>
<td>Introduction to Quantum Physics</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>PHYS 798</td>
<td>Departmental Seminar</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>13</td>
</tr>
<tr>
<td>2nd Quarter, Fall</td>
<td>PHYS 519</td>
<td>The Space Environment</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>PHYS 601</td>
<td>Electrodynamics I</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>PHYS 655</td>
<td>Quantum Mechanics</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>PHYS 798</td>
<td>Departmental Seminar</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>13</td>
</tr>
<tr>
<td>3rd Quarter, Winter</td>
<td>CHEM 675</td>
<td>Upper Atmospheric Chemistry</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>PHYS 600</td>
<td>Dynamics</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>PHYS 635</td>
<td>Thermal Physics</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>PHYS 798</td>
<td>Departmental Seminar</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>13</td>
</tr>
<tr>
<td>4th Quarter, Spring</td>
<td>MATH 508</td>
<td>Applied Numerical Methods</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>PHYS 598</td>
<td>Engineering Physics Thesis Seminar</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>PHYS 650</td>
<td>Kinetic Theory of Plasmas</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>PHYS 775</td>
<td>Ionospheric Physics and Chemistry</td>
<td>4</td>
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<tr>
<td></td>
<td>PHYS 798</td>
<td>Departmental Seminar</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>13</td>
</tr>
<tr>
<td>5th Quarter, Summer</td>
<td>PHYS 776</td>
<td>Structure and Dynamics of the Magnetosphere</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>PHYS 777</td>
<td>The Solar Atmosphere</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>PHYS 798</td>
<td>Departmental Seminar</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>PHYS 799</td>
<td>Thesis Research</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>13</td>
</tr>
<tr>
<td>6th Quarter, Fall</td>
<td>PHYS 798</td>
<td>Departmental Seminar</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>PHYS 799</td>
<td>Thesis Research</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>13</td>
</tr>
<tr>
<td>7th Quarter, Winter</td>
<td>PHYS 791</td>
<td>Operational Assessments in Space Sciences</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>PHYS 792</td>
<td>Space Weather Laboratory</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>PHYS 798</td>
<td>Departmental Seminar</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>PHYS 799</td>
<td>Thesis Research (as needed)</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>TENP 799</td>
<td>ENP Thesis (required for thesis grade, does not count as extra hours)</td>
<td>12*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>13</td>
</tr>
</tbody>
</table>
Atmospheric Science

Program Description

This program provides a broad foundation in Atmospheric Science (Atm Sci) at the graduate level with an emphasis in atmospheric dynamics, physics and remote sensing, as well as numerical weather prediction (NWP) techniques. The program is designed to provide the graduate student with critical thinking and technical capabilities in order to develop a scientifically sound course of action to solve a problem plaguing operational units.

The program length is six quarters for full-time students, although an additional quarter of mathematics review may be added to the curriculum, when necessary. The first two quarters usually stress foundational atmospheric physics/dynamics and mathematics. During the remaining quarters, the student concentrates on applied and specialized courses and pursues research in an area of specialization.

Each student must complete an independent study/thesis and a number of courses in the area of specialization. Flexibility in the program is maintained to take full advantage of the varied backgrounds and abilities of the students. The specific courses in the curriculum vary depending on the specialization pursued and the requirements associated with the student’s assigned Air Force education code.

Emphasis is placed on applying basic physical principles together with current state-of-the-art computational and experimental techniques to address Air Force and DoD problems.

Admission Requirements

Degree: An undergraduate degree in Atmospheric Science or Meteorology.

Mathematics: Ordinary differential equations is required for all department M.S. degree programs.

GRE: (general exam only; subject test not required); scores of 153 verbal and 148 quantitative (or 500 verbal and 600 quantitative for GREs taken prior to 1 August 2012).

GPA Required: Overall – 3.0; Mathematics – 3.0; Major – 3.0

Waivers to the above criteria may be granted on a case-by-case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply and allow the department to perform an academic evaluation.

Program Educational Objectives (PEOs)

The PEOs of the Atmospheric Science program identify desired capabilities and anticipated activities of our graduates three years after graduation:

1. Direct or perform basic research; conduct and evaluate design and analysis; and communicate their work clearly, working independently and in groups, with a focus on applications of interest to the commands to which they are assigned after graduation.

2. Learn program details and technologies in their new areas of responsibility and apply the skills and tools learned at the Air Force Institute of Technology.
3. Apply knowledge and skills to solve problems that arise in the technical work they conduct or supervise.

4. Study an Air Force weather operational issue, identify and evaluate alternative actions, propose appropriate courses of action, and identify optimal choices.

5. Develop and implement programs, working within their organizations, to implement the chosen solution.

6. Develop and implement, or sustain and improve, programs that entail multidisciplinary research, simulation, modeling, engineering design, production, and/or fielding of engineered systems.

7. Write, edit and/or supervise the preparation of reports, journal articles, military briefings, and professional presentations that clearly communicate their work and support the needs of decision makers; present their ideas effectively and defend them appropriately.

Program Outcomes (POs)

The POs of the Atmospheric Science program identify desired capabilities and anticipated activities of our graduates upon degree completion:

1. Apply advanced concepts in mathematics atmospheric dynamics and physics, including analytic, computational and statistical methods to applications in the areas of atmospheric science which support AF and DoD mission requirements.

2. Perform research, design, and analysis, working independently and in groups, with a focus on applications of interest to the commands for which they are assigned after graduation.

3. Understand and critically evaluate technical communications in the form of journal articles, research proposals, and conference presentations. Be able to contribute and communicate their results and understanding in these same forums.

Education codes supported

8FAC, Numerical Weather Prediction; 8FAY, Atmospheric Dynamics; 8FBY, Climatology; 8FEA, Synoptic Meteorology; 8FEG, Radar Meteorology; 8FEH, Satellite Meteorology; 8FEI, Tropical Meteorology; 8FEY, Analysis and Forecasting; 8FFA, Atmospheric Electricity; 8FFD, Cloud/Precipitation Physics; 8FFE, Radiative Transfer; 8FFY, Physical Meteorology; 8FAS, General Meteorology

Degree Requirements

A student in the Atmospheric Science program is required to complete at least 48 graduate credit hours for the M.S. degree. The 48 credit hours include:

- 12 credit hours: Independent Study (research)
- 12 credit hours: Atmospheric Science Core
- 8 credit hours: Mathematics and Statistics
- 8 credit hours: Application Courses
- 8 credit hours: Complementary Courses

The specific courses are determined by the student’s education code (AF only), previous background, and area of specialization. Most students will take additional courses beyond the 48 hour requirement to meet prerequisite requirements (such as PHYS 519, The Space Environment; METG 610, Radiative Transfer, and METG 620, Advanced Atmospheric Dynamics), to satisfy knowledge requirements specific to their follow-on assignment and to develop the breadth of experience to lead a rich and diverse career. Education plans are approved by your academic advisor prior to enrollment in courses.
All military students are required to enroll in PHYS 798, Departmental Seminar, each quarter and are required to enroll in PHYS 598, Engineering Physics Seminar, during spring quarter.

All students are required to satisfy the 12-credit-hour (minimum) research requirement by enrolling in:

METG 799  Thesis Research.

Additionally registration for a total of 12 credit hours of TENP 799 must be accomplished in the last quarter in order for the thesis grade to be counted.

TENP 799  (required for thesis grade)

Core Atmospheric Science courses establish the foundation for the program. The required 12 credit hours in this category are chosen from the following:

METG 612  Cloud Physics
METG 644  Satellite Meteorology
METG 650  Numerical Weather Prediction (NWP) for Scientists and Engineers

One mathematics and one statistical course is required at 4 credit hours each. Depending on undergraduate preparation and individual interest, students often take more such courses. These are typically chosen from:

MATH 508  Applied Numerical Methods
MATH 509  Mathematical Methods in the Physical Sciences
MATH 511  Methods of Applied Mathematics I
STAT 583  Introduction to Probability and Statistics
STAT 587  Applied Probability and Statistical Analysis

Two application courses of 8 credit hours are normally selected from the list below by each student depending upon the officer’s interests:

METG 642  Radar Meteorology
METG 655  Fine-Scale, Specialized and Probabilistic NWP
METG 640  Applied Climatology

Beyond these research, core, mathematic, statistic and application requirements, two additional complementary courses of 8 credit hours are normally selected from the list below to provide further scientific depth:

PHYS 521  Space Surveillance
METG 634  General Circulation and Tropical Meteorology
METG 660  Operational Assessments in Atmospheric Science Laboratory
MATH XXX  additional math
To clearly identify how specific educational codes are serviced within the program, the following table is provided as an example.

**Sample Education Plan**

**Atmospheric Science Track**  
**(Curriculum, 18 months)**

Short Term Review Session (4 weeks) includes: Calculus and Differential Equations, Atmospheric Science, MATLAB and Computational Review.

Typical program shown below is for a full-time resident student under DoD sponsorship; minimum required registration each quarter is 12 cr hrs.

<table>
<thead>
<tr>
<th>Quarter, Fall</th>
<th>Course Code</th>
<th>Course Name</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>MATH 511</td>
<td>Methods of Applied Mathematics I</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>PHYS 519</td>
<td>The Space Environment</td>
<td>4</td>
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<tr>
<td></td>
<td>PHYS 798</td>
<td>Departmental Seminar</td>
<td>1</td>
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<tr>
<td></td>
<td>STAT 587</td>
<td>Applied Probability and Statistical Analysis</td>
<td>4</td>
</tr>
<tr>
<td></td>
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<td>Total</td>
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<table>
<thead>
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<th>Quarter, Winter</th>
<th>Course Code</th>
<th>Course Name</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>2nd</td>
<td>METG 612</td>
<td>Cloud Physics</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>METG 620</td>
<td>Advanced Atmospheric Dynamics</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>METG 634</td>
<td>General Circulation and Tropical Meteorology</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>PHYS 798</td>
<td>Departmental Seminar</td>
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<table>
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<th>Quarter, Spring</th>
<th>Course Code</th>
<th>Course Name</th>
<th>Credit Hours</th>
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<tr>
<td>3rd</td>
<td>METG 610</td>
<td>Radiative Transfer</td>
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<tr>
<td></td>
<td>METG 644</td>
<td>Satellite Meteorology</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>METG 650</td>
<td>Numerical Weather Prediction (NWP) for Scientists</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>PHYS 598</td>
<td>Engineering Physics Seminar</td>
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</tr>
<tr>
<td></td>
<td>PHYS 798</td>
<td>Departmental Seminar</td>
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</tr>
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<th>Course Name</th>
<th>Credit Hours</th>
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<tbody>
<tr>
<td>4th</td>
<td>METG 640</td>
<td>Applied Climatology</td>
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<td></td>
<td>METG 642</td>
<td>Radar Meteorology</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>METG 655</td>
<td>Fine Scale, Specialized and Probabilistic NWP</td>
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<tr>
<td></td>
<td>METG 799</td>
<td>Thesis Research</td>
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<td>PHYS 798</td>
<td>Departmental Seminar</td>
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<table>
<thead>
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<th>Course Name</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>5th</td>
<td>METG 799</td>
<td>Thesis Research</td>
<td>12</td>
</tr>
<tr>
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<td>PHYS 798</td>
<td>Departmental Seminar</td>
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<td>Total</td>
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<table>
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<th>Quarter, Winter</th>
<th>Course Code</th>
<th>Course Code</th>
<th>Course Name</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>6th</td>
<td>METG 660</td>
<td></td>
<td>Operational Assessments in Atmospheric Science</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>METG 799</td>
<td></td>
<td>Thesis Research (as needed)</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>PHYS 798</td>
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<td>Departmental Seminar</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>TENP 799</td>
<td></td>
<td>(Required for thesis grade—does not count as extra</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>12 cr hrs)</td>
<td>&gt;12</td>
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Materials Science

Program Description
The goal of the Materials Science program is to provide a student who has a background in engineering or physical science with the knowledge of materials science and engineering necessary for work in the fields of structural and non-structural materials for aerospace systems. Such positions may range from those requiring very detailed and advanced level work in a specific discipline to those involving broad responsibilities and requiring interaction among many disciplines.

The Materials Science program is under joint supervision of the Department of Aeronautics and Astronautics (Structural Materials) and the Department of Engineering Physics (Electrical and Optical Materials, i.e., Non-Structural Materials). This program is normally six quarters in length. Five quarters are devoted to coursework, and one quarter is devoted to thesis research.

The program provides core preparation in thermodynamics and kinetics of materials, mechanical, electronic, and optical properties of materials, material characterization, material selection and processing, and mathematics. The materials studies emphasize atomic models of structure composition and proper- ties. Each student is also required to take an in-depth study and perform research either in structural materials (metallic, composite, polymer, ceramics, etc.) or non-structural materials (electronics, optical, magnetic, dielectric, nanoscale, nuclear, etc.). Emphasis is placed on applications of fundamental knowledge to the design, development, test, and evaluation of materials for Air Force and DOD systems. The student will master at least one specialty area in optical materials, electronic materials, dielectric materials, magnetic materials, nanoscale materials, nuclear materials, or computational materials science. Such positions may range from those requiring very detailed and advanced level work in a specific discipline to those involving broad responsibilities and requiring interaction among many disciplines.

Program Educational Objectives (PEOs)
The PEOs of the Materials Science program ensure that graduates are prepared to perform the following tasks successfully:
1. Possess a solid background in the fundamental areas of materials science and engineering (structural and non-structural materials, thermodynamics and kinetics, materials characterization, and materials selection and processing).
2. Possess an in-depth knowledge in at least one specialty area.
3. Possess experience in conducting and documenting an independent investigation, a thesis, or a problem of Air Force interest.

Program Outcomes (POs)
The POs of the Materials Science program describe what students will know or be able to perform upon degree completion:
1. Demonstrate a high level of understanding of mathematics, science, and engineering as it applies to properties and characterization of structural materials, electronic materials, and optical materials.
2. Demonstrate the ability to measure, analyze, and report results of measuring and modeling of materials properties.
3. Demonstrate the ability to develop, describe, and conduct significant research to meet a specific materials science objective.
4. Demonstrate educational accomplishments in materials science by presenting results of a research investigation into a problem of current or future defense interest that they planned and executed.
USAF Education Codes
Air Force students are typically assigned one of the following education codes: 4FYY, Materials Science and Engineering, General; 4KCB, Mechanical Properties of Materials; 4FBY, Electronic and Optical Materials; 4GCK, Nuclear Chemical Engineering; 4FCY Ceramic Engineering. Current sponsors of Air Force military education quotas are 4FYY - AFRL/RXPSE (WPAFB and Robins AFB), 4KCB - AFRL/RXLMN (WPAFB), 4NCY - AFRL/RXLMP (WPAFB), 4FBY - AFRL/RDHP (Kirtland AFB), AFRL/RXLP and AFRL/RYD (WPAFB).

