Revised Physics Department Graduate Curriculum

New Mexico Tech faculty primarily have expertise in Astrophysics and Atmospheric Physics. Most graduate students work in one of these areas. We also have research opportunities in cooperation with other departments on campus, in particular Mathematics and Electrical Engineering. Other interdisciplinary programs are also available through research organizations both on (e.g. shock physics at EMRTC) and off campus (Air Force Research Laboratory, Sandia National Laboratory, and Los Alamos National Laboratory).

Astrophysics

Astrophysics research at NMT encompasses planets, stars, the interstellar medium, galaxies, and active galactic nuclei. Specific faculty interests include stellar formation, galactic dynamics and evolution, and interstellar chemistry. The Jansky Very Large Array (VLA) and the Very Long Baseline Array (VLBA) radio telescopes, operated by the National Radio Astronomy Observatory (NRAO), are headquartered on campus, and offer unique opportunities for research in radio astronomy. The Magdalena Ridge Observatory (MRO) operates a 2.4-meter optical telescope and is developing an optical interferometer (MROI) that provides both opportunities in optical instrumentation design as well as scientific research once first light is achieved. Students may pursue dissertation work not only with regular faculty but also with a number of NRAO staff who have adjunct appointments at Tech.

Atmospheric Physics

Atmospheric physicists at Tech study convection and dynamics (on earth and other solar system planets), lightning, atmospheric electricity, and the middle and upper atmosphere (including ozone and space weather). Langmuir Laboratory for Atmospheric Physics is a facility unique in the world, providing an instrumented mountaintop specialized in lightning research. Langmuir also includes balloon-launch facilities and a capability in compact instrumentation appropriate for remote and airborne deployments. The convection and dynamics group has its own Beowulf clusters, while the upper atmospheric group supports extremely sensitive spectrographs. Students in our graduate program can acquire deep, hands-on experience with custom scientific instrumentation and electronics, computer modeling and automated data analysis and theoretical and mathematical methods of physics.

Masters of Science Program

All students are required to pass a preliminary exam ("prelim") at the MS level. The prelim covers material in physics and mathematics normally included in the undergraduate physics curriculum. The department offers the exam at the beginning of the Fall and Spring semesters. Failure to pass this exam in the time-line established on entry to the program usually results in dis-enrollment from the graduate physics program. See the "Physics Prelim Procedures" on the department website for further details.

The Master of Science degree in Physics may be earned with thesis or independent study:

With Thesis:
The student's course of study and thesis topic must be approved by the student's advisory committee. A thesis consists of directed research, and a write-up of the research. An oral defense of the thesis is required. The thesis is an archival document published electronically and kept in the NMT Library.

Without Thesis:
The student's course of study must be approved by the student's advisory committee. The student's committee may require additional coursework beyond that listed below. A student who elects to not write a thesis may or may not participate in research, but they typically write a paper on a topic selected with guidance by their advisory committee. Unlike a thesis, this paper is not archived electronically by the NMT Library.

Master of Science in Physics

In addition to the general masters degree requirements, all students enrolled in the Master of Science degree in Physics must satisfy the following course requirements:

- All students must complete PHYS 501 (2) and 502 (2) in their first two semesters.
- PHYS 509 (3)
- PHYS 505 (3) or 521 (3)
- 6 credit hours chosen from PHYS 508 (3), PHYS 510 (3), PHYS 518 (3)
- PHYS 579 (1), Graduate-Faculty seminar, must be taken for the first four semesters.

