Physics

***Professors**: Minschwaner, Raymond, Romero, Westpfahl*

***Associate Professors:** Creech-Eakman, Eack (Chair of the Department), Hofner, Morales, Sessions, Sonnenfeld, Young*

***Assistant Professors:** Arendt, Meier*

***Adjunct Faculty:** Avramidi, Bakker, Balasubramaniam, Burcher, Colgate, Elvis, Fuchs, Goss, Haniff, Jurgenson, Klinglesmith, Lopez Carrillo, Manney, Meason, Myers, Rison, Rupen, E. Ryan, W. Ryan, Shepard, Taylor, Teare, Thomas*

***Emeritus Professors:** Eilek, Hankins, Krehbiel, LeFebre, Winn*

Degrees Offered:
B.S. in Physics and in Physics with options in Astrophysics, Atmospheric Physics, and Computer Science; M.S. in Physics; M.S. in Physics with Specialty in Instrumentation; Ph.D. in Physics; Ph.D. in Physics with dissertation in Astrophysics, Atmospheric Physics, or Mathematical Physics

Departmental web site: http://physics.nmt.edu

Students in the Department of Physics are encouraged to pursue a broad scientific background and to master theory as well as experiment. The fundamental courses are offered in the principal areas of physics—atomic and nuclear physics, classical mechanics, electricity and magnetism, optics, quantum mechanics, statistical physics, and thermodynamics. The department also offers several laboratory classes. There is the opportunity for students to participate in research projects while taking classes and during summers.
Many undergraduate students become involved in faculty research, participate in the designing and building of scientific instruments and computer models. Undergrads sometimes co-author published papers with faculty.

A general degree in physics provides broad preparation for graduate work in physics, engineering, medicine and other sciences. A physics major with a BS and laboratory experience is often eligible for the same career options as engineering majors, but benefits from the breadth and more fundamental approach of a physicist.

For students who want to specialize further as undergraduates, there are three options to accompany the basic physics undergraduate degree: astrophysics, atmospheric physics, and computer science. The first two are designed around the main research interests of the faculty, so students can take advantage of the expertise of the faculty and the facilities that are offered on, or near, the campus. The latter option is present because computers play a crucial role in any application of physics. In addition, we encourage students to consider a minor in electrical engineering. Several of the faculty have expertise in these areas.

The areas of research in atmospheric physics include: thunderstorm electricity, precipitation, cloud particles, cloud dynamics, large- scale atmospheric dynamics, the photochemistry of the middle to upper atmosphere and the dynamics of planetary atmospheres. The Langmuir Laboratory for Atmospheric Research, located on a mountaintop an hour's drive from the campus, offers an unparalleled opportunity for active undergraduate and graduate student participation in observation and research.

The atmospheric physics group also operates a Beowulf cluster for atmospheric modeling, the Lightning Mapping Array, E-field-mill networks, and an active scientific ballooning program focused on charge motion and X-rays produced during storms. In addition, faculty members, as well as undergraduate and graduate students, participate in field programs that use the aircraft and radars of the National Center for Atmospheric Research in Boulder, Colorado.

Research in astrophysics includes pulsar radio emission, the dynamics and kinematics of nearby galaxies, quasars, radio galaxies, plasma astrophysics, comets, stellar evolution, and star formation. The Very Large Array and Very Long Baseline Array radio telescopes, operated by the National Radio Astronomy Observatory, are headquartered on campus and offer unique opportunities for research in radio astronomy for faculty and undergraduate and graduate students alike. In addition, the 2.4-meter optical telescope at New Mexico Tech's Magdalena Ridge Observatory (MRO) is now in operation, and its optical interferometer is under construction This facility is already involving students in research and development activities.

Undergraduate Program

Bachelor of Science in Physics

Minimum credit hours required—130

In meeting the General Education Core Curriculum, physics majors must choose PHYS 221 and 222. In addition, the following courses are required:

- PHYS 241(3), 242(4), 321(3), 333(3), 334(3), 336L(1), 340(3), 380(1), 411(3), 443(3), 451(2)
- MATH 231(4), 254(3), 332(3), 335(3), 336(3), and three hours of approved upper-division courses
- Language—six hours
- Electives—to complete 130 credit hours; in some instances, additional elective credit hours may be desired.

Sample Curriculum for the Bachelor of Science in Physics

Semester 1
5 PHYS 221 & 221L(general)
4 MATH 131 (calculus)
4 CHEM 121 & 121L (general)
3 ENGL 111 (college English)
16 Total credit hours

Semester 2
5 PHYS 222& 222L(general)
4 MATH 132 (calculus)
4 CHEM 122 & 122L (general)
3 ENGL 112 (college English)
16 Total credit hours

Semester 3
3 PHYS 241 (computational)
4 MATH 231 (calculus)
3 Social Science
3 Electives
3 Language
16 Total credit hours

Semester 4
4 PHYS 242 (waves)
3 MATH 332 (vector analysis)
3 MATH 335 (ordinary differential equations)
3 Humanities
3 Language
2 Electives
18 Total credit hours

Semester 5
3 PHYS 321 (mechanics)
3 PHYS 333 (electricity & magnetism)
3 MATH 254 (linear algebra)
4 Biology/Earth Science/Engineering with lab
3 ENGL 341 (technical writing)
16 Total credit hours

Semester 6
3 PHYS 334 (radiation and optics)
1 PHYS 336L (electrical & magnetic measurements lab)
3 PHYS 340 (quantum theory)
1 PHYS 380 (practicum in problem solving)
4 Biology/Earth Science/Engineering with lab
3 Social Science
1 Electives