Requirements in Materials Science
The Materials Science curriculum is built around five principle elements:

- Basic Materials Core
- Mathematics
- Specialty Sequence
- Thesis
- Elective Courses

The specific program requirements are five core courses in Materials Science and Engineering or equivalents, at least one graduate mathematics course, a 3-course specialty sequence, and an approved thesis. Additional elective courses are taken to achieve the 48 hour minimum requirement.

Basic Materials Core
Each student who graduates with a Master of Science (Materials Science) must have a foundation in the theoretical and applied aspects of the fundamental areas of materials. This foundation is laid through a core of courses taken by all materials science and engineering students. The five core courses are:

- MATL 525  Thermodynamics and Kinetics of Materials
- MATL 545  Mechanical Properties of Materials
- MATL 560  Electronic, Magnetic, and Optical Properties of Materials
- MATL 680  Materials Characterization
- MATL 685  Materials Selection and Processing

Mathematics
The second element of the Materials Science curriculum is mathematics. Nearly all students take one or more mathematics courses selected to facilitate student learning and research. Each student must complete at least one graduate-level mathematics course. A second course is highly desirable. The particular courses each student takes are based upon background and area of specialization. These cover some of the following topics: advanced calculus, complex variables, Fourier series and boundary value problems, linear algebra, numerical methods, and probability/statistics. Some AFIT courses designed to accomplish this goal are:

- MATH 511  Methods of Applied Math I
- MATH 513  Methods of Applied Math II
- STAT 527  Introduction to Probability
- STAT 537  Introduction to Statistics
- MATH 508  Numerical Methods

Mastery of a computational software tool (e.g., MatLab, Mathematica, or other) is required.

Specialty Sequence
The third element of the Materials Science curriculum consists of the specialty sequence. Each student is required to take one such sequence with the option of adding a second. These sequences, each composed of at least three courses, form a coherent body of knowledge in a particular area and provide the
student with a strong theoretical background for eventual applications in thesis work and post-graduation assignments. The specialty sequence can provide tools and expertise in a material area selected for research.

**Thesis**
The fourth element of the Materials Science program, the thesis, is an independent investigation of a problem of current Air Force interest, conducted and documented by the student, with supervision of the faculty. This independent study for a minimum of 12 credit-hours may be done under the direction of either the Department of Aeronautics and Astronautics (for structural materials) or the Department of Engineering Physics (for non-structural materials). A thesis can be theoretical, experimental, or numerical. Flexibility in the program is maintained in order to take full advantage of the varied backgrounds and abilities of individual students.

**Elective Courses**
Opportunities to take supporting courses and elective courses are provided. Also included are seminars covering current technical developments and Air Force projects. Electives are used to make up for undergraduate deficiencies, prepare for future assignments, increase depth in a specialty, develop an additional specialty, or pursue individual interests in taking courses not normally found in a materials science and engineering program.

**Advising—Joint Program**
This program is multidisciplinary in nature and will be updated, changed, and/or modified in consultation with the Materials and Manufacturing Directorate, Air Force Research Laboratory. Students with Ed Codes of 4FAY and 4FBY will be the responsibility of ENY and ENP, respectively, and will accordingly follow the rules and regulations of these departments. Students with the general Ed Code 4FY will initially be advised on topics available in both departments ENY and ENP, and will be allowed the opportunity to choose depending on their interest and background in the area of Structural (ENY) or Non-Structural (ENP) materials.
Materials Science (Electrical and Optical Materials)  
(Sample Curriculum)

Short Term Review Session (4 weeks) includes: Calculus and Differential Equations, Chemistry, and Computational Review

Typical program shown below is for a full-time resident student under DOD sponsorship; minimum required registration each quarter is 12 cr hrs.

1st Quarter, Fall
Math
- MATL 545  Mechanical Properties of Materials  4 cr
- MATL 560  Electronic, Magnetic and Optical Materials  4 cr
- Sequence/Elective/Prerequisite  4 cr
- PHYS 798  Departmental Seminar  1 cr

Credit Hours:  17

2nd Quarter, Winter
Math
- MATL 680  Materials Characterization  4 cr
- Sequence/Elective  4 cr
- Sequence/Elective  4 cr
- PHYS 798  Departmental Seminar  1 cr

Credit Hours:  17

3rd Quarter, Spring
- MATL 525  Thermodynamics and Kinetics of Materials  4 cr
- MATL 685  Materials Selection and Processing  4 cr
- Sequence/Elective  4 cr
- Elective  4 cr
- PHYS 598  Engineering Physics Thesis Seminar  1 cr
- PHYS 798  Departmental Seminar  1 cr

Credit Hours:  18

4th Quarter, Summer
- MATL 799  Thesis Research  4 cr
- Sequence/Elective  4 cr
- Sequence/Elective  4 cr
- PHYS 798  Departmental Seminar  1 cr

Credit Hours:  >12

5th Quarter, Fall
- MATL 799  Thesis Research  8 cr
- Sequence/Elective  4 cr
- PHYS 798  Departmental Seminar  1 cr

Credit Hours:  13

6th Quarter, Winter
- MATL 799  Thesis Research (if needed)  4 cr
- Sequence/Elective  4 cr
- Sequence/Elective  4 cr
- TENP 799  (required for thesis grade—*does not count as extra 12 cr hrs)  12* cr
- PHYS 798  Departmental Seminar  1 cr

Credit Hours:  >12
Nuclear Engineering

Program Description
This program provides each student with a broad foundation in nuclear technology and engineering at the graduate level. The unique combination of coursework and laboratory practice provides the student with experience working in the fields of proliferation of nuclear weapons, nuclear detection, nuclear weapon effects, nuclear forensics, the nuclear fuel cycle and nuclear power.

Curriculum
This program is normally six quarters in length (18 months). Five quarters are devoted to coursework, and one to thesis research. The research is normally conducted at the Air Force Institute of Technology. The first quarter is focused on neutron transport, fuels, and reactors, to provide a strong foundational basis for the subsequent core and applications courses. The following two quarters build on the first, providing deeper meaning and practice to the concepts. The fourth quarter includes advanced labs, designed to establish the skills needed to conduct research. The fifth quarter research is devoted to independent thesis research. In the final quarter, the thesis is defended and revised, as necessary, while the final coursework expands the program elements into present day analyses of problems students may face after graduation.

The program satisfies the Air Force education codes 4QYY (nuclear engineering) with subspecialties, 4QCY (Nuclear Radiation Effects), 4QDY (Nuclear Weapons of Mass Destruction) as well as 8HKY (Nuclear Effects Physics) and 8HLY (Nuclear Physics). The Commission on Institutions of Higher Education of the North Central Association of Colleges and Schools accredits the Air Force Institute of Technology through the doctoral degree level. The Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology, Inc. (ABET) also accredits certain engineering programs. The nuclear engineering program is ABET accredited at the MS level. ABET accreditation demonstrates our continuing commitment to the quality of our program—both now and in the future.

Program Educational Objectives (PEOs)
Our graduates, in their first (and subsequent) assignments within the military nuclear science and engineering career field, will be called upon to perform some or all of the following tasks:
1. Develop Technical Skills: Understand mathematics, computational modeling, science, and engineering and apply them to problems of interest to the Air Force and DoD.
2. Perform Analysis: Conduct measurements and experiments; evaluate data, and interpret results.
3. Communicate: Communicate technical subjects orally and in writing with peers and to supervisors
4. Behave Ethically: Act ethically in all aspects of science and engineering

AFIT Nuclear Engineering Student Outcomes
At graduation, students will have demonstrated:
1. A high level of understanding of mathematics, science, and engineering as it applies to nuclear weapons and effects.
2. An ability to design, develop, and conduct nuclear science and engineering related research to meet a specified objective or goal.
3. An ability to measure, analyze, and report the results of nuclear and radiation processes and measurements.
4. An ability to apply their education to research, and analyze a technical problem related to the needs of the defense of the nation.

**USAF Education Codes**
4QYY, Nuclear Engineering, General; 4QCY, Nuclear and Radiation Effects; 4QDY, Nuclear Reactor Engineering; 8HKY, Nuclear Effects Physics; 8HLY, Nuclear Physics

**Program Requirements**
A student in this program is required to submit at least 48 graduate credit hours for the degree. These credit hours must include the following:

<table>
<thead>
<tr>
<th>Credit Hours</th>
<th>Course Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Thesis Research</td>
</tr>
<tr>
<td>4</td>
<td>Mathematics at the 500 or higher level</td>
</tr>
<tr>
<td>24</td>
<td>Nuclear Engineering Core</td>
</tr>
<tr>
<td>4</td>
<td>Nuclear Applications Courses</td>
</tr>
<tr>
<td>4</td>
<td>Nuclear Engineering Capstone</td>
</tr>
</tbody>
</table>

The specific courses chosen depend on the student’s background, interests, and area of research. In addition, most students will take supplementary courses to meet prerequisite requirements, additional specialization, or technical requirements of the follow-on assignment. Many students will require prerequisite courses depending on their individual backgrounds and areas of specialization. For example, typical students require Nuclear Physics, NENG 651.

**Mathematics**
The courses in mathematics prepare the student for the physics and engineering courses later in the program, as well as practice in the field. Although only one mathematics course is strictly required, usually the student will complete two such courses chosen from:

- MATH 504 Differential Equations of Mathematical Physics
- MATH 508 Applied Numerical Methods
- MATH 509 Mathematical Methods in the Physical Sciences
- MATH 511 Methods of Applied Mathematics I
- MATH 513 Methods of Applied Mathematics II
- MATH 521 Applied Linear Algebra
- STAT 583 Introduction to Probability and Statistics

**Core**
The six nuclear engineering core courses represent the foundational material any AFIT nuclear engineering graduate is expected to master. The core courses also build a base the applications courses, independent research, and gives students nuclear weapon technology and effects expertise. Twenty-four credit hours are required in this category:

- NENG 685 Methods for Neutral Particle Transport
- NENG 681 Nuclear Fuel Cycles
- NENG 650 Nuclear Instrumentation
- NENG 605 Physics of Nuclear Explosives
- NENG 631 Prompt Effects of Nuclear Weapons
- NENG 635 Residual Effects of Nuclear Weapons
Applications
The nuclear applications courses are designed to provide the student with the background needed to conduct research operations and program management in a broad range of nuclear technology and weapons effects areas. The application courses also strengthen the student in areas of professional engineering practice identified by the American Nuclear Society. These areas include nuclear power systems, nuclear fuels, nuclear instrumentation and measurement, and radiation protection and shielding. The courses in this category are:

- NENG 601 Research Apprenticeship
- NENG 612 Nuclear Engineering Laboratory
- NENG 620 Nuclear Reactor Theory and Engineering
- NENG 625 Electromagnetic Pulse Effects
- NENG 660 Radiation Effects on Electronics
- NENG 664 Radiation Effects on Electronics Laboratory
- NENG 705 Methods of Radiation Transport
- MATL 525 Thermodynamics and Kinetics of Materials

Capstone
The capstone courses are designed to draw upon all aspects of the Nuclear Engineering program and solidify them into multidisciplinary applications. They are meant to reinforce ideas and concepts taught throughout the program and combine them into a single application.

- NENG 791 Non-Proliferation of Nuclear Weapons and Technologies

Complementary Courses
Beyond these requirements for mathematics, core nuclear engineering, and nuclear applications courses, complementary courses are selected by each student depending upon the officer’s background, interests, and follow-on assignment. These complementary courses are normally selected from the following:

- NENG 651 Nuclear Physics
- NENG 630 Radiation Health Physics
- PHYS 601 Electrodynamics I
- PHYS 635 Thermal Physics
- PHYS 650 Kinetic Theory of Plasmas
- PHYS 655 Quantum Mechanics I
- PHYS 670 Introduction to Solid State Physics

Students are prepared for assignments with the education code 4QYY, 4QCY, and 4QDY through nuclear engineering courses taken, such as NENG 605, NENG 685, and NENG 681. The nuclear effects courses that prepare students for education codes 8HKY are NENG 631, NENG 635, and NENG 625. Education code 8HLY students are prepared by taking nuclear physics courses, such as NENG 605, NENG 650, and NENG 651. Most students will end up taking all of these course, thereby preparing them for a wide variety of Air Force and DID nuclear weapons related assignments. Finally, all students are required to enroll in the Department Seminar, PHYS798/598, and to satisfy the 12 credit hour Independent Study thesis (research) requirement, NENG 799. The curriculum is also designed to meet specific engineering certification requirements. Students can apply coursework and research as engineering related experience, and are encouraged to seek professional engineering registration once they meet the qualifications.
**Nuclear Engineering**  
(Sample Curriculum)

*Example program guide for a typical full-time student in an 18-month program*

Short Term Review Session (4 weeks), September:  
- Calculus and Differential Equations (40 hours)  
- Nuclear Engineering (40 hours)  
- Computation (40 hours)  
- Chemistry (40 hours)