Master of Science in Physics with Specialty in Instrumentation

In addition to the general masters degree requirements, all students enrolled in the Master of Science degree in Physics with Specialty in Instrumentation must satisfy the following course requirements:

- All students must complete PHYS 501 (2) and 502 (2) in their first two semesters.
- PHYS 509 (3)
- MATH 587(3)
- 6 credit hours chosen from PHYS 508 (3), PHYS 510 (3), PHYS 518 (3)
- In addition, the student must take an additional 9 credit hours to be approved by their committee. Potential topics include advanced undergraduate or graduate courses in digital or analog electronics, control theory, optics, optical engineering, spectroscopy, NMR, laser physics, shop techniques, materials (metals, ceramics, polymers), explosives, mechanical design, robotics, vacuum and cryogenic techniques. Students are reminded that it is possible to pursue a limited number of credits at other approved higher educational institutions, and so this course work might also be pursued as part of an internship.
- PHYS 579 (1), Graduate-Faculty seminar, must be taken for the first four semesters.

Doctor of Philosophy in Physics Program

Students of exceptional ability as demonstrated in previous courses in physics and mathematics may pursue a program leading to the doctoral degree. Our department offers the following four doctoral paths (with requirements for each specified in the next sections.)

- Doctor of Philosophy in Physics with Dissertation in Astrophysics
- Doctor of Philosophy in Physics with Dissertation in Atmospheric Physics
- Doctor of Philosophy in Physics with Dissertation in Mathematical Physics
- Doctor of Philosophy in Physics

Doctoral Programs -- *General Requirements*

All doctoral students are required to pass a preliminary exam ("prelim") at the Ph.D. level. The prelim covers material in physics and mathematics normally included in the undergraduate physics curriculum. The department offers the exam at the beginning of the Fall and Spring semesters. Although doctoral students take the same prelim as MS students, a higher score is required of them.

Doctoral students must pass the exam at the PhD level by the time-line established on their entry into the program. A student without a Masters degree in Physics must pass the exam at the MS level within their first year in the PhD program. Failure to pass this exam with the required scores and within the specified time usually results in dis-enrollment from the PhD physics program. See the "Physics Prelim Procedures" on the department website for further details.

In addition to the general doctoral degree requirements, the following course requirements apply to all curricula:

- All students must take PHYS 501 (2) and 502 (2) in their first two semesters.
- PHYS 505 (3), 508 (3), 509 (3), 510 (3), 518 (3), and 521 (3)
- PHYS 579 (1), Graduate-Faculty seminar, must be taken for the four semesters.
- 9 credit hours in mathematics beyond that required of an undergraduate physics major.

Doctor of Philosophy in Physics with Dissertation in Astrophysics

In addition to the degree requirements specified above, students completing their dissertation in astrophysics must also complete

- 6 credit hours chosen from PHYS 426 (3), 564 (3), 565 (3), 566 (3). PHYS 426 must be completed unless the student has had equivalent material in previous courses.

- 6 credit hours chosen from PHYS 425 (3), 562 (3), 563 (3), 567 (3)

Doctor of Philosophy in Physics with Dissertation in Atmospheric Physics

In addition to the degree requirements specified above, students completing their dissertation in atmospheric physics must also complete

- PHYS 427 (3), 428 (3)

- An additional 6 credit hours must be taken in areas pertinent to the student's program. This can be achieved by taking PHYS 527 (3), 532 (3), 533 (3), 535 (3), 536 (3), and/or other courses approved by the student's advisory committee.

Doctor of Philosophy with Dissertation in Mathematical Physics

In addition to the general degree requirements specified above, students completing their dissertation in mathematical physics must also complete

- MATH 435 (3), 438 (3), 442 (3), 471 (3), 535 (3). These may be used to satisfy the (9) credit hours in mathematics required for all curricula.

- An additional (6) credits in mathematics and (6) credits in physics, approved by the student's advisory committee.

Doctor of Philosophy in Physics

In addition to the general degree requirements specified above, (12) credit hours of graduate physics or appropriate related fields, approved by the student's advisory committee, should be completed in his/her field of specialization.

Graduate Minor in Physics (*update* to course numbers only)

A student seeking a graduate minor in physics must complete at least 6 hours from the following: PHYS 505, PHYS 508, PHYS *510*, PHYS *511*, PHYS *518*, PHYS *519*, or PHYS *521*. The remaining physics courses must be graded, at least 300-level or above, and be approved by the minor advisor. A total of 12 credits hours in physics (minimum 6 hours at the 500-level) are required for a minor at the master's level, and 18 hours (minimum 12 hours at the 500-level) for the doctorate level minor.

