Physics and Astronomy

College of Science and Mathematics

Department Chair: Ana Cristina Cadavid
Live Oak Hall 1128
(818) 677-2775
www.csun.edu/physics

Staff
Carole Arciero, Jeffrey Batten, Konstantin Daskalov, Deborah Klevens, Victor Sarca

Faculty
Ana Cristina Cadavid, Gary Chapman, Debi Choudhary, Duane Doty, Nicholas Kioussis, Paul Lee, Say-Peng Lim, Gang Lu, Robert Park, Miroslav Peric, Henk Postma, Radha Ranganathan, Deqing Ren, Ryoichi Seki, Donna Sheng, Yohannes Shiferaw

Emeritus Faculty
Barney L. Bales, Paul Chow, Peter Collas, John Lawrence, Mortimer N. Moore, Giovan G. Natale, Roy E. Olson, Paul H. Richter, Robert J. Romagnoli, Harbhajan S. Sandhu, Stephen Walton

Adjunct Faculty:
Matthew Penn, Alexander Ruzmaikin

Programs

Undergraduate:
- **B.A., Physics**
- **B.S., Physics**
- **Physics Option**
- **Astrophysics Option**
- **Minor in Physics**

Graduate:
- **M.S., Physics**

Credential:

The Physics Subject Matter Program for the Single Subject Credential sunsets on July 1, 2009. Only those students who started the program beforeJuly 1, 2005 and who can complete it before the sunset date will be eligible to receive the subject matter program verification. Please contact the department for more information.

The Physics and Astrophysics Majors

Quarks, black holes, and chaotic systems–discoveries like these make front-page news as physicists continue to learn about the universe's fundamental structure. Studying how matter and energy behave, beginning physics majors and senior physicists alike find challenges and excitement in solving problems and discovering new concepts. Physicists in business and industry work with revolutionary technology such as lasers, superconductors, and modern electronic and optical devices. Jobs in these fields are often in high demand and pay well.

Perhaps the most fundamental of all sciences, physics provides a background for understanding other scientific disciplines as well as many aspects of everyday life. Physics principles are crucial to such diverse applications as home electrical wiring, the motion of a rocket or skydiver, solar energy, and an echocardiogram of the human heart. Thus, understanding physics helps us make sense of our world.

Careers

Many students go on to advanced degrees in physics or related fields. The department's majors have been accepted by the nation's best graduate schools, such as Cornell, Stanford, Caltech, and Berkeley. Other students go to work immediately. Graduates fill a variety of scientific and technical positions in business and industry, including research scientist, technical staff member or manager, technical salesperson, or business owner. Others teach in high schools, community colleges, or universities; some become medical physicists or physicians.

Academic Advisement

All physics majors must consult the appropriate department faculty advisor each semester before registering. Say-Peng Lim is the undergraduate advisor Miroslav Peric is the graduate advisor.

Student Learning Outcomes of the Undergraduate Program

Students earning a bachelor degree in the Department of Physics and Astronomy should:

1. Demonstrate knowledge of physical principles used to model natural phenomena.
2. Demonstrate ability to convey physical concepts with mathematical expressions, and effectively derive quantitative predictions from a model through mathematical analysis.
3. Demonstrate understanding of scientific methodology, including:
   a. data collection from observations, setting up laboratory experiments and data collection from experiments,
   b. analysis of data,
   c. testing of a model or hypothesis by comparing with data.
4. Demonstrate competency in using computer tools, including:
   a. use of software programs for data analysis and presentation,
   b. numerical analysis,
   c. computer simulations.
5. Demonstrate special knowledge of their subprogram.
6. Communicate clearly and articulately physical concepts, findings, and interpretations in oral presentations.
7. Acquire ability to write clear, organized and illustrated technical reports with proper references to previous work in the area.