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Course</th>
<th>Credit Hours</th>
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<tbody>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt; Quarter, Fall</td>
<td>NENG 651 Nuclear Physics</td>
<td>4</td>
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<tr>
<td></td>
<td>NENG 685 Methods for Neutral Particle Transport</td>
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<tr>
<td></td>
<td>NENG 681 Nuclear Fuel Cycles</td>
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<tr>
<td></td>
<td>PHYS 798 Departmental Seminar</td>
<td>1</td>
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<tr>
<td></td>
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<td>13</td>
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<tr>
<td>2&lt;sup&gt;nd&lt;/sup&gt; Quarter, Winter</td>
<td>NENG 605 Physics of Nuclear Explosives</td>
<td>4</td>
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<tr>
<td></td>
<td>NENG 650 Nuclear Instrumentation</td>
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<tr>
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<td>PHYS 798 Departmental Seminar</td>
<td>1</td>
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<td>One math course, normally chosen from the following:</td>
<td>MATH 508 Applied Numerical Methods</td>
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<tr>
<td></td>
<td>MATH 509 Mathematical Methods in the Physical Sciences</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>MATH 511 Methods of Applied Mathematics</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>STAT 583 Introduction to Probability and Statistics</td>
<td>4</td>
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<tr>
<td></td>
<td></td>
<td>13</td>
</tr>
<tr>
<td>3&lt;sup&gt;rd&lt;/sup&gt; Quarter, Spring</td>
<td>NENG 631 Prompt Effects of Nuclear Weapons</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>PHYS 798 Departmental Seminar</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>PHYS 598 Engineering Physics Seminar</td>
<td>1</td>
</tr>
<tr>
<td>Plus two courses, typically from the following:</td>
<td>NENG 660 Radiation Effects on Electronics</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>NENG 705 Methods of Radiation Transport</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13</td>
</tr>
<tr>
<td>4&lt;sup&gt;th&lt;/sup&gt; Quarter, Summer</td>
<td>NENG 635 Residual Effects of Nuclear Weapons</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>NENG 799 Thesis Research</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>PHYS 798 Departmental Seminar</td>
<td>1</td>
</tr>
<tr>
<td>Plus one of the following courses:</td>
<td>NENG 664 Radiation Effects Laboratory</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>NENG 625 EMP Effects</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>NENG 612 Nuclear Engineering Laboratory</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13</td>
</tr>
<tr>
<td>Quarter</td>
<td>Course Code</td>
<td>Course Title</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------</td>
<td>-------------------------------------------</td>
</tr>
<tr>
<td>5th Quarter, Fall</td>
<td>PHYS 798</td>
<td>Departmental Seminar</td>
</tr>
<tr>
<td></td>
<td>NENG 799</td>
<td>Thesis Research</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6th Quarter, Winter</td>
<td>NENG 791</td>
<td>Non-Proliferation of Nuclear Weapons</td>
</tr>
<tr>
<td></td>
<td>PHYS 798</td>
<td>Departmental Seminar</td>
</tr>
<tr>
<td></td>
<td>PHYS 799</td>
<td>Thesis Research (if needed)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Assignments for Graduates**

Nuclear Engineering graduates have primarily been assigned to the Air Force Technical Applications Center, Air Force Nuclear Weapons Center, Defense Threat Reduction Agency, and Air Force Global Strike Command. Graduates can be extended directly into the AFIT resident PhD program where appropriate. This program is open to officers of the Army, Navy, Marine Corps, DOD civilians and qualifying DOD contractors. This program is especially suited to prepare officers for inter-service assignments such as those at the Defense Threat Reduction Agency, Department of Homeland Security, and National Nuclear Security Agency. Army, Navy, and Marine Corps officer graduates have received varied assignments from their parent services, which also makes immediate use of their education. Since classified material under the Atomic Energy Act of 1954 is included in some course in the nuclear engineering specialization, the nuclear specialization is only open to qualifying US citizens.
Optical Sciences and Engineering

Program Description
The Optical Sciences and Engineering program is a multi-disciplinary study designed to provide a student who has a background in engineering or physical sciences with the knowledge of optics and laser technology necessary for work in the field of optical sciences and engineering.

The coursework in this program is in the areas of optical physics and engineering with emphasis on the application of fundamental knowledge in the design, development, test, and evaluation of Air Force systems.

This program is normally six quarters for a full-time Air Force student. Each student must complete an independent study, i.e., thesis, in an area related to optical sciences and engineering and selected from topics proposed by Air Force Institute of Technology faculty and solicited from Air Force research and development organizations. Research toward the Master’s thesis is typically conducted at the Air Force Institute of Technology but may be conducted under a cooperative research program at one of the Air Force laboratories. Flexibility in the program is maintained to take full advantage of the varied backgrounds and abilities of individual students.

Program Educational Objectives (PEOs)
The PEOs of the Optical Sciences and Engineering program ensure that graduates are prepared to perform the following tasks successfully:

1. Primarily within, but not limited to, the field of optical sciences and engineering, direct or perform basic or applied research, conduct and/or evaluate design and analyses, and work independently and in groups.
2. Communicate their work clearly, both orally and in writing. (This includes writing, editing, and/or supervising the preparation of subordinates’ or contractors’ written reports, journal articles, briefings, and professional presentations to communicate their work clearly.)
3. Effectively interpret/translate between optical physicists and engineers who may not always understand each other’s technologies and jargon.
4. Understand the details of technologies and programs in their area of responsibility.
5. Study an issue, identify and evaluate alternative actions, propose appropriate courses of action, and develop programs to implement optimal solutions.
6. Develop and implement, or sustain and improve, programs that entail multidisciplinary research, simulation, modeling, engineering design, production, and/or fielding of engineered optical systems.

Program Outcomes (POs)
The POs of the Optical Sciences and Engineering program describe what students will know or be able to perform upon degree completion:

1. Apply advanced concepts in mathematics and optical physics and engineering, including analytic, experimental, and computational methods, to a particular application in the field of optical sciences and engineering.
2. Perform optical sciences and engineering research, design, and analysis, working independently or in groups, limited to a particular problem or problems of interest with which they have experience during their Air Force Institute of Technology experience.
3. Communicate optical sciences and engineering research, design, and analysis effectively, working independently or in groups, limited to a particular problem or problems of interest with which they have experience during their Air Force Institute of Technology experience.

4. Understand and critically evaluate technical communications in the form of journal articles, research proposals and conference presentations, and contribute and communicate their results and understanding in these same forums.

**USAF Education Code**

4K0Y

**Requirements in Optical Sciences and Engineering**

The Optical Sciences and Engineering (OSE) program has a concentrated optical physics and engineering curriculum selected to provide both the breadth and depth expected of an optical scientist/engineer at the graduate level. A student in the OSE program is required to submit at least 48 graduate credit hours for the degree; these 48 credit hours must include the following:

<table>
<thead>
<tr>
<th>Credit Hours</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Thesis Research</td>
</tr>
<tr>
<td>4</td>
<td>Mathematics at the 500 level or higher</td>
</tr>
<tr>
<td>16</td>
<td>Optics core</td>
</tr>
<tr>
<td>4</td>
<td>OSE depth (700-level)</td>
</tr>
<tr>
<td>4</td>
<td>Optical Engineering laboratory at the 600 level</td>
</tr>
<tr>
<td>8</td>
<td>OSE elective</td>
</tr>
</tbody>
</table>

The specific courses chosen will depend on the student’s previous background and assigned specialization area. It may be that a student must take other courses in order to satisfy prerequisites for the required courses. Prerequisites that are also offered at the Air Force Institute of Technology, either in the quarter prior to or as part of a normal six-quarter program, include:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 531</td>
<td>Electromagnetism</td>
</tr>
<tr>
<td>PHYS 556</td>
<td>Introduction to Quantum Physics</td>
</tr>
<tr>
<td>PHYS 570</td>
<td>Physics of Solid State Devices</td>
</tr>
</tbody>
</table>

Please check with your academic advisor as you make your course plan. Students with these courses equivalencies already in their transcripts may have these prerequisites waived.

The optics core covers fundamental optical physics, and the generation, propagation, and detection of electromagnetic radiation. The 16 credit hours at the 600 level required in this category are:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 640</td>
<td>Optics</td>
</tr>
<tr>
<td>OENG 620</td>
<td>Laser Engineering</td>
</tr>
<tr>
<td>OENG 644</td>
<td>Linear Systems and Fourier Optics</td>
</tr>
<tr>
<td>OENG 650</td>
<td>Optical Radiometry and Detection</td>
</tr>
</tbody>
</table>
A prerequisite to the 4 credit hours of optical engineering laboratory at the 600 level offered as part of the normal six-quarter program is:

PHYS 542 Optics Laboratory

Students with equivalent lab course work already in their transcripts or previous optics laboratory experience may have this prerequisite waived. The 4 credit hours of a graduate laboratory at the 600 level required in this category must be chosen from the following:

OENG 616 Electro-Optical Systems Laboratory
OENG 651 Optical Diagnostics Laboratory

The 4 credit hours of OSE depth at the 700 level must be chosen from the following set:

EENG 716 Imaging through Turbulence
OENG 720 Laser Devices and Applications
OENG 740 Optical System Design
OENG 775 Introduction to Photonic Devices
OENG 780 Infrared Technology
PHYS 740 Optics II
PHYS 781 Laser Spectroscopy

Note that some of the 700-level courses also have other prerequisites which are listed among the following 600-level electives.

EENG 622 Advanced Electromagnetics I
EENG 630 Applications of Electromagnetic Theory
EENG 634 Computational Methods in Electromagnetics
EENG 658 Lidar Systems
EENG 665 Random Signal and Systems Analysis
EENG 672 Statistical Optics
MATL 672 Optical Properties of Materials
OENG 645 Wave Optics I
OENG 647 Hyperspectral Remote Sensing
OENG 660 Introduction to Nonlinear Optical Devices
OENG 681 Digital Image Processing
PHYS 570 Physics of Solid State Devices
PHYS 601 Electrodynamics I
PHYS 655 Quantum Mechanics I
PHYS 661 Atomic and Molecular Spectroscopy
Optical Sciences and Engineering  
(Sample Curriculum)

Short Term Review Session (4 weeks) includes: Calculus, Differential Equations, Physics, and Computational Review

Typical program shown below is for a full-time resident student under DOD sponsorship; minimum required registration each quarter is 12 cr hrs. (Core courses are in bold; depth courses are in italics)

1st Quarter, Fall  

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 640</td>
<td>Optics</td>
<td>4</td>
</tr>
<tr>
<td>PHYS 798</td>
<td>Department Seminar</td>
<td>1</td>
</tr>
<tr>
<td>MATH 5XX</td>
<td>Graduate Mathematics</td>
<td>4</td>
</tr>
</tbody>
</table>

Typically 1-2 of:  

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>EENG 622</td>
<td>Advanced Electromagnetic I</td>
<td>4</td>
</tr>
<tr>
<td>PHYS 570</td>
<td>Physics of Solid State Devices</td>
<td>4</td>
</tr>
<tr>
<td>PHYS 601</td>
<td>Electrodynamics I</td>
<td>4</td>
</tr>
<tr>
<td>PHYS 655</td>
<td>Quantum Mechanics I</td>
<td>4</td>
</tr>
<tr>
<td>STAT 586</td>
<td>Probability Theory for Communication and Control</td>
<td>4</td>
</tr>
</tbody>
</table>


2nd Quarter, Winter  

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>OENG 644</td>
<td>Linear Systems and Fourier Optics</td>
<td>4</td>
</tr>
<tr>
<td>OENG 650</td>
<td>Optical Radiometry and Detection</td>
<td>4</td>
</tr>
<tr>
<td>PHYS 798</td>
<td>Departmental Seminar</td>
<td>1</td>
</tr>
</tbody>
</table>

One other, such as: (other options also available as pre-reqs to future courses)  

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>EENG 630</td>
<td>Applications of Electromagnetic Theory</td>
<td>4</td>
</tr>
<tr>
<td>EENG 665</td>
<td>Random Signal and Systems Analysis</td>
<td>4</td>
</tr>
<tr>
<td>PHYS 661</td>
<td>Atomic and molecular spectroscopy</td>
<td>4</td>
</tr>
</tbody>
</table>


3rd Quarter, Spring  

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>OENG 620</td>
<td>Laser Engineering</td>
<td>4</td>
</tr>
<tr>
<td>PHYS 598</td>
<td>Engineering Physics Seminar</td>
<td>1</td>
</tr>
<tr>
<td>PHYS 798</td>
<td>Departmental Seminar</td>
<td>1</td>
</tr>
</tbody>
</table>

Typically 2-3 of:  

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>EENG 634</td>
<td>Computational Methods in Electromagnetic</td>
<td>4</td>
</tr>
<tr>
<td>EENG 658</td>
<td>Lidar Systems</td>
<td>4</td>
</tr>
<tr>
<td>OENG 645</td>
<td>Wave Optics I</td>
<td>4</td>
</tr>
<tr>
<td>PHYS 542</td>
<td>Optics Laboratory</td>
<td>2</td>
</tr>
<tr>
<td>EENG 716</td>
<td>Imaging Through Turbulence</td>
<td>4</td>
</tr>
<tr>
<td>OENG 780</td>
<td>Infrared Technology</td>
<td>4</td>
</tr>
<tr>
<td>PHYS 740</td>
<td>Optics II</td>
<td>4</td>
</tr>
</tbody>
</table>


4th Quarter, Summer  

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 798</td>
<td>Departmental Seminar</td>
<td>1</td>
</tr>
</tbody>
</table>

Must take 1 of:  

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>OENG 616</td>
<td>Electro-Optics Systems Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>OENG 651</td>
<td>Optical Diagnostics Laboratory</td>
<td>4</td>
</tr>
</tbody>
</table>

Typically 2 of:  

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATL 672</td>
<td>Optical Properties of Materials</td>
<td>4</td>
</tr>
<tr>
<td>OENG 647</td>
<td>Hyperspectral Remote Sensing</td>
<td>4</td>
</tr>
<tr>
<td>OENG 660</td>
<td>Introduction to Non-linear Optical Devices</td>
<td>4</td>
</tr>
<tr>
<td>OENG 799</td>
<td>Thesis Research</td>
<td>4</td>
</tr>
<tr>
<td>PHYS 781</td>
<td>Laser Spectroscopy</td>
<td>4</td>
</tr>
</tbody>
</table>


≥13
## 5th Quarter, Fall

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 798</td>
<td>Departmental Seminar</td>
<td>1</td>
</tr>
<tr>
<td>OENG 799</td>
<td>Thesis Research</td>
<td>12</td>
</tr>
</tbody>
</table>

## 6th Quarter, Winter

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 798</td>
<td>Departmental Seminar</td>
<td>1</td>
</tr>
<tr>
<td>OENG 799</td>
<td>Thesis Research</td>
<td>4</td>
</tr>
<tr>
<td>TENP 799</td>
<td>(Required for thesis grade – does not count as 12 cr hrs)</td>
<td>12*</td>
</tr>
</tbody>
</table>

Typically 2 of:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>EENG 672</td>
<td>Statistical Optics</td>
<td>4</td>
</tr>
<tr>
<td>OENG 720</td>
<td>*Laser Devices and Applications</td>
<td>4</td>
</tr>
<tr>
<td>OENG 740</td>
<td>Optical System Design</td>
<td>4</td>
</tr>
<tr>
<td>OENG 775</td>
<td>Introduction to Photonic Devices</td>
<td>4</td>
</tr>
</tbody>
</table>

Total: 13
Nuclear Weapons Effects, Policy, & Proliferation Graduate Certificate
(NWEPP)

Program Description

The Nuclear Weapons Effects, Policy, and Proliferation (NWEPP) graduate certificate program is a series of three courses educating students in a broad range of nuclear weapons topics at the graduate level. This program is targeted for captains and majors assigned to positions in the Air Force Nuclear Enterprise conducting nuclear operations, maintenance, security, and logistics. NWEPP graduates will understand the basic technical aspects of nuclear weapons operations and employment and develop the skills necessary to advise and develop nuclear strategy and policy.