16 Total credit hours

Semester 7
3 PHYS 411 (thermodynamics)
3 PHYS 443 (atomic and nuclear)
3 MATH 336 (applied analysis)
3 Humanities
3 Social Science
3 Electives
18 Total credit hours

Semester 8
2 PHYS 451 (senior lab)
3 Humanities/Social Science
6 Electives
3 MATH 382 (probability & statistics)
14 Total credit hours

Bachelor of Science in Physics with Astrophysics Option

Minimum credit hours required—130
In meeting the General Education Core Curriculum (page 87), physics majors must choose PHYS 221 and 222. Requirements include the courses listed above for the Bachelor of Science Degree in Physics and the following courses:
PHYS 325(3), 326(3), 327L(1), 328L(1), 425(3), 426(3)

Sample Curriculum for the Bachelor of Science in Physics with Astrophysics Option

Semester 1
5 PHYS 221 & 221L (general)
4 MATH 131 (calculus)
4 CHEM 121 & 121L (general)
3 ENGL 111 (college English)
16 Total credit hours

Semester 2
5 PHYS 222& 222L (general)
4 MATH 132 (calculus)
4 CHEM 122 & 122L (general)
3 ENGL 112 (college English)
16 Total credit hours

Semester 3
3 PHYS 241 (computational)
4 MATH 231 (calculus)
3 Social Science
3 Language
1 Elective
14 Total credit hours

Semester 4
4 PHYS 242 (waves)
3 MATH 332 (vector analysis)
3 MATH 335 (ordinary differential equations)
3 Humanities
3 Language
16 Total credit hours

Semester 5
3 PHYS 321 (mechanics)
4 PHYS 325 & 327L (astrophysics)
3 PHYS 333 (electricity & magnetism)

3 MATH 254 (linear algebra)
4 Biology/Earth Science/Engineering with lab
17 Total credit hours

Semester 6
4 PHYS 326 & 328L (astrophysics)
3 PHYS 334 (radiation and optics)
1 PHYS 336L (electrical & magnetic measurements lab)
3 PHYS 340 (quantum theory)
1 PHYS 380 (practicum in problem solving)
3 Humanities
3 Social Science
18 Total credit hours

Semester 7
3 PHYS 411 (thermodynamics)
3 PHYS 425 (advanced astrophysics)
3 PHYS 443 (atomic and nuclear)
3 MATH 336 (intro partial differential equations)
4 Biology/Earth Science/Engineering with lab
16 Total credit hours

Semester 8
3 PHYS 426 (advanced astrophysics)
2 PHYS 451 (senior lab)
3 MATH 382 (probability & statistics)
3 ENGL 341 (technical writing)
3 Social Science
3 Humanities/Social Science
17 Total credit hours

Bachelor of Science in Physics with Atmospheric Physics Option

Minimum credit hours required—130
In meeting the General Education Core Curriculum, physics majors must choose PHYS 221 and 222. Requirements include the courses listed above for the Bachelor of Science Degree in Physics and the following courses:
PHYS 331(3), 332(3), 432(3), 433(3)
Note: PHYS 331, 332, and 432 are offered in alternate years.

Students may take either of the following two sequences:
1. Junior year: PHYS 331 (fall); PHYS 332 (spring)
   Senior year: PHYS 432 (fall); PHYS 433 (spring)
2. Junior year: PHYS 432 (fall)
   Senior year: PHYS 331 (fall), PHYS 332, PHYS 433 (spring)

Sample Curriculum for the Bachelor of Science in Physics with Atmospheric Physics Option (Sequence 1)

Semester 1
5 PHYS 221 & 221L (general)
3 ENGL 111 (college English)
4 CHEM 121 & 121L (general)
4 MATH 131 (calculus)
16 Total credit hours

Semester 2
5 PHYS 222 & 222L (general)
3 ENGL 112 (college English)
4 CHEM 122 & 122L (general)
4 MATH 132 (calculus)
16 Total credit hours

Semester 3
3 PHYS 241 (computational)
4 MATH 231 (calculus)
3 ENGL 341 (technical writing)
3 Social Science
3 Language
16 Total credit hours

Semester 4
4 PHYS 242 (waves)
3 MATH 332 (vectors)
3 MATH 335 (ordinary differential equations)
3 Humanities
3 Language
16 Total credit hours

Semester 5
3 PHYS 321 (mechanics)
3 PHYS 331 (weather and climate)
3 PHYS 333 (electricity and magnetism)
3 MATH 254 (linear algebra)
4 Biology/Earth Science/Engineering with lab
16 Total credit hours

Semester 6
3 PHYS 332 (weather and climate)
3 PHYS 334 (radiation/optics)
1 PHYS 336L (electricity and magnetism lab)
3 PHYS 340 (quantum)
1 PHYS 380 (practicum in problem solving)
3 Humanities
3 Social Science
17 Total credit hours

Semester 7
3 PHYS 411 (thermodynamics)
3 PHYS 432 (atmospheric remote sensing)
3 PHYS 443 (atomic and nuclear)
3 MATH 336 (intro partial differential equations)
4 Biology/Earth Science/Engineering with lab
16 Total credit hours

Semester 8
3 PHYS 433 (special atmospheric problems)
2 PHYS 451L (senior lab)
3 MATH 438 (partial differential equations)
3 Humanities/Social Science
3 Social Science
3 Electives
17 Total credit hours

Sample Curriculum for the Bachelor of Science in Physics with Atmospheric Physics Option (Sequence 2)

Semester 1 through 4 are the same as for Sequence 1

Semester 5
3 PHYS 321 (mechanics)
3 PHYS 333 (electricity and magnetism)
3 MATH 254 (linear algebra)