Physics Courses (modified listings only):

The renumbering of undergrad courses will be presented at council of chairs (included for completeness only).

PHYS 331 (427), Atmospheric Physics, 3 cr, 3 cl hrs

Prerequisite: PHYS 122 or 222

Offered alternate years

Covers dry and moist thermodynamics, radiative transfer, some microphysics, and dynamics (including hydrostatic balance, geostrophic balance, and thermal wind equation).

PHYS 332 (428), Climate Physics, 3 cr, 3 cl hrs

Prerequisite: PHYS 427; MATH 332 and 335

Offered alternate years

This course, a continuation of PHYS 427, includes the dynamics needed to understand general circulation (e.g. Rossby waves), also covers basics in climate modeling and observations.

NOTE: PHYS 427 and 428 replace PHYS 331 and 332. Material has been reorganized and will be offered at a more advanced level.

PHYS 501, 502 Introduction to Research and Scientific Communication, 2 cr, 3 lab hrs each semester

This course involves beginning graduate students in a modest project, usually related to ongoing research in the department, and provides a background in scientific communication. The research portion emphasizes independent work by the student, but is supervised by a faculty member. Possible projects include data analysis, software development, theoretical modeling, a literature survey, and design and/or construction of research or teaching equipment. The communication portion incorporates the research topic into several written and oral assignments, including conference abstracts, proposals, oral and poster presentations, and peer-reviewed research papers.

PHYS 509, Methods of Theoretical Physics, 3 cr, 3 cl hrs

(NOTE: MATH 535, 536 is Methods of Mathematical Physics)

Prerequisite: MATH 254, 332 and 336 or equivalent

Covers mathematics essential for PHYS 510 and 518, including Dirac delta functions, vector spaces, operators and eigenvalues, Dirac notation, Fourier series and transforms, orthogonal polynomials, complex variables, and tensor notation.

PHYS 510, Electromagnetism, 3 cr, 3 cl hrs

Prerequisite: PHYS 509

Electrostatic and magnetostatic boundary-value problems, electromagnetic radiation generation, wave propagation in materials and at interfaces, polarization characteristics of radiative processes, and the relativistic covariance of electromagnetism will be covered.

PHYS 511, Advanced Electromagnetism, 3 cr, 3 cl hrs

Prerequisite: PHYS 510

Selected topics taken from advanced electromagnetism: optical fiber propagation, plasma waves and instabilities, scattering of radiation, optical coherence, and other topics based upon interests of the class.

PHYS 518, Quantum Mechanics, 3 cr, 3 cl hrs

Prerequisite: PHYS 505 and 509

Review of experiments leading to quantum theory: Schroedinger's Equation, applications to simple physical systems, perturbation theory, theory of angular momentum, and Dirac Theory.

PHYS 519, Advanced Quantum Mechanics, 3 cr, 3 cl hrs

Prerequisite: PHYS 512

Advanced topics in quantum mechanics, including scattering theory, Feynman path integrals, an introduction to quantum field theory, and other topics based upon interests of the class.

PHYS 521, Continuum Mechanics, 3 cr, 3 cl hrs

Stress, strain, rate of strain, and applications of these ideas in fluid dynamics and elastic body mechanics. Statics of elastic bodies and elastic waves. Navier-Stokes equation, vorticity dynamics, flows at low and high Reynolds number. Examples taken from a broad variety of areas. Co-taught with physics 421. Extra work assigned for graduate credit.

PHYS 527 Geophysical Fluid Dynamics, 3 cr, 3 cl hrs (Already Adopted by Faculty Senate – included for completeness)

Dynamics of stratified, rotating fluids; governing equations for the ocean and atmosphere, inertia-gravity waves, quasi-geostrophic theory, Rossby waves, instabilities, and jets, diabatic and frictional effects, tropical atmospheric dynamics.