This program consists of three, 4-credit hour courses. Focus topics include the historic and current state of US nuclear policy and strategy, the elements and technology involved in building nuclear weapons capabilities, and the unique effects of nuclear weapon detonations.

All students successfully completing and maintaining a GPA of at least 3.0 in the NWEPP program (12 credit hours) will receive a certificate and have the completed certificate noted on their AFIT graduate transcript.

Program Educational Objectives (PEOs)

1. Apply knowledge and skills to solve problems that arise in the technical work they conduct or supervise.
2. Understand the science, phenomenology, and technology involved in nuclear weapons effects, nuclear weapons proliferation, and nuclear policy.
3. Communicate technical subjects orally and in writing, perform analysis, and interpret results.
4. Apply their knowledge to meet the defense needs of their organization and the nation.
5. Understand the international political environment as it applies to the interplay among technology, national objectives, and adversary postures that shape nuclear policy.

Student Outcomes (SOs)

1. Understand the science, phenomenology, and technology involved in the areas of nuclear weapons effects, nuclear policy, and nuclear proliferation.
2. Apply advanced concepts in the areas of nuclear weapons effects, nuclear policy, and nuclear proliferation.
3. Perform analysis on data, working independently and in groups, with a focus on applications to nuclear weapons effects, nuclear policy, and nuclear proliferation.
4. Demonstrate the ability to quantify and estimate various nuclear effects in a scenario.
5. Demonstrate the ability to analyze nuclear policy decisions and ramifications.
6. Demonstrate the ability to identify and analyze nuclear proliferation areas of concern.

Program Prerequisites

A bachelor’s degree is required and candidates must have taken a course in college level algebra. Certificate is available to US citizens only.
**Program Requirements**

The Nuclear Weapons Effects, Policy, & Proliferation Graduate Certificate requires the following three courses with options, some are offered via distance learning only as noted:

1. NENG 596 Nuclear Weapons Effects (Distance Learning only) or NENG 631 Prompt Effects of Nuclear Weapons
2. NENG 591 Nuclear Weapons and Proliferation (Distance Learning only) or NENG 791 Non-Proliferation of Nuclear Weapons or CWMD 791 Combating Weapons of Mass Destruction
3. NENG 500 Nuclear Weapons Strategy and Policy (Distance Learning only)

**Admissions**

A completed application form and submission of transcripts is required at least 6 weeks prior to start of entering quarter. Academic eligibility does not guarantee admission. Candidates will be nominated to the program by AETC/A10 in consultation with Air Force Global Strike Command (AFGSC) and AETC/A10.
Doctoral Program

The doctoral program is designed to produce graduates broadly educated at the highest level who are capable of actively identifying, conducting, directing, and evaluating research at the frontiers of knowledge. The successful student should be able to perform duties as a research scientist/engineer and scientific manager in order to develop the basic science and technology base required for new Air Force weapons systems.

The Ph.D. program in the Department of Engineering Physics offers specialization in lasers, optics and optical systems, optical processing, remote sensing and signature analysis, semiconductor physics and devices, photonics, chemical physics, transport theory, and nuclear engineering. Program length (for full-time AF students) is 3 yrs. The program content is largely determined by the areas and depth of knowledge required by the student in order to adequately carry out the research required in their chosen specialty. These program requirements are embodied in the student’s “approved program” and reflect certain departmental requirements, as well as the doctoral degree requirements. These degree requirements adhere to standards defined by the Graduate School of Engineering and Management faculty. These basic requirements are discussed in this section.

Admission to the Ph.D. Program

Admission to the doctoral program in the Department of Engineering Physics requires:

- B.S. GPA of >3.0
- Master’s degree in Physical Science or Engineering or Physics
- M.S. GPA of >3.5
- GRE scores of 550 verbal and 650 quantitative, or higher, on old scale; equivalent scores on new scale have been chosen as 156 verbal and 151 quantitative.

Interested candidates should contact the Air Force Institute of Technology Admission (AFIT/ENER) for details on selection and admission procedures. Civilian applicants should also contact Dept of Engineering Physics faculty in research area or interest; or, contact Department Head.

General Ph.D. Degree Requirements

A summary of the general Air Force Institute of Technology Graduate School of Engineering and Management doctoral degree requirements is listed here for the convenience of the reader. For more complete information and for final authority on these requirements, the reader should consult the current applicable Graduate School of Engineering and Management Operating Instruction ENOI 36-114*. In addition, the policies regulating the Air Force Institute of Technology Doctoral Program as set by the Air Force Institute of Technology Doctoral Council are contained in a series of policy letters** that are a “must” reading for all doctoral students. A set of these policy letters can be found on the Air Force Institute of Technology web pages.

*Operating Instructions:
http://org.eis.afit.edu/dept/en/OperatingInstructions/Forms/AllItems.aspx

**AFIT Doctoral Council policy letters:
http://org.eis.afit.edu/dept/en/doctoralcouncil/policyltrs/Forms/AllItems.aspx

All DOD-sponsored military Ph.D. students must be enrolled in a minimum of 12 cr hrs each quarter. An approved education plan is required by the end of the first quarter of full-time enrollment. Modifications to the plan can be made after the first quarter.
The Ph.D. degree may be awarded for the successful completion of a curriculum that has the approval of the faculty as meriting the degree. To satisfy the specific requirements for this degree, the student must have:

1. Been admitted to candidacy for the doctoral degree at least one year before receipt of the degree. Admission to candidacy is granted by the Dean of the Graduate School of Engineering and Management. The requirements for candidacy are:
   - Completion of a M.S. degree in an appropriate discipline
   - Completion of at least 36 quarter hours of coursework beyond the M.S. degree in an approved program with an average of at least 3.0 on all courses taken.
   - Approval by the student’s research committee of a prospectus for the dissertation project.
   - Satisfactory completion of the specialty courses and specialty examinations
   - Satisfactory completion of the mathematics requirement.

2. Completed an approved program of study. This consists of:
   - Three consecutive quarters of full-time coursework in residence, plus any additional hours necessary to total at least 36 quarter hours in residence beyond the M.S. degree. Of the 36 quarter hours in residence, 24 quarter hours must be successfully completed in the specialty area.
   - An average grade of at least 3.0 over all courses attempted after admission to the program.

3. Satisfactorily completed and submitted an acceptable dissertation on an approved research project.

4. Satisfactory completion of the mathematics requirement.

5. Completed all of the above requirements within eight years from the beginning of their full-time doctoral studies, and not more than four years after admission to candidacy.

6. Been recommended for the degree by the academic department and the Faculty Council Academic Standards Committee of the Graduate School of Engineering and Management.

**Department Core Requirements for the Ph.D.**

The Department of Engineering Physics offers Ph.D. programs in the areas of Applied Physics, Materials Science and Engineering, Nuclear Engineering, and Optical Sciences and Engineering. Courses that constitute a program of study will be determined by the Research Advisor (must be chosen by end of first quarter) and must be approved by the Department Head. The faculty have specified a set of core requirements to be met by candidates for the Ph.D. degree in the various disciplines offered by the department. These requirements are designed to ensure that students who enter the program with varied backgrounds will develop sufficient knowledge in their chosen doctoral area to qualify for the Ph.D. degree in that area. A typical specialty or major sequence of courses will usually consist of three core courses, plus an in-depth specialty sequence of six courses typically at the 7XX or 8XX level that lays the groundwork for the dissertation research.

A written specialty exam is normally taken during the 5th quarter (after completion of most required courses. Prior to this exam, the student’s research committee is established by formal memo subject to approval of Dept Head.

Upon completion of lecture/lab courses, the full-time military Ph.D. student must enroll in a minimum of 11 research hours (NENG 999, PHYS 999, for example) each quarter; all PhD military students are required to enroll in PHYS 798 (1 cr hr) each quarter, thus giving a total of 12 cr hrs once classes are completed. Non-military students must take 48 cr hrs of 999 research hours in their program.
Course Offerings

Biology (BIOL)

BIOL 597-Biological Weapons Effects and Technology
The malicious use of microorganisms and threats of further acts of war or of terrorism drive this course. A review of fundamental microbial biology and organisms known to have biowarfare applications will be followed by coverage of current advances in biotechnology and the potential for offensive or defensive applications. Finally, current technologies for detection and response to microbial agents will be reviewed.
Note: U.S. Citizens only
Prerequisites/Corequisites: None
Terms offered: Summer (Distance Learning) 4 credit hours

Chemistry (CHEM)

CHEM 560-Chemistry for Engineers
The course presents a quantitative treatment of selected topics from physical chemistry that are important to environmental and nuclear engineering. Topics presented will include thermodynamics principles, chemical equilibrium, kinetic theory of gases, liquids and solutions, acids and bases, electrochemistry, kinetics, chemical bonding, etc. Emphasis is on fundamental physical chemistry that plays an important role in engineering processes.
Prerequisites/Corequisites: None
Terms offered: Winter 4 credit hours

CHEM 581-Introduction to Nuclear Fuel Cycles
Introduction to nuclear fuel cycles with emphasis on engineering techniques important to produce materials for nuclear weapons. Topics relevant to nuclear nonproliferation will be introduced, including uranium and plutonium chemistry relevant to milling, mining, and refining; isotope enrichment; fuel element fabrication; reactor operation; fuel separation; and reprocessing. Nuclides possibly released during these processes will be considered.
Prerequisite/Corequisites: NENG 651
Terms offered: Winter 4 credit hours

CHEM 597-Chemical Weapons: Materials, Effects, and Technology
The potential use of chemical agents as weapons of war or as weapons of terror motivates this course. The chemistry and physiochemical properties of chemical agents important to their production, employment, and effects will be presented. Technology relevant to personnel protection will be reviewed.
Note: U.S. Citizens only
Prerequisites/Corequisites: None
Terms offered: Spring (Distance Learning) 4 credit hours

CHEM 675-Upper Atmospheric Chemistry
This course focuses on the physical and chemical characteristics of the upper atmosphere of which the ionosphere is a vital and integral part of this region. The principle ionization sources are photoionization and energetic particle collisions with ambient atoms and molecules. A variety of processes that operate in the upper atmosphere will be identified and related to input and output parameters by detailed mathematical and physical descriptions of the processes. This course should bridge the gap between elementary studies in the fields of physics and research literature in upper atmosphere physics and chemistry.
Prerequisites/Corequisites: PHYS 519
Terms offered: Winter 4 credit hours
CHEM 680-Atmospheric Chemistry
This course is a study of atmospheric physics and atmospheric chemistry to understand natural atmospheric processes and the effects of human activities on the atmosphere. The course begins with a study of physical and chemical processes in the atmosphere, focusing largely on atmospheric water, carbon, and nitrogen in the oxidizing environment. The origin and nature of chemistry of atmospheric pollutions is framed for particulate pollutants, gaseous inorganic pollutants, and organic pollutants. The chemistry of these materials in the atmosphere is given emphasis. A particularly important focus is the photochemical induced radical, ion, and excited state chemistry of pollutants. Models of anthropomorphic changes in the atmosphere are considered. A quantitative, problem-solving approach is used throughout the course. This course will be useful to individuals involved in compliance issues associated with the Environmental Protection Agency (EPA) Clean Air Act, with atmospheric environmental assessment, and in the interpretation of environmental data obtained from air sampling (environmental engineers and managers involved with Resource Conservation and Recover Act [RCRA] and Comprehensive Environmental Response, Compensation, and Liability Act [CERLA] sites).
Prerequisites/Corequisites: None
Terms offered: As needed 4 credit hours

CHEM 681-Nuclear Chemical Engineering
Chemical engineering aspects of the military nuclear fuel cycles are studied to characterize weapon sources. Topics include an overview of the nuclear fuel cycle, including uranium mining and milling; solvent extraction for fuel reprocessing; and U-235 enrichment. Chemical and physical properties of plutonium and the actinides are applied to understand sources of plutonium and the properties of irradiated fuel. A detailed treatment of stable isotope separation is included with particular emphasis on uranium enrichment techniques, tritium production, and their use in nuclear weapons.
Note: SECRET (RESTRICTED DATA) clearance required
Prerequisites/Corequisites: NENG 651, NENG 605
Terms offered: Winter 4 credit hours

CHEM 699-Master’s Level Special Study
Course content determined by faculty member based on student need.
Prerequisite/Corequisites: None
Terms offered: All 1-12 credit hours

CHEM 720-Kinetics of Fast Reactions
Advanced level investigation of the rates and mechanism of chemical reactions and energy transfer. Theoretical methods of Slater and RRKM are presented for the calculations of rate coefficients from fundamental properties. Current experimental methods used to study the kinetics of jet engines, rockets, lasers, plasmas, and the Earth’s atmosphere are discussed.
Prerequisites/Corequisites: None
Terms offered: Spring 4 credit hours

CHEM 750-Computational Chemistry and Materials Science
This computational laboratory will build on topics covered in MATL 662 through a series of four to five computational projects. Each project will explore a specific technique used in computational chemistry and materials science through the use of the computational facilities at the Major Shared Resource Center (MSRC).
Prerequisite/Corequisites: CHEM 662, CSCE656
Terms offered: As needed 4 credit hours

CHEM 780-Radiation Chemistry
Advanced treatment of chemistry produced by ionizing radiation. Important radiation interactions and reaction mechanisms involved in irradiation of gas and condensed phases will be reviewed. The nature, properties and reaction of intermediate species, including solvated electron and important radicals, will be studied.
Prerequisites/Corequisites: CHEM 560, PHYS 665 or permission of the instructor.
Terms offered: As needed 4 credit hours
CHEM 825-Chemical Physics
An advanced study in the area of chemical physics. Topics covered include the approximate solutions of the time dependent Schrödinger equation for reacting systems and for systems interacting with an electromagnetic field. The foundations of infrared and ultraviolet spectroscopy, angular momentum considerations, symmetry studies, and electronic states are included.
Prerequisite/Corequisites: CHEM 720 or permission of instructor
Terms offered: As needed 4 credit hours

CHEM 840-Advanced Chemical Kinetics
A seminar course covering the theoretical aspects of chemical kinetics; calculation of rate constants from consideration of the fundamental properties of atoms and molecules; analysis of classical methods, such as Slater or RRKM; and introduction to quantum and statistical solutions involving the Liouville equation.
Prerequisite/Corequisites: CHEM 720 or CHEM 825 or permission of instructor
Terms offered: As needed 4 credit hours