3 PHYS 432 (atmospheric remote sensing)
4 Biology/Earth Science/Engineering with Lab
16 Total credit hours

Semester 6
3 PHYS 334 (radiation/optics)
1 PHYS 336L (electricity and magnetism lab)
3 PHYS 340 (quantum)
1 PHYS 380 (practicum in problem solving)
3 Humanities
3 Social Science
3 Electives
17 Total credit hours

Semester 7
3 PHYS 331 (weather and climate)
3 PHYS 411 (thermodynamics)
3 PHYS 443 (atomic and nuclear)
3 MATH 336 (intro partial differential equations)
4 Biology/Earth Science/Engineering with Lab
16 Total credit hours

Semester 8
3 PHYS 332 (weather and climate)
3 PHYS 433 (special atmospheric problems)
2 PHYS 451 (senior lab)
3 MATH 438 (partial differential equations)
3 Humanities/Social Science
3 Social Science
17 Total credit hours

Bachelor of Science in Physics with Computer Science Option

Minimum credit hours required—131
In meeting the General Education Core Curriculum, physics majors must choose PHYS 221 and 222. Requirements include the courses listed above for the Bachelor of Science Degree in Physics and the following courses:
• CSE 113(4), 122(3), 221(3)
• An additional six (6) hours of CSE courses numbered 300 or higher

Two particularly interesting sequences are:
1. CSE 344 and 451
2. CSE 410 and 411

Sample Curriculum for the Bachelor of Science in Physics with Computer Science Option

Semester 1
5 PHYS 221 & 221L (general)
4 MATH 131 (calculus)
4 CSE 113 (computer science)
3 ENGL 111 (college English)
16 Total credit hours

Semester 2
5 PHYS 222 & 222L (general)
4 MATH 132 (calculus)
3 CSE 122 (algorithms and data structures)
4 CHEM 121 & 121L (general)
16 Total credit hours

Semester 3

3 PHYS 241 (computational)
4 MATH 231 (calculus)
3 CSE 221 (system organization)
4 CHEM 122 & 122L (general)
3 Social Science
17 Total credit hours

Semester 4
4 PHYS 242 (waves)
3 MATH 332 (vector analysis)
3 MATH 335 (ordinary differential equations)
3 MATH 352 (basic concepts)
3 ENGL 112 (college English)
16 Total credit hours

Semester 5
3 PHYS 321 (mechanics)
3 PHYS 333 (electricity & magnetism)
3 MATH 254 (linear algebra)
3 CS 344 (design and analysis of algorithms)
3 ENGL 341 (technical writing)
15 Total credit hours

Semester 6
3 PHYS 334 (radiation and optics)
1 PHYS 336L (electrical & magnetic measurements lab)
3 PHYS 340 (quantum theory)
1 PHYS 380 (practicum in problem solving)
4 Biology/Earth Science/Engineering with Lab
3 Humanities
15 Total credit hours

Semester 7
3 PHYS 411 (thermodynamics)
3 PHYS 443 (atomic and nuclear)
3 MATH 336 (intro partial differential equations)
3 CSE 451 (parallel processing)
3 Humanities/Social Science
3 Language
18 Total credit hours

Semester 8
2 PHYS 451 (senior lab)
4 Biology/Earth Science/Engineering with Lab
3 Humanities
6 Social Science
3 Language
18 Total credit hours

See the Physics Department website at www.physics.nmt.edu for sample curricula for a B.S. in Physics with minors in electrical engineering and mathematics.

Minor in Physics

Minimum credit hours required—19

- PHYS 241(3), 242(4)
- Three of the following courses: PHYS 321(3), 333(3), 334(3), 340 (3)
- Three (3) additional hours of upper-division physics

Graduate Program

Master of Science in Physics

The Master of Science degree in Physics may be earned under either of the following plans:

With Thesis:

The student's course of study must be approved by the student's advisory committee and must fulfill the general requirements for the master's degree with thesis and must include a minimum of nine credit hours selected from: PHYS 505, 508, 513, 514, 515, 516, 526.
All students must complete PHYS 501 and 502 in their first two semesters.
PHYS 579(1), Graduate- Faculty Seminar, must be taken for the first four semesters.
The preliminary examination will cover courses in physics and mathematics normally included in the undergraduate physics curriculum. Thesis topics will be chosen in consultation with an advisory committee.

Without Thesis:

Courses approved by the student's advisor must fulfill the general requirements for the master's degree without thesis and must include the following:

- All students must complete PHYS 501(1), and 502(1) in their first two semesters
- PHYS 590(3)
- a minimum of nine credit hours selected from: PHYS 505, 508, 513, 514, 515, 516, 526.
- PHYS 579 (1), Graduate- Faculty Seminar, must be taken for the first four semesters.

The preliminary examination will cover courses in physics and mathematics normally included in the undergraduate physics curriculum.

Master of Science in Physics with Specialty in Instrumentation

Students entering this M.S. program should have a bachelor's degree in engineering, one of the sciences, mathematics, or computer science. Students will also be expected to complete at Tech basic undergraduate physics and electronics courses they have not had.
Given the varied backgrounds and interests of students in this specialty, the program of study is tailored to each student's needs. The flexibility needed to do this is evident in the following requirements:

Credits

9 Graduate physics courses approved by the student's advisory committee
3 EE 322, 322L (Advanced Electronics)
4 EE 451, 451L (Digital Signal Processing)
3 MATH 587 (Time Series)
6 At least two of the following:
- EE 341, 342 (Linear Systems)
- EE 443 (Control Theory)
- EE 446 (Communications Theory)
- CS 331, 432 (Computer Architecture, VLSI)
- PHYS 565 (Astronomical Techniques)

3 Graduate course approved by the advisory committee
3 PHYS 590 (Independent Study)
32 Total credit hours

PHYS 579(1), Graduate- Faculty Seminar, must be taken for the first four semesters. In addition to the above
requirements, students must satisfy the general requirements for the M.S. degree and pass a preliminary examination on undergraduate physics and electronics.

Doctoral Programs

Students of exceptional ability as demonstrated in previous courses in physics and mathematics, or in the preliminary examination, may pursue a program leading to the doctoral degree. All applicants to the physics doctoral degree program must submit GRE general and physics subject test scores.

The major doctoral programs of the Physics Department are in astrophysics and atmospheric physics. A

degree in mathematical physics is offered in cooperation with the mathematics department. Students may also work in other areas of physics in which the department has expertise.

The following general requirements apply to all curricula: A minimum of 50 credit hours of graduate and upper-division courses approved by the student's committee should be taken, of which 12 credit hours must be mathematics beyond that required of an undergraduate physics major. PHYS 501 and 502 (where required below) may be waived for those students who have completed the equivalent through an experimental master's thesis. PHYS 579, Graduate- Faculty Seminar, must be taken for the first four semesters.

Doctor of Philosophy in Physics with Dissertation in Astrophysics

Current areas of research in astrophysics include quasars, pulsars, and radio galaxies, X- ray astronomy, solar and stellar activity, plasma astrophysics, and comets. New Mexico Tech operates the Magdalena Ridge Observatory (MRO) and also takes advantage of the proximity of the facilities of the National Radio Astronomy Observatory (NRAO). Students may pursue dissertation work not only with regular faculty but also with a number of NRAO staff who have adjunct appointments at Tech.

The following courses must be completed: PHYS 501(1), 502(1), 505 or 526(3), 513(3), 514(3), 515(3), 516(3), 562(3), 563(3), 564(3), 565 or 566(3), and 579. In addition, PHYS 426(3) must be completed unless the student has had equivalent material in previous courses.

Doctor of Philosophy in Physics with Dissertation in Atmospheric Physics

Current areas of research in atmospheric physics are the dynamics and microphysics of clouds and mesoscale weather systems, geophysical fluid dynamics, dynamics of planetary atmospheres, thunderstorm electrification and lightning, atmospheric radioactivity, physics of the middle and upper atmosphere, precipitation mechanisms, and radar meteorology. Research facilities include an instrumented aircraft for thunderstorm penetrations, several meteorological radars, and Langmuir Laboratory, a mountaintop observing site. Also available are the observational and computer facilities of the National Center for Atmospheric Research in Boulder, Colorado.

The following core courses must be completed:
• PHYS 331(3), 332(3), 501(1), 502(1), 505 or 526(3), 508(3), 513(3), 514(3), 515(3), 516(3), and 579.
• An additional six (6) credit hours must be taken in areas pertinent to the student's program. This can be achieved by taking PHYS 532, PHYS 533, PHYS 535, PHYS 536, and/or other courses approved by the student's advisory committee.

Doctor of Philosophy in Physics

The following courses must be completed: PHYS 501(1), 502(1), 505(3), 508(3), 513(3), 514(3), 515(3), 516(3), and 579. In addition, nine credit hours of graduate physics should be completed in the student's field of specialization.

Doctor of Philosophy in Physics with Dissertation in Mathematical Physics

The mathematical physics program is operated in cooperation with the Mathematics Department. Dissertation supervision may be obtained in either department. Students normally pursue research based on faculty interest in one or both departments.
The following courses must be completed:
• PHYS 505(3), 513(3), 514(3), 515(3), 516(3), 579
• MATH 435(3), 438(3), 442(3), 471(3), 535(3)
• Additional approved graduate and upper-division courses, including at least six credit hours from mathematics and six credit hours from physics, should be elected to bring the total to a minimum of 51 credit hours beyond the bachelor's degree. The following courses have been approved:
• MATH 410(3), 411(3), 511(3), 531(3), 532(3), 533(3), 536(3), 538(3)
• PHYS 508(3), 526(3), 532(3), 533(3), 535(3), 536(3), 562(3), 563(3), 564(3)
Additional courses may be approved at the discretion of the candidate's committee.

Physics Courses:

PHYS 121, General Physics I, 4 cr, 3 cl hrs, 2 recitation hrs
Corequisites: PHYS 121L; MATH 131
Introductory concepts. Mechanics, including Newton's Laws of force, linear and angular momentum, energy, gravitation, heat and thermodynamics, and applications.
[NMCCNS PHYS 1215: General Education Area III]

PHYS 121L, General Physics Laboratory I, 1 cr, 3 lab hrs
Corequisite: PHYS 121
Experiments from the subject matter of PHYS 121.
[NMCCNS PHYS 1215: General Education Area III]

PHYS 122, General Physics II, 4 cr, 3 cl hrs, 2 recitation hrs
Prerequisite: PHYS 121
Corequisites: MATH 132; PHYS 122L
Continuation of PHYS 121 including electricity and magnetism, optics, and atomic and nuclear phenomena.
[NMCCNS PHYS 1225: General Education Area III]

PHYS 122L, General Physics Laboratory II, 1 cr, 3 lab hrs
Corequisite: PHYS 122
Experiments from the subject matter of PHYS 122.
[NMCCNS PHYS 1225: General Education Area III]