CHEM 850-Molecular Orbital Theory
A study of modern variational methods to calculate electronic structure and properties of molecules. Topics include molecular orbitals and molecular orbital symmetry, mathematical methods for solving the wave equation for molecules, HF-SCF, LCAO, MCSCF, CI, perturbation methods, and density functional methods.
Prerequisites/Corequisites: PHYS 655
Terms offered: As needed 4 credit hours

Environmental Science (EVSC)

EVSC 560-Environmental Monitoring
This laboratory/lecture course is an integrated approach to sampling and analyses of pollutants or target molecules in various environmental media. The student will have a hands-on laboratory experience to illustrate statistical sampling, sampling methods, instrumental chemistry analysis, and data handling. Students will study and apply selected principles and techniques of environmental monitoring, including learning to develop sampling and analysis plans, implement sampling and analysis plans, and report results of a monitoring study.
Prerequisites/Corequisites: STAT 526 or permission of instructor
Terms offered: as needed 4 credit hours

EVSC 650-Environmental Measurement Techniques
This course treats the proper application of the various chemical, physical, and thermophysical analytical methods that are used to characterize environmental samples. Techniques include emission spectroscopy, atomic absorption spectroscopy, X-ray fluorescence analysis, neutron activation analysis, gamma-ray spectroscopy, wet analytical chemistry, gas chromatography, mass spectrometry, scanning electron microscopy, transmission electron microscopy, and X-ray diffractometry. Hands-on experience will be obtained in the associated library.
Prerequisites/Corequisites: EVSC 560 or permission of instructor
Terms offered: As needed 4 credit hours

EVSC 666-Remote Sensing of the Environment
This course considers techniques for remote sensing of atmospheric and water pollution, which uses nearly the entire electromagnetic spectrum. For example, airborne and satellite visible and infrared measurements are used to map oil spills and monitor chemical effluents from facilities. Radiation source characterization and transport of that radiation through free space, along with principles of optical detection, are considered. Remote laser techniques for monitoring gaseous pollutants, including infrared absorption, laser back-scatter (LIDAR), laser-induced fluorescence, and Raman back-scatter, are also treated.
Prerequisites/Corequisites: None
Terms offered: As needed 4 credit hours
Materials (MATL)

MATL 525-Thermodynamics and Kinetics of Materials
Applications of thermodynamics and kinetics relevant to materials science and engineering are presented. Concepts treated include free energy of phases, phase diagrams, metastability, and applications to problems in solids and thin films. Thermodynamics is applied to pure materials, solid solutions, phase equilibria, interfaces and defects. Kinetics topics include diffusion in solids, nucleation kinetics, composition-invariant solid/solid interface migration, and kinetics of surface deposition.
Prerequisite/Corequisites: Undergraduate strength of material course
Terms offered: Spring 4 credit hour

MATL 545-Mechanical Properties of Materials
Course is designed to provide a background for the understanding of the mechanical behavior of metals, ceramics, polymers, and composites in aerospace applications. Topics include behavior of materials under simple and combined stress symptoms, elastic and plastic behavior, introduction to dislocation theory, plastic deformation of single crystals and polycrystalline aggregates, strengthening mechanisms, fatigue, creep, residual stress, fracture, and mechanical testing.
Prerequisite/Corequisites: Undergraduate material science course
Terms offered: Fall 4 credit hours

MATL 560-Electronic, Magnetic, and Optical Properties of Materials
Introduction to the theory and engineering applications, magnetic, and optical materials. Atomic bonding, crystal structure, crystal defects, lattice properties, diffusion, electrical properties of materials, metals, dielectrics, semiconductors, magnetic properties of materials, ferroelectrics, superconductors, polymers, ceramics and the growth and processing of materials are covered. Use of such materials in solid state devices, hard and soft magnets, superconductors, and optical devices are treated.
Prerequisites/Corequisites: None
Terms offered: Fall 4 credit hours

MATL 598-Materials and Processes Seminar
Current technologies, applications, and research issues in the materials and processes are presented by experts from the Air Force, Industries and other universities.
Prerequisites/Corequisites: Undergraduate materials science course
Terms offered: As needed 1 credit hours

MATL 620-Chemistry of Materials
A study of the electrochemistry, inorganic chemistry, organic chemistry, polymer chemistry and solid-state chemistry relevant to synthesis processing of materials. Computational methods of predicting and correlating materials structure with properties of alternative materials will be introduced. This course introduces the student to chemical reactions of materials and chemical processes which produce significant quantities of toxic chemicals. Emphasis will be placed on chemistry of materials and processes important in current and future aerospace manufacture and maintenance. This course provides background for understanding pollution prevention.
Prerequisites/Corequisites: MATL 525 or permission of instructor
Terms offered: Fall 4 credit hours

MATL 662-Electronic Properties of Molecules and Solids
This course is an introduction to the electronic behavior of molecules and solid state materials with an emphasis on the symmetrization, postulate, tight binding methods, band theory, Hartree-Fock-self consistent field methods, configuration interaction methods, and density functional theory.
Prerequisites/Corequisites: MATL 620, PHYS 655
Terms offered: As needed 4 credit hours

MATL 672-Optical Properties of Materials
Study of the various optical phenomena in materials; topics will be selected from absorption, reflection and emission processes, luminescence, dispersion theory, optical materials, polymers, wave propagation in anisotropic media, and nonlinear properties of materials. Application will be made to the material requirements of optical devices such as lasers, detectors, etc.
Prerequisites/Corequisites: PHYS 670
Terms offered: Summer 4 credit hours
MATL 680 - Materials Characterization
This course provides an integrated view of materials characterization as a process requiring the application of many methods. This course will focus on several representative methods, including methods based on photons (IR, visible, UV, X-ray), on electrons, and on atoms/ions/neutrons. Acoustic, microwave and mechanical test methods will be introduced. Advanced understanding of the interactions between the material and the sensor or probe used in the characterization will be stressed.
Prerequisites/Corequisites: None
Terms offered: Winter 4 credit hours

MATL 685 - Materials Selection and Processing
This course provides an introduction to the principles and techniques that are used in selection, fabrication, and processing of bulk, thin film and nanoscale materials for applications in electronic and structural systems, including risk and cost assessments. A selected group of fabrication methods will be emphasized. Techniques and underlying principles for synthesis and assembly of materials with one or more micro- to nano-scale dimensions, will be presented.
Prerequisites/Corequisites: None
Terms offered: Spring 4 credit hours

MATL 699 - Masters Level Special Study
Course content determined by faculty member based on student need.
Prerequisite/Corequisites: None
Terms offered: All 1-12 credit hours

MATL 701 - Research and Apprenticeship
Students will work on special problems related to an individual professor’s or laboratory scientist’s material research program. These special problems will range from pedagogical problems intended to bring the student up to the state of knowledge to problems which represent immediate goals of a research program. The programs may be computational, experimental or theoretical and will vary depending upon the needs of the student and the individual research interests of the professor or laboratory scientist.
Prerequisites/Corequisites: Permission of instructor
Terms offered: Summer 4 credit hours

MATL 799 - Thesis Research
This course is an in-depth study of a research topic selected from a wide variety of problems of current interest to the Air Force, with the results presented in a formal thesis and defense. Ordinarily, this course extends over several quarters, and no credit is given until the end of the last quarter. An oral presentation and defense of the research are required.
Prerequisites/Corequisites: none
Terms offered: All 1-12 credit hours

MATL 899 - Doctoral Level Special Study
Directed study for doctoral students on a special topic which is not normally covered in a regularly scheduled course or as part of dissertation research. Topic, format, and requirements of the course are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.
Prerequisites/Corequisites: None
Terms offered: All 1-12 credit hours
Atmospheric Science (METG)

METG 610-Radiative Transfer
This course covers topics in radiative transfer for visible, infrared, and acoustic energy including emission, absorption, scattering and atmospheric refraction. Application of the theory will be examined in operational models, such as Electro-optical Tactical Decision Aid, Integrated Refractive Effects Prediction System, Radio Physical Optics. Prerequisites/Corequisites: None
Terms offered: Spring 4 credit hours

METG 612-Cloud Physics
Covers the theories of cloud formation, precipitation, and atmospheric electricity. Particular emphasis will be placed on lightning formation, detection, and its effects. Convective clouds and mesoscale storm systems will be discussed in detail to include the general structure, scale, and vertical motions within these storms. A computer-based project will be included to help visualize the formation of clouds and the moisture behaves in them. Prerequisites/Corequisites: Permission of instructor
Terms offered: Winter 4 credit hours

METG 620-Advanced Atmospheric Dynamics
This course covers geophysical fluid dynamics including the development of the fundamental equations governing atmospheric motion, basic approximations, simplified flows, and physical interpretation of the corresponding theory. It also includes circulation theory, vorticity, planetary boundary layer, quasi-geostrophic, ageostrophic and linear theories and introductory numerical modeling concepts. Prerequisites/Corequisites: Permission of instructor
Terms offered: Winter 4 credit hours

METG 634-General Circulations and Tropical Meteorology
This course extends atmospheric dynamics to the tropics where large scale circulations dominate. Phenomena discussed will include cumulus convection, meso-scale convection systems, tropical waves and disturbances, as well as 30-50 day, and semi-annual oscillations: El Nino, La Nina, Madden-Julian and the Inter-tropical Convergence Zone. Prerequisites/Corequisites: METG 620
Terms offered: Winter 4 credit hours

METG 640-Applied Climatology
This course introduces the student to the field and application of climatology and its vast databases. The Earth's complex climate system, and contributing elements of climate change will be discussed while students learn military applications and the limitations of supporting operations. Prerequisites/Corequisites: METG 634
Terms offered: Summer 4 credit hours

METG 642-Radar Meteorology
This course provides students with a background on the theory of remote sensing using weather radar. Emphasis will be given to current interpretation techniques, and recent technology advancements to interrogate phenomena such as precipitation type and intensity, lightning onset, turbulence, wind shear, meso-scale convective complexes, and various severe weather scenarios. Prerequisites/Corequisites: METG 612
Terms offered: Summer 4 credit hours

METG 644-Satellite Meteorology
This course will provide students with a broad foundation on the history, theory, data, and application of meteorological satellites/sensors, so that they will be able to interpret and fully utilize these data for operational and/or re-search applications and understand their capabilities and limitations. It includes techniques, research, and operational applications related to satellite-based remote sensing of the atmosphere and their applications in numerical weather prediction. Prerequisites/Corequisites: METG 610
Terms offered: Spring 4 credit hours
METG 650-Numerical Weather Prediction (NWP) for Scientists and Engineers
This course provides students with a background in available dynamic, microphysical and climate models with a rigorous treatment of numerical modeling techniques, physical parameterizations and data assimilation. This course provides tools for future research using transport, dispersion, and fallout techniques, as well as numerical weather prediction and long range climate modeling.
Prerequisites/Corequisites: METG 620
Terms offered: Spring 4 credit hours

METG 655-Fine Scale, Specialized and Probabilistic Numerical Weather Prediction (NWP)
Building on the basis of METG 650, this course delves further into Numerical Weather Prediction models to better understand fine and meso-scale modeling as well as the latest state of ensembles. Topics discussed include current model capabilities, limitations and operational applications.
Prerequisites/Corequisites: METG 650
Terms offered: Summer 4 credit hours

METG 660-Operational Assessments in Atmospheric Science Laboratory
Building on the basis of METG 612, METG 644, and METG 650, this course delves into current operational aspects of USAF environmental forecasting and observing. Topics discussed include current or future DoD operational environment-related problems through the use of remote sensors, required inputs for each model and evaluation of output, instrumentation and models used to observe and characterize the environment, and experiments that illustrate how environmental conditions can ultimately impact daily operations.
Prerequisites/Corequisites: METG 612, METG 644, and METG 650
Terms offered: Winter 4 credit hours

METG 799-Thesis Research
This course enables an in-depth study selected from Air Force Weather's annual, prioritized thesis topic list. Results are presented in a written thesis, oral presentation and formal defense. Course credit is applied to TENP 799 when the thesis is complete.
Prerequisites/Corequisites: None
Terms offered: All 1-12 credit hours

Nuclear Engineering (NENG)  *Note: U.S. citizens only*

NENG 500-Nuclear Weapons Strategy and Policy
This course provides students with a professional understanding of the historical and current US nuclear policy and the implementation of that policy by the Department of Defense and the Air Force. The course starts with analysis of the current Nuclear Posture Review and then reviews the historical development of nuclear weapons policy and strategy. The course then provides a functional and critical understanding of how national and Air Force policy is implemented through current force structures, nuclear surety, and weapons employment. The course also incorporates current debates and case studies. Part of NWEPP graduate certificate program.
Prerequisites/Corequisites: None
Terms offered: DL offering —all 4 credit hours

NENG 585-Introduction to Modern Fortran with Applications in Computational Nuclear Engineering
Modern Fortran programming techniques are presented and practiced using example problems from the nuclear engineering curriculum. The objectives include developing knowledge of the structure and syntax of Fortran-95; developing skill in programming and effective use of the provided development environment; and practicing writing, debugging, and validating portable FORTRAN programs. Relevant ANSI/ANSI standards are presented. Programming exercises focus on numerical computations needed to solve problems encountered in the Air Force Institute of Technology nuclear engineering curriculum. Modern programming approaches, including operator overloading, data abstraction, encapsulation, and objects, are introduced using Fortran-95 user-declared types and modules.
Prerequisites/Corequisites: None
Terms offered: Fall 4 credit hours
NENG 591- Nuclear Weapons and Proliferation
This course examines the elements and technology involved in building a nuclear weapons capability, including producing or obtaining nuclear fuel; assembling a weapon; fusing and firing; testing, storage, surety, and delivery; and how a proliferator might clandestinely complete the steps. The course covers elements of the United States nuclear weapon program, from fuel production to the maintenance of a nuclear arsenal at an unclassified level. Part of NWEPP graduate certificate program.
Prerequisites/Corequisites: None
Terms offered: DL offering — all

NENG 596- Nuclear Weapons Effects
This course provides an understanding of the unique effects of nuclear weapon detonations: blast, thermal, radiation, electromagnetic, and fallout. Each effect is treated by examining its generation, transmission, and mechanisms of interaction with the environment. The course covers the physical origin of each effect, the manner in which these effects impact targets, and how these effects can shape a battle space both tactically and strategically. The course also covers survivability/vulnerability issues at the unclassified level. Part of NWEPP graduate certificate program.
Prerequisites/Corequisites: None
Terms offered: DL offering — all