PHYS 221, General Physics I, 4 cr, 3 cl hrs, 2 recitation hrs
Corequisites: PHYS 221L; MATH 131
A treatment of physics for science and engineering students from a modern point of view. The subject is logically developed starting with optics and the theory of relativity. Quantum and classical mechanics are then introduced. This course is required for physics majors.
[NMCCNS PHYS 1215: General Education Area III]

PHYS 221L, General Physics Laboratory I, 1 cr, 2 lab hrs
Corequisite: PHYS 221
Laboratory experiments from the subject matter of PHYS 221.
[NMCCNS PHYS 1215: General Education Area III]

PHYS 222, General Physics II, 4 cr, 3 cl hrs, 2 recitation hrs
Prerequisites: PHYS 221; MATH 131
Corequisites: PHYS 222L; MATH 132
Continuation of PHYS 221. Attempts to probe successively smaller scales are explored. The four forces of nature; practical applications of gravity and electromagnetism. Dynamics of large numbers of particles are introduced, resulting in applications to the everyday world. This course is required for physics majors.
[NMCCNS PHYS 1225: General Education Area III]

PHYS 222L, General Physics Laboratory II, 1 cr, 2 lab hrs
Corequisite: PHYS 132
Laboratory experiments from the subject matter of PHYS 222.
[NMCCNS PHYS 1225: General Education Area III}

PHYS 232, General Physics III, 3 cr, 3 cl hrs
Prerequisite: PHYS 122 or PHYS 222 or consent of instructor
Corequisite: MATH 231
Introduction to modern physics including special relativity, basic ideas of quantum mechanics, atomic and nuclear physics, elementary particles.

PHYS 241, Computational Physics, 3 cr, 3 cl hrs
Prerequisites: PHYS 222; MATH 132
This course goes into more depth than first-year college physics courses on key classical concepts such as force, acceleration, Newton's Laws, and conservation laws. New mathematics will include numerical solution of differential equations and statistical techniques for experimental scientists. The fundamental physics is reinforced by numerical simulations and calculations that the students write themselves. Along the way, students are taught to program in a scientific computing environment. Students should emerge with a firm grasp of classical mechanics and computational skills.

PHYS 242, Vibrations and Waves, 4 cr, 3 cl hrs, 3 lab hrs
Prerequisites: PHYS 122 or PHYS 132; MATH 231
Vibrations and waves are examined from both theoretical and experimental standpoints. Theory describing simple vibrating systems, including coupled oscillators. Laboratory measurements on electrical analogs of vibrating systems. Wave theory for transverse and longitudinal waves. Experiments using electromagnetic radiation in the visible, microwave, and X- ray regions are used to illustrate the nature of waves.

PHYS 301, Laboratory and Shop Techniques, 1 cr, 1 afternoon per week
Instruction in drill and tool bit sharpening, use of hand tools, drill press, lathe, milling machine, shaper, and sheet metal brake.

PHYS 321, Intermediate Mechanics, 3 cr, 3 cl hrs
Prerequisites: PHYS 241
Corequisite: MATH 335
An intermediate course in the dynamics and statics of particles and rigid bodies. Introduction to Lagrangian and Hamiltonian mechanics.

PHYS 325, Astrophysics I: Stars, 3 cr, 3 cl hrs
Prerequisites: PHYS 242
Astrophysics is the application of physics to the universe. This course begins with a review of relevant physics and then applies those concepts to the lives of stars. The subject matter includes stellar atmospheres, stellar interiors, star formation, stellar evolution, variable stars, and compact objects.

PHYS 326, Astrophysics II: Planetary and Extrgalactic Systems, 3 cr, 3 cl hrs
Prerequisites: PHYS 325
This course continues the application of physics to the rest of the universe. Our own solar system and its formation and evolution, normal galaxies, active galaxies, the large- scale structure of the universe, and cosmology.

PHYS 327L, 328L, Astronomy Laboratory, 1 cr, 3 lab hrs each semester
Prerequisites: PHYS 122, 122L or PHYS 132, 132L; or consent of instructor
A self- paced introduction to astronomical observing and data reduction. Emphasis on techniques such as the
operation of telescopes and their auxiliary equipment, astronomical photography, photometry, spectroscopy, and data handling. Exercises chosen from topics in solar system, stellar, galactic, and extragalactic astronomy.

PHYS 331, Physics of Weather and Climate I, 3 cr, 3 cl hrs
Prerequisite: PHYS 122 or 222
Offered alternate years
The flows of energy and water in the atmosphere, ocean, and land surface work together to form the environment in which we live. Short- term variations in these flows give rise to weather, while longer term averages are related to the Earth's climate. This course explores the physical and chemical processes which are important for understanding weather and climate—atmospheric and oceanic thermodynamics, cloud formation and precipitation, solar and thermal radiation, and the photo- chemistry of the atmosphere.

PHYS 332, Physics of Weather and Climate II, 3 cr, 3 cl hrs
Prerequisites: PHYS 331; MATH 332 and 335
Offered alternate years
This course, a continuation of PHYS 331, introduces the principles of geophysical fluid dynamics and investigates the factors controlling winds and ocean currents, floods, drought, and temperature change, as well as climate phenomena such as El Niño, the Greenhouse Effect, and the ice ages.

PHYS 333, Electricity and Magnetism, 3 cr, 3 cl hrs
Prerequisites: PHYS 122 or PHYS 222; PHYS 242; MATH 332
Corequisite: MATH 335
This subject is one of the cornerstones for understanding a huge variety of phenomena — electronic and optical devices, communication by telephone, radio waves, optical fibers, and the behavior of atoms and molecules. It is remarkable that so much insight comes from Maxwell's four equations and the Lorentz force law. This course develops these equations in detail and applies them to a variety of problems. It also helps students develop an understanding of the applications of more advanced mathematics in a physical context.

PHYS 334, Radiation and Optics, 3 cr, 3 cl hrs
Prerequisites: PHYS 333; MATH 335
This course explores the behavior of electromagnetic waves, including optical waves, using Maxwell's equations and the Lorentz force law. Included in the course are the topics of radiation, conservation laws, relativistic and non- relativistic electrodynamics, basic geometrical optics and aberration theory, and specific phenomena such as polarization, diffraction and interference. The class will include demonstrations and discussions of these phenomena and modern optical devices.

PHYS 336L, Electrical and Magnetic Measurements Lab, 1 cr, 3 lab hrs
Prerequisite: PHYS 333
Experiments in electricity and magnetism, emphasizing applications to measurements in physics and geophysics.

PHYS 340, Introduction to Quantum Theory, 3 cr, 3 cl hrs
Prerequisites: PHYS 321; MATH 254, 335, or consent of instructor
Electrons, atoms, and radiation. Wave- particle experiments, introductory quantum mechanics, atomic structure and spectra, the hydrogen atom, exclusion principle, electronic structure of atoms, and diatomic molecules.

PHYS 362, Image Processing, 2 cr, 2 cl hrs
Prerequisite: PHYS 122 or 222
An introduction to image processing and computational physics designed for scientists and engineers. Topics will include properties of imaging devices and systems, image construction, analysis, and display. Data will come from satellites and terrestrial sources. Examples will come from current research whenever possible.

PHYS 380, Practicum in Problem Solving, 1 cr, 2 cl hrs
Prerequisite: PHYS 321, or consent of instructor
Methods of problem solving, including dimensional and scale analysis, rapid estimation, and combining knowledge from various disciplines. Class time will be spent analyzing and solving problems posed by the instructor and students. Students will normally be graded S/U, and sections will be strictly limited in size to facilitate active participation of all students.

PHYS 389, Pilot Course, topic, hrs, and cr to be arranged
PHYS 391, Directed Study, hrs and cr to be arranged
PHYS 408, Cooperative Education
On- the- job training to supplement the academic program. Students alternate periods (usually six months long) of full- time semiprofessional employment in their chosen field with periods of full- time academic study.

PHYS 411, Thermodynamics and Statistical Physics, 3 cr, 3 cl hrs
Prerequisite: PHYS 122 or PHYS 222; PHYS 340
Corequisite: MATH 335
A course dealing with the effects of heat and work on gases, liquids, and solids. The equations of state and the first and second laws of thermodynamics are presented with applications to heat engines and chemical processes. An introduction is given to kinetic theory and statistical mechanics.

PHYS 421, Continuum Mechanics, 3 cr, 3 cl hrs
Prerequisites: PHYS 121 or PHYS 222; MATH 332, 335
Offered on demand
Statics and dynamics of fluids and elastic bodies.

PHYS 425, Astrophysics III: Plasma Astrophysics, 3 cr, 3 cl hrs
Prerequisites: PHYS 325, 326, 333
Plasma and fluid physics govern most of the luminous matter in the universe. This course surveys the many aspects of plasma physics, from microphysics (single particle motions, waves and oscillations, collisions) to macrophysics (the fluid description and magnetohydrodynamic effects). Applications will include a wide variety of astrophysical objects, from the earth's magnetosphere and the solar wind, to accretion disks and radio jets.

PHYS 426, Astrophysics IV: High Energy Astrophysics, 3 cr, 3 cl hrs
Prerequisites: PHYS 333 and 425; or consent of instructor

This course continues the application of fluid and plasma physics to astrophysics. Radiation processes and diagnostics, shock physics, high energy plasmas, and cosmic ray acceleration. Many applications will come from our galaxy, including the interstellar medium, star formation, supernovae, black holes, and pulsars. We will go beyond the boundaries of our galaxy to study active galactic nuclei and their connection to galaxy formation.

PHYS 432, Atmospheric Remote Sensing, 3 cr, 3 cl hrs
Prerequisite: PHYS 122 or 222
Remote sensing from space and ground- based instruments is a useful technique for monitoring the physical and chemical state of the atmosphere. This course will examine the physics of remote sensing using radio, microwave, infrared, visible, and ultraviolet instruments. Topics will include both active and passive systems for measuring atmospheric temperature, composition, and dynamics.

PHYS 433, Special Problems in Atmospheric Physics, 3 cr, 3 cl hrs
Prerequisite: PHYS 331
Offered spring semesters
Project in which student works with a member of the atmospheric physics group on current research. This project is expected to lead to a report, conference presentation, or contribution to a published paper. The student should contact an appropriate faculty member within the first two weeks of the fall semester to organize a project.

PHYS 443, Atomic and Nuclear Physics, 3 cr, 3 cl hrs
Prerequisite: PHYS 340
Continuation of PHYS 340. Further topics in atomic and molecular structure. Quantum statistics with applications to degenerate Fermi and Bose Fluids. Radioactivity, elements of nuclear structure, nuclear energy sources. Mesons, hyperons, and resonances.

PHYS 444, Solid- State Physics, 3 cr, 3 cl hrs
Prerequisite: PHYS 340 or consent of instructor
Offered on demand
Theory and application of solid- state devices; binding in molecules and crystals; energy bands; electrons in metals; imperfections in solids; electrical, thermal, and magnetic properties of solids; and semiconductor theory.