NENG 601-Research Apprenticeship
Student will work on special problems related to individual professor’s research programs. These special problems will range from pedagogical problems intended to bring the student up to the state of knowledge to problems which are part of the immediate goals of the program. The problems may be computational, experimental or theoretical. This will vary from professor to professor.
Prerequisites/Corequisites: Permission of instructor
Terms offered: As needed

NENG 605-Physics of Nuclear Explosives
Elementary theory of fission and fusion explosives devices is taught. Diffusion theory is developed to examine the space-time variation of neutrons in fission devices. Critically, yield and disassembly mechanisms are included. Methods of statistical physics including Maxwell-Boltzmann and Planck distributions are employed. In fusion systems, reaction rate production, radiation-loss balance and yield calculations are examined. Size, mass, density, and temperature ranges for fusion burning are developed. Some Secret (RD) material is included.
Note: SECRET (RESTRICTED DATA) clearance required
Prerequisites/Corequisites: NENG 651
Terms offered: Winter

NENG 612– Nuclear Engineering Laboratory
Experimental techniques in nuclear engineering. Typical projects include the analysis of environmental radiation from natural and man-made sources, and of stable components of airborne particulates. General techniques include gamma-ray spectrometry, coincidence methods, activation with fast and thermal neutrons, X-ray fluorescence. Special techniques include Mossbauer spectrometry and Rutherford scattering of protons. Individual and group project approach is used. Students must set criteria, decide what to measure, how to measure it and analyze results.
Prerequisites/Corequisites: NENG 650 and NENG 631
Terms offered: Spring, or as needed

NENG 620-Nuclear Reactor Theory and Engineering
This course presents nuclear reactor theory, building upon the coverage of nuclear physics (reactions, radiations, fission, etc.) from NENG 651 and the coverage of neutron diffusion, prompt fast criticality, and prompt kinetics from NENG 605. Delayed and thermal neutrons are incorporated into the treatment of criticality and kinetics. Reactor dynamics are examined, including aspects of reactor core and system design, which provide reactivity feedback for reactor control. Nuclear reactor engineering topics include thermal management, energy conversion, radiation shielding, and mechanical and structural aspects of reactor and system design. This course provides a broadened exposure to applications of nuclear science and provides the necessary foundation for the study of space nuclear power and the nuclear fuel cycle.
Prerequisites/Corequisites: MATH 508 or equivalent
Terms offered: Winter
NENG 625-Electromagnetic Pulse Effects
Source, propagation, and interaction of the nuclear weapon generated electromagnetic pulse. Source generation is developed for high altitude burst, surface burst, and system generated situation. Propagation of the radiated signal is developed from classical electromagnetism (solution of Maxwell’s equation) for free space and extended to the atmosphere. EMP interaction is examined using antenna theory. Energy coupling from the wave is developed. Methods of shielding are considered.
Prerequisites/Corequisites: PHYS 531, NENG 605
Terms offered: Summer 4 credit hours

NENG 630-Radiation Health Physics
This course in radiation health physics provides the foundation for understanding the biological effects of ionizing radiation and protecting individuals and population groups. The content depends in part on the student’s back-grounds and curricular goals. Topics may include physical measurements and properties of different types of radiation and radioactive materials; quantitative relationships between radiation exposure and biological damage; movement of radioactivity through the environment; and the design of radiologically safe equipment, processes, and environments with the intent on assessing the radiological impact on humans. In some offerings of the course, the effects of non-ionizing radiation may be included. This course will be useful to bioenvironmental engineers, environmental managers, radiation safety officers, nuclear research officers, or medical personnel who will have responsibility for managing radiation safety programs and managing environmental activities of military installations that have nuclear sources (hospital, PMEL, or nuclear weapons) or who must interact in their environmental management jobs with the Department of Energy.
Prerequisites/Corequisites: NENG 651, NENG 650
Terms offered: As needed 4 credit hours

NENG 631-Prompt Effects of Nuclear Weapons
Topics include source, transmission, and mechanisms of interaction of x-ray, blast, thermal, neutron, and prompt gamma radiation. X-ray interactions include shock generation and propagation. The conservation equations of fluid dynamics are used to describe shocks. These same equations are applied to blasts in air and underwater shock. Shock “jump conditions” and scaling laws are derived and applied. Thermal transmission is examined. The heat transfer equation is used to study thermal interaction. Buildup factors and fits of transport calculations are employed to study neutron and gamma transmission. Various neutron and gamma interaction phenomena are studied. In the case of each effect, systems response is examined, hardening techniques are surveyed, and design trade-offs are discussed. Some secret (RD) material is discussed.
Notes: SECRET (RESTRICTED DATA) clearance required.
Prerequisites/Corequisites: NENG 605
Terms offered: Spring 4 credit hours

NENG 635-Residual Effects of Nuclear Weapons
Environmental radioactivity from natural, nuclear industry and weapon fallout is treated. The emphasis is on weapon fallout, both local and global. Methods of fallout modeling are included for both ground dose and airborne crew dose. Health physics fundamentals including mechanisms of biological response calculation of dose, body burdens and maximum permissible concentrations are also included. Seismic detection of nuclear explosions and worldwide detection systems are examined.
Prerequisites/ Corequisites: NENG 605
Terms offered: Summer 4 credit hours

NENG 650-Nuclear Instrumentation
Radiation detectors and detection systems; characteristics, applications, and principles of operation of gas-filled detectors, scintillation detectors, semiconductor detectors; applications and principles of electronic components such as single and multi-channel analyzers, pulse amplifiers, discriminators, scalers, etc.
Prerequisites/Corequisites: NENG 651
Terms offered: Winter 4 credit hours
NENG 651-Nuclear Physics
A basic graduate level treatment of nuclear physics with emphasis on interaction of radiation with matter, nuclear reactions and radioactive decay processes. Essential ideas of nuclear structure, stability of nuclei and quantum characterization of nuclear energy levels are covered. A practical understanding and interpretation of nuclear data tabulations to serve the needs of the nuclear engineer are stressed.
Prerequisites/Corequisites: PHYS 556
Terms offered: Summer, Fall
4 credit hours

NENG 660-Radiation Effects on Electronics
This course covers the range of damage and effects that gamma rays, neutrons and charged particles can have on modern electronic devices. Emphasis will be on the effects and possible measures for protection. Temporary and permanent damage will be investigated. Topics to be discussed include: bulk effects, latch-up, charge trapping and single event upsets.
Prerequisites/Corequisites: None
Terms offered: Spring
4 credit hours

NENG 664-Radiation Effects on Electronics Laboratory
Experimental procedures used in radiation effects testing. Typical projects will include ionizing and non-ionizing radiation dosimetry, optical and electrical measurements, and irradiation of devices. The course will cover practical dosimetry, device modeling, characterization, development of a test plan, modeling device changes, irradiation of devices, and interpreting data. Special techniques include calibrating a PIN diode dosimeter, foil activation dosimetry, device irradiation, and development of test systems and controls. Students must establish test criteria, model effects, develop system controls and interpret data. This is a lecture with laboratory course. Classes will meet for 1 hour, 3 days per week, for the lectures and for 3 hours, 1 day a week for the laboratory. May require travel to off-site irradiation facilities.
Prerequisites/Corequisites: NENG 650, NENG 660—permission of instructor
Terms offered: Summer
4 credit hours

NENG 681-The Nuclear Fuel Cycles (see CHEM 681)
This course covers the nuclear fuel cycles with emphasis on engineering techniques important to produce materials for nuclear weapons. Uranium and plutonium chemistry relevant to milling, mining and refining; isotope enrichment; fuel element fabrication; reactor operation; fuel separation; and fuel reprocessing are all covered. Topics relevant to nuclear nonproliferation, especially regarding physical and material requirements for reactor operations and key signatures related to materials processing, will be included.
Prerequisites/Corequisites: NENG 651
Terms offered: As needed
4 credit hours

NENG 685-Computational Methods for Neutral Particle Transport
This course covers the principal methods used for deterministically solving the Boltzmann transport equation for neutral particles (neutrons and photons). This course presents the fundamental mathematical and computational methods using discretizations in space, energy, and angle. Iterative methods for the efficient solution of transport problems are explored and analyzed. Monte Carlo and Discrete Ordinance methods are explicitly developed and applied to shielding and criticality problems of interest. The course will include both code development and use of exiting codes for solving criticality and shielding problems of interest in nuclear engineering.
Prerequisites/Corequisites: None
Terms offered: As needed
4 credit hours
NENG 699-Master’s Level Special Study
Directed study at an intermediate graduate level on a special topic which is not normally covered in a regularly scheduled course or as part of thesis research. Topic, format, and course requirements are determined by the faculty member directing the study.
Prerequisite/Corequisites: None
Terms offered: All 1-12 credit hours

NENG 705-Methods of Radiation Transport
The transport of X-rays, gamma rays and neutrons is examined by analysis and numerical solution of the Boltzmann transport equation. Theoretical analysis includes discussion of various approximations to the transport equation, such as particle streaming and one-speed transport theory. Numerical methods of radiation transport such as the P(n) and S(n) methods, are derived and then used by the students to solve nontrivial transport problems.
Prerequisites/Corequisites: MATH 504, NENG 605, NENG 685
Terms offered: As needed 4 credit hours

NENG 720-Nuclear Reactor Systems
A survey of current systems from a design point of view. An advanced course in that the prerequisites involve similar theory, both statics and kinetics, for explosive systems, some heat transfer, and a study of reactor effluents. The same theory and methods are applied to nuclear chain reactors in this course. Large civilian power production reactors, small military power reactors, and space nuclear systems are examined. Safety, cost, and performance are included.
Prerequisites/Corequisites: NENG 605, NENG 631, NENG 635
Terms offered: Winter 4 credit hours

NENG 721-Space Nuclear Power Systems
Current and future nuclear power systems such as radioisotope thermal generators, solid core, fluidized bed and gas core reactors are analyzed. Converter and heat rejection theory is studied and integrated with nuclear heat sources. One of the outstanding research issues for advanced nuclear space power systems is assigned as a group design project.
Prerequisites/Corequisites: NENG 631 or NENG 620
Terms offered: As needed 4 credit hours

NENG 725-Monte Carlo Methods of Radiation Transport
Monte Carlo calculational techniques are introduced and developed. The technique is applied to problems of X-ray, neutron, and gamma transport from and in nuclear explosions. Monte Carlo techniques are contrasted with and compared to the Boltzmann equation solutions considered in NENG 705.
Prerequisite/Corequisites: Permission of instructor
Terms offered: As needed 4 credit hours

NENG 751 - Nuclear Physics II
This course will be an advanced study of nuclear phenomena based upon quantum mechanics. It assumes knowledge of nuclear phenomena at the level of the course NENG 651, Nuclear Physics, and non-relativistic quantum physics at the undergraduate level. This course will investigate current models of the nucleus, nuclear reactions, and the sources and interactions of photons, electrons, charged particles, and neutrons. Students will apply knowledge of nuclear physics to problems of interest to the Air Force and Department of Defense.
Prerequisites/Corequisites: NENG 651
Terms Offered: Fall 4 credit hours

NENG 785-Topics in Computational Nuclear Engineering
Advanced numerical problem solving techniques are examined in the context of problems encountered in nuclear engineering and/or nuclear weapons effects. State of the art numerical methods are adapted to the problems examined in the course. Numerical experiments are used to augment analysis in evaluating the stability, conditioning, accuracy, and efficiency of the resulting algorithms.
Prerequisites/Corequisites: Permission of instructor
Terms offered: As needed 4 credit hours
NENG 790 - Nuclear Systems Design
Students are assigned to groups for the purpose of conducting a design study on an open-ended problem. Students must mathematically model the problem and propose solutions. Solutions are evaluated against established objectives and realistic constraints such as cost, reliability, survivability, safety, human factors, ethics, and social impact. The best solution is then optimized. Recent class problems have included future terrestrial and space-based Air Force systems.
Prerequisites/Corequisites: NENG 631
Terms offered: As needed 4 credit hours

NENG 791 - Non-Proliferation of Nuclear Weapons and Technologies
This course examines the problem of global proliferation through a multidisciplinary approach. This course provides an understanding of the technology necessary to produce weapons of mass destruction as well as the means of delivering these weapons. The effects of chemical and biological weapons (with specific emphasis on the differences between them and nuclear weapons) are studied. Combating proliferation with an emphasis on U.S. Government legal obligations, treaty requirements, and DOD capabilities is considered. Detection of WMD and protection from their effects is examined. Finally, this knowledge is combined with a working knowledge of the current status of international proliferation to assess future trends.
Prerequisites/Corequisites: NENG 635
Terms offered: Winter 4 credit hours

NENG 799 - Thesis Research
This course is an in-depth study of a research topic selected from a wide variety of problems of current interest to the Air Force, with the results presented in a formal thesis and defense. Ordinarily, this course extends over several quarters, and no credit is given until the end of the last quarter. An oral presentation and defense of the research are required.
Prerequisites/Corequisites: None
Terms offered: All 1-12 credit hours

NENG 816 - Advanced Topics in Neutral Particle Transport
Problems in neutron, gamma ray and x-ray transport are formulated and solved. Emphasis is on numerical methods of solution of the Boltzmann equation. Topics introduced in NENG 705 are expanded and extended. Current topics from the literature are examined.
Prerequisites/Corequisites: none
Terms offered: As needed 4 credit hours

NENG 830 - Advanced Nuclear Weapons Effects
Examines in depth selected problems in neutron, gamma, x-ray, thermal and electromagnetic radiation and in shock, debris, blackout and Argus effects. Treats problems both experimentally and theoretically on the basis of the most recent literature and information available.
Prerequisites/Corequisites: none
Terms offered: As needed 4 credit hours

NENG 880 - Advanced Nuclear Forensics
This advanced PhD topics course covers nuclear technologies used in pre- and post-detonation forensics. The course is designed to provide students with an opportunity to explore the most recent experimental and computational methods in the field and apply them to real problems related to modern national security. A wide range of topics are explored. Some travel to interact with experts in the field and observe data collection is required.
NOTE: Clearance Required
Prerequisites/Corequisites: NENG 605, NENG 631, NENG 635, NENG 681, NENG 650
Terms offered Spring 4 credit hours

NENG 899 - Doctoral Level Special Study
Course content determined by faculty member based on student need.
Prerequisite/Corequisites: None
Terms offered: All 1-12 credit hours
NENG 999-Dissertation Research
This course consists of dissertation research conducted in nuclear engineering, including both the research itself and the preparation and defense of the dissertation. Selection of the research advisor and topic, formation of the research committee, supervision of the research, presentation and defense of the dissertation, and so on, are conducted in accordance with the Doctoral Council Policy Letters.
Prerequisites/Corequisites: none
Terms offered: All 1-12 credit hours