PHYS 451, Senior Laboratory, 1 or 2 cr, 3 or 6 lab hrs
Prerequisites: Senior status or consent of instructor
Experiments in atomic, nuclear, and solid- state physics.
PHYS 489, Pilot course, topic, hrs, and cr to be arranged
PHYS 491, Directed Study, hrs and cr to be arranged
PHYS 500, Directed Research, cr to be arranged
This course may not be used to fulfill graduate degree requirements.
Research under the guidance of a faculty member.

PHYS 501, 502, Graduate Project, 1 cr, 3 lab hrs each semester
This course involves beginning graduate students in a modest project, usually related to ongoing reserch in the department. While the work will be supervised by a faculty member, the emphasis is on independent work by the student. Possible types of projects include data analysis, software development, theoretical modeling, a literature survey, and design and/or construction of research or teaching equipment.

PHYS 505, Advanced Dynamics, 3 cr, 3 cl hrs
Offered Fall 2009 and alternate years
Introduction to classical mechanics: Lagrangian and Hamiltonian formalism, rigid body motion, normal modes. Hamilton- Jacobi Theory, and problems in relativistic mechanics.

PHYS 508, Statistical Mechanics, 3 cr, 3 cl hrs
Offered Spring 2010 and alternate years
Entropy, randomness, the Boltzmann distribution, and the chemical potential. Translational, rotational, vibrational, and electronic contributions to the partition function. Calculation of mean energies, heat capacities, and equilibrium constants. Stability. The influence of wave function symmetry: Bose- Einstein and Fermi- Dirac statistics. The quantum statistical operator. Coherence and the Pauli principle. (Same as CHEM 524)

PHYS 513, 514, Electromagnetics I & II, 3 cr, 3 cl hrs each semester
Offered 2009- 2010 and alternate years
The electromagnetic field equations; boundary value problems in electrostatics and magnetostatics; plane, cylindrical, and spherical waves, wave guides; the Hertz Vectors, retarded potentials and simple radiating systems; relativistic electrodynamics; radiation from moving charges.

PHYS 515, 516, Quantum Mechanics I and II, 3 cr, 3 cl hrs each semester
Offered 2008–09 and alternate years
Review of experiments leading to quantum theory: Schroedinger's Equation, operators and eigenvalues, perturbation theory, and applications to simple physical systems. The second semester includes introduction to scattering theory, the theory of angular momentum, and Dirac Theory.

PHYS 526, Fluid Dynamics, 3 cr, 3 cl hrs
Offered 2010 and alternate years
Basic equations, potential and viscous flow, scaling. Compressible flow including characteristics and shock waves. Magnetohydrodyamics, including MHD waves, shocks, and confinement. Fluid and MHD instabilities. Turbulence.

PHYS 532, Atmospheric Remote Sensing, 3 cr, 3 cl hrs
Physics of remote sensing using radio, microwave, infrared, visible, and ultraviolet instruments. Topics will include both passive and active systems for measuring atmospheric temperature, composition, and dynamics. Shares lectures with PHYS 432, but is graded separately and additional graduate- level work is required.

PHYS 533, Advanced Topics in Atmospheric Physics, 1–3 cr, 1–3 cl hrs
Specialized coursework in the student's areas of interest. Advanced topics in the area of atmospheric physics. Selection of topics changes from semester to semester. Current faculty interests can be found at the department web site: ***www.physics.nmt.edu***. This course may be repeated for credit if the material covered in each instance is different.

PHYS 535, Physics of Lightning, 3 cr, 3 cl hrs
Offered Fall 2009 and alternate years
Theory and experimental techniques concerning cloud charging mechanisms. Remote and in-situ sensing of lightning. Lightning phases and properties. Properties of the long spark and leaders in the lab and in the sky. Simple numerical models of cloud charging, lightning initiation, and propagation.

PHYS 536, Atmospheric Convection, 3 cr, 3 cl hrs
Governing equations, turbulence, thermodynamics, and microphysics of moist convection. Models for convection ranging from plumes and thermals through numerical simulations are discussed, as well as interactions of convection with the atmospheric environment.

PHYS 562, Stellar Astrophysics, 3 cr, 3 cl hrs
Prerequisites: PHYS 425, 426 or equivalent or consent of the instructor.
Offered Spring 2007 and alternate years.
This course covers in- depth the physics of stars, their structure and evolution. Topics include energy generation and transport, nucleosynthesis, equations of state, stellar modelling, asteroseismology, and stellar pulsation and rotation — all studied in the context of the evolution of a star. There are detailed discussions and derivations of the various stages in star formation and evolution, and the end states of stars (e.g. white dwarfs, planetary nebulae, black holes). The course stresses current refereed literature and has occasional guest speakers on various topics.

PHYS 563, Extragalactic Astrophysics, 3 cr, 3 cl hrs
Prerequisites: PHYS 425, 426 or equivalent or consent of instructor
Offered Fall 2009 and alternate years.
The structure and dynamics of galaxies. Distribution of galaxy types. Potential and orbit theory. Spheroidal galaxies as self-gravitating systems. Instabilities in disk galaxies. Constraints on dark matter and on galaxy formation.

PHYS 564, Relativity and Cosmology, 3 cr, 3 cl hrs
Prerequisites: PHYS 425, 426 or equivalent or consent of instructor
Offered Spring 2009 and alternate years.
General relativity with application to cosmology. Basic principles of relativity. Applications to orbits,

gravitational radiation, and black holes. Relativistic cosmography and cosmology. The early universe, galaxy formation, and active galaxies.

PHYS 565, Astronomical Techniques, 3 cr, 3 cl hrs
Offered alternate years
Optical, IR, X- ray and gamma- ray astronomical telescopes and detectors. Throughput, detector quantum efficiency, the modulation transfer function, noise and estimation error. Photometers and photometric systems, CCD imaging, slit and objective grating spectrometry, Fourier spectroscopy. Astrometry, orbit determination. Computer analysis and astronomical databases. Class work will be augmented by extensive optical observing using local facilities.

PHYS 566, Advanced Radio Astronomy, 3 cr, 3 cl hrs
Offered Spring 2009 and alternate years
The design and operational characteristics of radio telescopes and interferometers. Properties of antennas, telescope optics, feeds, waveguides, receivers, and amplifiers. Spectrometers and spectroscopy. Sensitivity and noise. Amplitude and phase calibration, faint signal detection, astrometry, and mapping. Factors that affect radio data, including instrumental characteristics, atmospheric limitations, and propagation phenomena. The VLA and VLBA and the techniques of radio imaging by aperture synthesis. Hands-on astrophysical exercises to be solved by imaging.

PHYS 567, Advanced Topics in Astrophysics, 2–3 cr, 2–3 cl hrs
Offered on demand
A one- semester tutorial may be selected from any one of the following: our solar system, comets, solar and stellar activity, galactic structure and kinematics, active galaxies and quasars, astrophysical plasmas, accretion disks, black holes, stellar spectroscopy, stellar photometry and astrometry.

PHYS 571, Advanced Topics in Physics, 3 cr, 3 cl hrs
Offered on demand
Study of a special topic not otherwise treated, normally one related to a field of research interest at Tech.

PHYS 579, Graduate- Faculty Seminar, 1 cr, 1 cl hr
Offered every semester
A seminar in which current research topics are discussed by faculty, students, and outside speakers. Graded S/U, where satisfactory performance consists of regular attendance and participation. Credit earned may not be applied towards the 30 credits required for the M.S. degree.

PHYS 581, Directed Study, cr to be arranged
Study under the guidance of a member of the graduate faculty. In general, subject matter will supplement that available in other graduate course offerings.

PHYS 590, Independent Study, cr to be arranged

PHYS 591, Thesis (master's program), cr to be arranged

PHYS 595, Dissertation (doctoral degree program), cr to be arranged

Physics Faculty Research Interests

Avramidi – Mathematical Physics, Analysis on Manifolds, Quantum Field Theory
Bakker – Astronomical Instrumentation, Active Galactic Nuclei, Circumstellar Environments
Balasubramaniam – Spectroscopy and Polarized Radiative Transfer Dynamics of Solar Active Regions, Vector Magnetometry
Buscher – Optical/IR Interferometry, Atmospheric Seeing Measurement, Adaptive Optics, Early and Late Stages of Stellar Evolution
Colgate – Astrophysics, Plasma Physics, Atmospheric Physics
Creech-Eakman – Stellar Astrophysics, Mass- loss, Optical/IR Interferometry, IR Instrumentation
Eack – Production of Energetic Particles and Gamma Rays in Thunderstorms
Eilek – Plasma Astrophysics, Quasars, Radio Galaxies, Pulsars
Elvis – Quasars and Active Galactic Nuclei, X- ray Astronomy
Fuchs – Atmospheric Dynamics
Goss—Radio Astronomy, Interstellar Medium

Haniff – Spatial Interferometry at Optical and Near-Infrared Wavelengths, Atmospheric Turbulance, Imaging Theory, Evolved Stars
Hankins – Radio Astronomy of Pulsars, Instrumentation, Signal Processing
Hofner – Star Formation, Interstellar Medium, X-ray Astronomy, Extragalactic Interstellar
Klinglesmith – Asteroids, Robotic Telescope Operations
Krehbiel – Lightning studies; radar meteorology; thunderstorm electrification
Lopez Carrillo – Doppler Radar and Data Analysis, Tropical Dynamics
Manney – Atmospheric Science, Stratospheric Dynamics/Transport, Stratospheric Polar Processes and Ozone Loss
Meason – Nuclear Physics, Nuclear & Space Radiation Effects, Electromagnetic Radiation Effects & Directed Energy
Meyers – Cosmology, Extragalactic Radio Astronomy, Interferometric Imaging Algorithms
Minschwaner – Radiative Transfer and Climate, Physics of the Middle and Upper Atmosphere
Morales – Outer planets observations and atmospheric dynamics
Myers – Cosmology, Extragalactic Radio Astronomy, Interferometric Imaging Algorithms
Raymond – Geophysical Fluid Dynamics, Cloud Physics, Clouds and Climate
Rison – Atmospheric Electricity, Radar Meteorology, Instrumentation
Romero – Energetic Materials, Shock Phenomena, High Energy Physics
Rupen – Gas and Dust in Galaxies, Radio Transients
E. Ryan – Asteroid Collisional Physics, Observational and Theoretical Studies
W. Ryan – Asteroid Astronomy, High Energy Physics
Schery – Environmental Radioactivity
Sessions – Field Theoretic Approaches to Atmospheric Physics
Sheperd – Star Formation
Sonnenfeld – Charge Transport by Lightning, Embedded Systems and Instrumentation
Taylor – Very Long Baseline Radio Astronomy, Active Galactic Nuclei
Teare – Experimental Adaptive Optics, Radiation Effects and Directed Energy
Thomas – Atmospheric Physics, Instrumentation
Westpfahl – Dynamics of Spiral and Dwarf Galaxies
Winn – Atmospheric physics; electrical discharges in gases; instrumentation
Young – Star Formation and the Interstellar Medium, Dwarf and Elliptical Galaxies

** Any differences between this webpage and the Official NMT Course Catalog; the NMT Course Catalog is always the governing document.*