Optical Engineering (OENG)

OENG 520-Lasers for Engineers
A basic course in lasers for the non-specialist. The course covers systems engineering, the laser weapon, basic physics of a laser system, solid state, chemical, free electron, semiconductor lasers, laser beam propagation and control, laser lethality and laser weapon design.
Prerequisites/Corequisites: None
Terms offered: Limited; as approved by Dept Head 4 credit hours

OENG 530-Fundamentals of Remote Sensing Data Exploitation & Sensor Technology
This course lays the groundwork for solving GEOINT (Geospatial Intelligence) remote sensing problems, with emphasis on infrared sensor technology. Both the signature and metric aspects of GEOINT will be considered. Topics include source characteristics, radiometry, atmospheric and propagation effects, optics, detectors, and elementary signal/image processing. Students should have a background in algebra and basic physics.
Prerequisites/Corequisites: None
Terms offered: DL; Limited; as approved by Dept Head 4 credit hours

OENG 531-Wide Area Overhead Electro-Optical Surveillance
The principles developed in OENG 530 will be applied to explore the current technology for collecting, processing, and exploiting satellite-based infrared sensor data for missile warning, missile defense, support for military operations, technical intelligence, and environmental monitoring.
Prerequisites/Corequisites: OENG 530
Terms offered: Limited; 3 credit hours

OENG 533-Spectral Imagery Systems and Data Exploitation
Presents commercial and DOD/IC multi-/hyper-spectral sensors, including data collection issues and GEOINT applications. Examines information that can be extracted from multi-/hyper-spectral data sets collected by GEOINT sensors. Introduces concepts of signature exploitation for materials identification and pattern recognition. Techniques covered include background suppression, principle components, anomaly detection, and signature-based detection.
Prerequisite/Corequisites: OENG 530
Terms offered: Limited; as approved by Dept Head 3 credit hours

OENG 616-Electro-Optical Systems Laboratory
A laboratory and lecture course that introduces laboratory techniques for the measurement of optical observables (emissions or reflections of optical radiation from aerospace vehicles). The weekly two-hour-long lecture period is used to discuss the design of experiments, safe and practical laboratory techniques, and the communication (in written and oral form) of experimental results. The experiments are in the areas of spectroradiometry, optical cross section measurement, TV sensors, and IR sensors.
Prerequisites/Corequisites: OENG 650
Terms offered: Summer 4 credit hours

OENG 620-Laser Engineering
Treats the basic operation and components of the laser with emphasis on the knowledge required to use the laser as an optical system component. Covers laser media, resonator, pump, and waste heat removal, as well as types of lasers available. Both CW and pulsed lasers will be treated. Stress will be placed on the laser output beam and the device parameters that affect the beam.
Prerequisites/Corequisites: PHYS 556 or PHYS 655, PHYS 640
Terms offered: Spring 4 credit hours
OENG 644 - Linear Systems and Fourier Optics
This course covers the linear systems approach to modeling optical wavefront propagation, diffraction, and imaging. Introductory material includes analysis tools and two-dimensional Fourier transforms. The majority of the course is devoted to using these tools to solve problems in optics imaging, and optical information processing.
Prerequisites/Corequisites: PHYS 640; Terms offered: Winter 4 credit hours

OENG 645 - Wave Optics I
This course covers the first principles of wave optics modeling. Beginning with vacuum propagation of a single source of light, techniques will be examined to include the effects of extended sources, optical aberrations, and finally turbulent media. Particular attention will be paid to the assumptions and simplifications necessary to model a continuous system in a discrete simulation and methodology to increase fidelity.
Prerequisite/Corequisites: OENG 644
Terms offered: Spring 4 credit hours

OENG 647 - Hyperspectral Remote Sensing
This course provides a thorough treatment of the primary components of the field of Hyperspectral remote sensing, including the underlying spectral signature characteristics of natural and man-made materials, the radiative transfer to remote sensors, the design of imaging spectrometers, and the data processing methods employed. The goal is to prepare the student to model the observed spectral radiance for several remote sensing scenarios, analyze the performance of Hyperspectral imaging systems, and implement standard Hyperspectral classification and detection algorithms.
Prerequisites/Corequisites: PHYS 640, OENG 650
Terms offered: Summer 4 credit hours

OENG 650 - Optical Radiometry and Detection
Radiation source characterization and the transport of that radiation through free space is considered in the first half of this course. In the second half, the principles of optical detection are considered along with specific application of various types of detectors.
Prerequisites/Corequisites: PHYS 640
Terms offered: Winter 4 credit hours

OENG 651 - Optical Diagnostics Laboratory
An advanced laboratory and lecture course in optical diagnostic techniques. The lecture phase of this course treats radiometry, optical sources, spectroscopic techniques, detector physics and performance, error analysis and laser safety. The laboratory experiments emphasize the design of optical systems for the purpose of analyzing physical phenomena. Typical experiments include: diagnostics of CW and pulsed laser systems, spectroscopic analysis of the luminescence from solids and plasmas, interferometric measurements, holography, and calorimetry.
Prerequisites/Corequisites: OENG 620, PHYS 542
Terms offered: Summer 4 credit hours

OENG 660 - Introduction to Non-Linear Optical Devices
This course is designed to develop those areas of electromagnetic wave interaction with matter necessary for an understanding of nonlinear optical devices. Plane wave propagation in anisotropic media, commonly called “crystal optics” is stressed. Passive optical devices, such as wave plates, polarizers and compensators, are designed. Parametric processes are introduced, and applications, such as amplitude and frequency modulation, second harmonic generation, and parametric oscillation are considered.
Prerequisites/ Corequisites: PHYS 640
Terms offered: As needed 4 credit hours
OENG 681-Digital Image Processing
The principle objectives of this course are to develop the concepts and techniques of digital image processing and lay a foundation that can be used as the basis for research in this field. Topics covered include the characteristics of digital images, image transforms, image enhancement, image restoration, image segmentation, and image representation and description.
Prerequisites/Corequisites: PHYS 640
Terms offered: As needed
4 credit hours

OENG 699-Master’s Level Special Study
Directed study at an intermediate graduate level on a special topic which is not normally covered in a regularly scheduled course or as part of thesis research. Topic, format, and course requirements are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.
Prerequisites/Corequisites: None
Terms offered: All
1-12 credit hours

OENG 720-Laser Devices and Applications
Treats specific laser systems of importance to the commercial world and Air Force in particular. The course stresses current laser technology and engineering analysis of specific systems. Topics covered typically include operations characteristics, such as power and energy output, their scalability, spectral and temporal characteristics, and beam quality and the factors limiting the performance. Where appropriate, design issues associated with specific systems are also discussed. In addition to the laser systems commercially available, laser systems appropriate for the Air Force and other military applications, such as laser ranging, target designation, imaging, electro-optic countermeasure, and laser weapons, are discussed.
Prerequisites/Corequisites: OENG 620
Terms offered: Winter
4 credit hours

OENG 740-Optical System Design
This course is designed to introduce the basic principles of computer-aided optical system design. Topics include basic principles of optical ray tracing (both geometric and analytic), chromatic aberrations, third-order Seidel aberrations, techniques for reducing these aberrations, current computer optical design programs, Gaussian beams, and modulation and scanning techniques. This course concludes with a design project of an optical system using a state-of-the-art computer optical design code.
Prerequisites/Corequisites: PHYS 640
Terms offered: As needed
4 credit hours

OENG 775-Introduction to Photonic Devices
Provides an introduction to photonic components and devices, focusing on their basic principles of operation and applications. This course covers the basic components that are used in photonic devices: dielectric waveguides; semiconductor lasers, including distributed feedback and quantum well lasers; semiconductor detectors; acousto-optic modulators; and fiber optics. Specific photonic devices are covered, including directional couplers, phase modulators, intensity modulators, photonic switches, bistable optical devices, and self-electro-optic-effect devices.
Prerequisites/Corequisites: PHYS 570 or PHYS 670, PHYS 640, OENG 620
Terms offered: Winter
4 credit hours

OENG 780-Infrared Technology
This course presents the principles and technology required for the design and analysis of electro-optic systems, with emphasis on those systems operating in the infrared, and considers the overall problem of the reduction of optical observables by studying the aircraft infrared signature scenario. Sources of radiation, propagation through the atmosphere, detection of radiation, and reduction of infrared signature are all discussed.
Prerequisites/Corequisites: OENG 650
Terms offered: Spring
4 credit hours
OENG 780-Infrared Technology
This course presents the principles and technology required for the design and analysis of electro-optic systems, with emphasis on those systems operating in the infrared, and considers the overall problem of the reduction of optical observables by studying the aircraft infrared signature scenario. Sources of radiation, propagation through the atmosphere, detection of radiation, and reduction of infrared signature are all discussed.
Prerequisites/Corequisites: OENG 650
Terms offered: Spring 4 credit hours

OENG 799-Thesis Research
This course is an in-depth study of a research topic selected from a wide variety of problems of current interest to the Air Force, with the results presented in a formal thesis and defense. Ordinarily, this course extends over several quarters, and no credit is given until the end of the last quarter. An oral presentation and defense of research are required.
Prerequisite/Corequisites: none
Terms offered: All 1-12 credit hours

OENG 899-Doctoral Level Special Study
Course content determined by faculty member based on student need.
Prerequisite/Corequisites: none
Terms offered: All 1-12 credit hours

OENG 999-Dissertation Research
This course consists of dissertation research conducted in optical sciences and engineering, including both the research itself and the preparation and defense of the dissertation. Selection of both the research advisor and topic, formation of the research committee, supervision of the research, presentation and defense of the dissertation, and so on, are conducted in accordance with the Doctoral Council Policy letters.
Prerequisites/Corequisites: none
Terms offered: All 1-12 credit hours

Physics (PHYS)

PHYS 519-The Space Environment
The near-earth environment, from the surface to geosynchronous altitude, is that in which satellites and astronauts must operate. This course is concerned with the radiation, particles, and general conditions encountered in the Earth’s atmosphere, ionosphere, and magnetosphere. Specific effects that may be studied include spacecraft thermal equilibrium, orbit decay, spacecraft charging, space-to-ground communications, atmospheric chemistry, Van Allen belts, and solar phenomena.
Prerequisites/Corequisites: None
Terms offered: Summer (DL) and Fall (in-residence and DL) 4 credit hours

PHYS 521-Space Surveillance
This course covers the fundamental physics necessary for an understanding of remote sensors with an emphasis on visible light and infrared systems. Beginning with the sources of electromagnetic radiation, the following aspects of the problem are treated phenomenologically; the interaction of light with matter, atmospheric absorption and scattering, radiometry, optical systems, spectral and spatial resolution and imaging, and electro-optical detectors. Where appropriate, examples are chosen from current Air Force technology.
Prerequisites/Corequisites: None
Terms offered: Fall (DL) and Winter (in-residence) 4 credit hours

PHYS 531-Electromagnetism
An intermediate level course stressing basic principles of electromagnetic field theory. Treats electrostatics, Maxwell’s equations, good conductor and good dielectric approximations, and wave propagation through interfaces. Poynting’s theorem and the flow of power are covered. Waveguides and simple radiating systems are introduced.
Prerequisites/Corequisites: None; Terms offered: Summer
PHYS 542 - Optics Laboratory
A fundamental laboratory course with experiments in coherence, diffraction, lenses, interference, polarization and lasers. Lectures will introduce selected topics in laboratory practice such as error calculation, radiometry, spectrometry, coherence, and detectors.
Prerequisites/Corequisites: PHYS 640
Terms offered: Spring 2 credit hours

PHYS 556 - Introduction to Quantum Physics
Basic mathematical and conceptual principles of quantum physics. Includes black body radiation, photoelectric effect, Rutherford scattering, Bohr theory of the atom, wave-particle duality, Schrodinger wave equation and applications, one electron atom, atomic spectra, X-rays, periodic table, statistical physics, and statistical distribution functions.
Prerequisites/Corequisites: None
Terms offered: Summer 4 credit hours

PHYS 570 - Physics of Solid State Devices
Basic solid state physics for the non-physicist who needs an understanding of solid state devices. Topics include quantum theory, quantum statistics, crystal structure and binding, reciprocal lattice, crystal lattice dynamics, free electron theory, energy band theory, and semiconductors.
Prerequisites/Corequisites: PHYS 556, if no modern physics in undergrad
Terms offered: Fall 4 credit hours

PHYS 598 - Engineering Physics Thesis Seminar
This seminar, offered once a week, normally during the third quarter, is designed primarily to provide students with the information they need to carry out their thesis research and complete the thesis document. Topics covered include the student-advisor relationship, literature surveys, research prospectus, the thesis document, grading standards, and the thesis defense.
Prerequisites/Corequisites: None
Terms offered: Spring 1 credit hours

PHYS 600 - Dynamics
Treatment of theoretical mechanics at the advanced level. Develops Lagrangian and Hamiltonian formulations of dynamics from variational principles. Applications include central force problems, rigid body motion by matrix transformations, and coupled oscillators.
Prerequisites/Corequisites: none
Terms offered: Spring 4 credit hours

PHYS 601 - Electrodynamics I
A course in classical electromagnetic radiation. Treats wave propagation in space and in material media, reflection and refraction, and radiating systems.
Prerequisites/Corequisites: none
Terms offered: Fall 4 credit hours

PHYS 624 - High Power Microwave Systems
A modular approach to the design and characterization of a high power microwave weapon system is adopted. The course objective is to provide an understanding of the system components and the attributes of the weapon system. The weapon system is viewed as consisting of five modules: prime power and power conditioning equipment, a microwave source, structures to couple the source to the propagation media, and the target. The physical principles associated with a module, module characteristics, and the influence and constraints of each module on total system requirements and effectiveness are identified and discussed.
Prerequisites/Corequisites: PHYS 531 or PHYS 601
Terms offered: As needed 4 credit hours
PHYS 635-Thermal Physics
Treats statistical mechanics and thermodynamics. Topics include statistical methods, statistical thermodynamics with applications, ensemble theory, Maxwell-Boltzmann, Fermi-Dirac, and Bose-Einstein statistics with applications.
Prerequisites/Corequisites: PHYS 556 or PHYS 655
Terms offered: Winter 4 credit hours

PHYS 640-Optics
Introduction to modern optics, with a treatment of both geometrical and physical optics. Geometrical topics include reflection and refraction, lenses, mirrors, stops, ray tracing, telescopes, and optical instruments. Wave phenomena treated will include interference, optical testing, polarization, and Fraunhofer and Fresnel diffraction.
Prerequisites/Corequisites: None
Terms offered: Fall 4 credit hours

PHYS 650-Kinetic Theory of Plasmas
Study of the basic concepts and definitions of plasma physics and the parameters that characterize plasma behavior. Includes applications of the Boltzmann equation and kinetic theory to such basic plasma phenomena as Debye shielding, plasma waves, magnetic confinement, and ionospheric physics.
Prerequisites/Corequisites: PHYS 531 or PHYS 601
Terms offered: Spring 4 credit hours

PHYS 655-Quantum Mechanics I
An introduction to the Schrödinger approach to quantum mechanics. Presentation and analysis of experimental background, postulatory basic, and perturbation methods. Application of theory to linear oscillator, free particle, hydrogen atom, hydrogen molecule, and tunnel effect is presented.
Prerequisites/Corequisites: None
Terms offered: Fall 4 credit hours

PHYS 661-Atomic and Molecular Spectroscopy
Treats selected topics in atomic and molecular physics. Includes spectroscopy of atomic systems, diatomic and triatomic molecules, line shape, line broadening and interaction of radiation fields with matter, particularly in lasers. Approximation methods in quantum mechanics are applied to the spectroscopy of complex atoms and molecules. Analysis of electronic, vibrational and rotational experimental data is emphasized.
Prerequisites/Corequisites: PHYS 655
Terms offered: Winter 4 credit hours

PHYS 670-Introduction to Solid State Physics
Study of fundamental concepts in solid state physics. Topics include crystal structure and binding, X-ray diffraction and reciprocal lattice, lattice vibrations and phonons, free electron Fermi gas, transport properties of metals, quantum theory of electrons and energy bands, semiconductors and semiconductor devices.
Prerequisites/Corequisites: PHYS 635, PHYS 655
Terms offered: Winter 4 credit hours

PHYS 671-Selected Topics in Solid State Physics
This course embodies the study of various phenomena in solids. Topics will be selected from semiconductors and semiconductor devices, optical and surface phenomena, transport properties, and superconductivity.
Prerequisites/ Corequisites: PHYS 670
Terms offered: As needed 4 credit hours

PHYS 686-Computational Methods for Atmospheric and Space Sciences
Develops fundamental computational techniques, while emphasizing modern programming practices, with a focus on terrestrial and space weather applications. Topics include numerical integration, linear and nonlinear ODEs, finite difference discretization of PDEs and data assimilation.
Prerequisites/Corequisites: None
Terms offered: Fall 4 credit hours
**PHYS 699-Master's Level Special Study**
Directed study at an intermediate graduate level on a special topic which is not normally covered in a regularly scheduled course or as part of thesis research. Topic, format, and course requirements are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.
Prerequisites/Corequisites: None
Terms offered: All 1-12 credit hours

**PHYS 730-Electrodynamics II**
A continuation of PHYS 601 into areas appropriate for the study of charged particle beams and electromagnetic pulse effects. Treats relativistic particle dynamics, bremsstrahlung, and waves in a magneto-ionic medium.
Prerequisites/Corequisites: PHYS 601
Terms offered: Fall 4 credit hours

**PHYS 735-Statistical Physics**
Development of tools for the description of macroscopic systems based on microscopic insights. The physics of critical phenomena including superconductivity in the Landau-Ginzburg theory, mean field theories, renormalization group, cluster expansion and path integral approaches, and Monte Carlo techniques are developed. Elements of non-equilibrium statistical mechanics including Onsager’s theorem and the method of maximum entropy are also introduced.
Prerequisites/Corequisites: PHYS 635
Terms offered: Winter 4 credit hours

**PHYS 740-Optics II**
This course is designed to give a more rigorous mathematical treatment of optics principles. The properties of light propagation through practical optical components and systems, as well as free space, are described both in terms of geometric optics and physical optics languages. In particular, wave front aberrations and their implications on image quality and focal intensity are discussed in depth. Topics covered include matrix method in geometric optics and Gaussian beam optics, Jones matrix treatment of polarization, optics of the solids (crystal optics), coherence theory, and diffraction theory of aberration.
Prerequisites/Corequisites: PHYS 640, PHYS 601
Terms offered: Winter 4 credit hours

**PHYS 751-Plasma Dynamics**
Expands the development of plasma physics beyond the basic phenomena discussed in PHYS 650 to include derivations of the Vlasov, Boltzmann, and Fokker-Planck equations. These equations are applied to plasma problems that illustrate the fluid equations and wave phenomena. Plasma oscillations, dispersion relations, Landau damping, and velocity space instabilities will be included in a study of plasma confinement and gas discharges.
Prerequisites/Corequisites: PHYS 650
Terms offered: As needed 4 credit hours

**PHYS 755-Quantum Mechanics II**
Intermediate quantum mechanics: develops the formal mathematical basis and postulates of quantum mechanics. Examines topics in measurement theory, two level systems, scattering, spin, and quantum dynamics. Applications in atomic and nuclear physics are developed.
Prerequisites/Corequisites: PHYS 655
Terms offered: Fall 4 credit hours

**PHYS 756-Quantum Mechanics III**
Advanced quantum mechanics: examines topics of invariance and symmetries, systems of identical particles, time independent and dependent perturbation theory, and relativistic quantum theory of the Klein-Gordon and Dirac equations. Application topics in lasers, solid state and plasma physics are developed.
Prerequisites/Corequisites: PHYS 755
Terms offered: As needed 4 credit hours
PHYS 757-Quantum Computing
The foundational elements of quantum computing and quantum information will be developed with a focus on the theoretical description of quantum bits (qubits) and the entanglement of qubits required for quantum computation and quantum information technologies. Several quantum algorithms will be discussed including the elementary Deutsch algorithm and the more important quantum Fourier transform algorithm. The course will conclude with a discussion of various physical realizations that have been proposed or employed to construct an actual quantum computer.
Prerequisites/Corequisites: PHYS 655
Terms offered: Summer 4 credit hours

PHYS 770-Solid State Physics I
First course in a sequence of course covering topics in solid state physics at an advanced level. Topics include free electron theory, crystal structure, x-ray diffraction, reciprocal lattice, electron dynamics, energy band calculations, transport theory, Fermi surfaces, band structure of metals, electronic scattering and cohesive energy.
Prerequisites/Corequisites: PHYS 670, PHYS 755
Terms offered: As needed 4 credit hours

PHYS 771-Solid State Physics II
Second course in a sequence of courses covering solid state physics at an advanced level. Topics include lattice dynamics, phonons, anharmonic effects, dielectric properties, semiconductor properties, defects, magnetism, and superconductivity.
Prerequisites/Corequisites: PHYS 770
Terms offered: As needed 4 credit hours

PHYS 772-Solid State Physics III (Advanced Topics In SSP)
An in-depth study of advanced topics in solid state physics. Special emphasis will be given to the topics covering the optical properties and optical processes in semiconductors, dealing with the interactions among photons, electrons, holes, and impurities in semiconductor crystals. Topics include energy states, radiative and non-radiative transitions, emissions, and absorptions in semiconductors, processes and p-n junctions, and photovoltaic effects on semiconductors.
Prerequisites/Corequisites: PHYS 771
Terms offered: As needed 4 credit hours

PHYS 775-Ionospheric Physics and Chemistry
Formation and chemical properties of the ionosphere. Topics include ionization mechanisms, conductivity, energy loss mechanism, and electromagnetic wave propagation.
Prerequisites/Corequisites: CHEM 675, PHYS 635, PHYS 650
Terms offered: Spring 4 credit hours

PHYS 776-Structure and Dynamics of the Magnetosphere
Physics of solar wind, formation of the magnetosphere, and properties of magnetosphere. Topics include solar wind flow, solar wind-earth magnetic field interaction, magnetosphere plasma wave interactions, Van Allen belts, and auroral phenomena.
Prerequisites/Corequisites: PHYS 650
Terms offered: Summer 4 credit hours

PHYS 777-The Solar Atmosphere
This course deals with the source of the Earth’s space weather, the sun. In particular, the student will study the outer solar regions, including the “quiet” photosphere, the chromosphere, the corona, and solar wind. The course heavily emphasizes both descriptions of instrumentation and data used to observe solar conditions and the “active” sun, which perturbs the Earth’s environment, and it is intended to provide the space environment student with a quantitative description of solar events that impact the forecaster’s mission. Class discussion will focus on sunspot activity, flares, prominence, coronal mass ejections, coronal holes, and other pertinent observables that indicate active conditions on the sun’s surface.
Prerequisites/Corequisites: PHYS 635, PHYS 650
Terms offered: Summer 4 credit hours
PHYS 780-Group Theory and Quantum Mechanics
Treats abstract theory of groups and the theory of group representations in sufficient detail to aid in understanding current theories of the structure of atoms, molecules, and solids.
Prerequisites/Corequisites: PHYS 755
Terms offered: As needed 4 credit hours

PHYS 781-Laser Spectroscopy
A first course in laser spectroscopy designed to provide the student with the fundamental principles underlying modern spectroscopic methods utilizing lasers. Topical coverage includes the discussion of elements of radiation physics relevant to laser spectroscopy, characteristics of lasers as a spectroscopic tool, and spectroscopic instrumentation including various detection techniques. These topics are followed by an overview of selected experimental techniques, such as laser induced fluorescence, laser Raman, and two-photon absorption spectroscopy.
Prerequisites/Corequisites: PHYS 661, OENG 620
Terms offered: Summer 4 credit hours

PHYS 782-Selected Topics In Nonlinear Optics
An advanced course in nonlinear optics designed to provide the student with the fundamental principles underlying nonlinear optical phenomena. Topical coverage includes the discussion of nonlinear interaction of light with matter in terms of nonlinear susceptibility. A semi classical theory of nonlinear susceptibility is also included. These topics are followed by a discussion of applications in selected subject areas in nonlinear optics and/or laser spectroscopy, such as frequency conversion, phase conjugation, stimulated Raman and Brillouin scattering, and coherent anti-Stokes Raman spectroscopy.
Prerequisites/Corequisites: OENG 660, OENG 620, PHYS 755
Terms offered: As needed 4 credit hours

PHYS 790-Engineering Physics Design
Treats the principles involved in the design of systems in the areas of optics, solid state physics, plasma physics and others. The student will participate in an engineering design study in one of these areas. Classified papers may be included.
Prerequisites/Corequisites: Permission of instructor
Terms offered: As needed 4 credit hours

PHYS 791-Operational Assessments in Atmospheric and Space Sciences Laboratory
In this course, students will study the current operational aspects of USAF space and terrestrial environmental forecasting and observing. Additionally, students will attempt to solve a current or future DoD operational environment-related problems through the use of solar and terrestrial remote sensors. Students will learn about the required inputs for each model, and evaluate the output. The course also discusses instrumentation and models used to observe and characterize the environment from the earth to the sun. Finally, students will be exposed to experiments that illustrate how space and terrestrial weather can ultimately impact daily operations.
Prerequisites/Corequisites: Permission of instructor
Terms offered: Winter 4 credit hours

PHYS 792-Space Weather Laboratory
This laboratory course introduces the student to the space weather computer codes used to provide operational weather support to DoD, including solar wind, magnetospheric, ionospheric, and thermospheric models. Students will learn about the required inputs for each model, gain experience running the codes, and evaluate the output. The course also discusses instrumentation used to observe the environment. Finally, students will exposed to experiments that illustrate how space weather affects operations.
Prerequisites/Corequisites: PHYS 775, PHYS 776, PHYS 777
Terms offered: Winter 4 credit hours

PHYS 798-Departmental Seminar
This seminar is offered once a week during the academic quarters for all students in Doctoral and Master’s programs in the Department of Engineering Physics. This seminar is intended to provide the student with information on a wide range of topics from current scientific research to practical engineering design. Where possible, the focus is on specific Air Force needs and programs in areas related to their studies and the structure
and organization of the R&D community within the Air Force.
Prerequisites/Corequisites: None
Terms offered: All

**PHYS 799-Thesis Research**
This course is an in-depth study of a research topic selected from a wide variety of problems of current interest to the Air Force, with the results presented in a formal thesis and defense. Ordinarily, this course extends over several quarters, and no credit is given until the end of the last quarter. An oral presentation and defense of the research are required.
Prerequisites/Corequisites: none
Terms offered: All

**PHYS 840-Advanced Topics in Optics**
Selections from a host of advanced topics such as the use of variational principles in geometrical optics, Fresnel-Kirchhoff scalar diffraction theory, coherence, holography, imaging theory, interaction of light with materials and waves, dielectric waveguides and optical fibers.
Prerequisites/Corequisites: PHYS 740, OENG 644, OENG 620
Terms offered: As needed

**PHYS 845-Quantum Optics**
A modern introduction to light and its interactions with quantum mechanical systems. Treats the photon concept and the fundamental physics that underlie modern optical phenomena, such as self-induced transparency, photon-echo, coherent pulse propagation, Lamb’s theory of the laser, and superradience.
Prerequisites/Corequisites: PHYS 730 and PHYS 755
Terms offered: As required

**PHYS 880-Positron Physics and Chemistry**
Advanced treatment of physics and chemistry of positrons and positronium. Topics include: 1) physical chemistry of positrons, 2) compounds and chemistry of positrons and positronium, 3) experimental techniques in positron spectroscopy, 4) positron porimetry, materials applications, and 5) quantum computational methods to model positron chemistry.
Prerequisites/Corequisites: PHYS 655 or permission of instructor
Terms offered: Summer

**PHYS 899-Doctoral Level Special Study**
Directed study for doctoral students on a special topic which is not normally covered in a regularly scheduled course or as part of dissertation research. Topic, format, and requirements of the course are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.
Prerequisites/Corequisites: None
Terms offered: All

**PHYS 999-Dissertation Research**
This course consists of dissertation research conducted in applied or engineering physics, including both the research itself and the preparation and defense of the dissertation. Selection of the research advisor and topic, formation of the research committee, supervision of the research, presentation, and defense of the dissertation, and so on, are conducted in accordance with the Doctoral Council Policy letters.
Prerequisites/Corequisites: none
Terms offered: All

**TENP 799 ENP Thesis**
Thesis Completion course for graduating students to be taken during the last quarter of study. Registration in TENP 799 for 12 non-billable credit hours is required for all master's students whose research advisors are in the Department of Engineering Physics. The grade assigned to this course is the official thesis grade.
Prerequisites/Corequisites: None
Terms offered: All