Student Learning Outcomes of the Graduate Program

M.S. graduates in Physics should demonstrate an advanced level of:

1. Knowledge of physical principles used to understand and model natural phenomena.
2. Ability to convey physical concepts with mathematical expressions, and effectively derive quantitative predictions from a model through mathematical and numerical analysis.
3. Understanding of scientific methodology, which may include for example: a) data collection from observations, b) setting up laboratory experiments and data collection from experiments, c) analysis of data, and d) testing a model or hypothesis.
4. Competency using computational tools, which may include for example: a) use of scientific software for data analysis and presentation, b) numerical analysis, and c) computer simulations.
5. Ability to communicate clearly and accurately physical concepts, findings, and interpretations in oral presentations.
6. Ability to write clear, organized and illustrated technical reports with proper references to previous work in the area.
7. (a) For students selecting the Comprehensive Examination Option: Comprehensive knowledge of the graduate core curriculum in classical mechanics, classical electrodynamics, statistical physics and quantum mechanics.
   (b) For students completing the Thesis Option: Ability to successfully carry out a program of graduate research and thesis.

Department Programs

The Department of Physics and Astronomy offers two undergraduate degrees and a graduate degree. The undergraduate degree programs are: the B.S. degree in Physics (with two options) and the B.A. degree in Physics. The graduate degree is an M.S. degree in Physics. A minor in Physics is also offered.

The B.S. Program in Physics is designed for students who desire to 1) pursue a career in physics-related research and development either in industry or government or 2) prepare for graduate work in physics or related subjects. The B.S. program in Physics has two options: Option I –Physics and Option II – Astrophysics.

Option I is a balanced program in experimental and theoretical physics. This option can be specialized towards applications in engineering or a more mathematical approach to theoretical physics. This is accomplished by the appropriate choice of the elective courses via consultation with the department undergraduate advisor.

Option II specializes in applications of physics to astrophysical problems and may be tailored to be more experimental or theoretical in nature.

The B.A. Program in Physics is designed for students seeking a broad foundation in Physics as part of a liberal education in the arts and sciences. It is particularly appropriate for those students 1) seeking a secondary teaching career, or 2) planning to combine physics with other disciplines such as music, law, and business.

The M.S. Program in Physics provides the student with an opportunity for advanced study in Physics and to develop skills to do independent research. It prepares the student for the doctoral program in physics and related fields or for more technical jobs in research and development.

The Minor in Physics is available for students who wish to augment their major field of study. It is particularly appropriate for those students in engineering and the other sciences and mathematics who desire to develop interdisciplinary skills.

General Education

Knowledge of a foreign language is viewed as an asset by many potential employers and may be beneficial for graduate study in Physics. Students are encouraged to study at least one foreign language, which may be applied to General Education, Comparative Cultural Studies.

Requirements for the Bachelor of Arts Degree in Physics

To enroll in the 1st courses in Mathematics and Chemistry, students must obtain a satisfactory score on the Mathematics Placement Test (MPT) and the Chemistry Placement Test (CPT). Without satisfactory scores, students may be required to take additional courses in preparation for the required courses. Students must complete the course requirements listed. In addition, all students are required to take 2 comprehensive exams – one on general physics upon completion of PHYS 227 or its equivalent and one on advanced physics just before they graduate. The dates of these exams will be posted in the department office. For more information, please consult the department undergraduate advisor.

1. Lower Division Required Courses (39 Units)

MATH	150A	Calculus I (5)
MATH	150B	Calculus II (5)
MATH	250	Calculus III (3)
MATH	262	Introduction to Linear Algebra (3)
MATH	280	Applied Differential Equations (3)
PHYS	225/220AL	Physics I and Mechanics Lab (4/1)
PHYS	226/220BL	Physics II and Electricity and Magnetism Lab (4/1)
PHYS	227/L	Physics III and Lab (4/1)
CHEM	101/L	General Chemistry I and Lab (4/1)

2. Upper Division Required Courses (16 Units)

PHYS	301	Analytical Mechanics I (3)
PHYS	311	Electromagnetism I (3)
PHYS	365	Experimental Physics I (2)
PHYS	375	Quantum Physics I (3)
PHYS	431	Thermodynamics and Statistical Mechanics (4)
PHYS	493	Physics and Astronomy Colloquium (1)

3. Upper Division Electives (6 Units)

Electives should be chosen with approval of the department undergraduate advisor. Note: Upper Division courses in the major plus Upper Division courses outside the major must total a minimum of 40 units in accordance with university requirements for a B.A. degree.

General Education: Basic Skills Mathematics is satisfied by MATH 150A. Natural Sciences is satisfied by CHEM 101/L and PHYS 225/220AL. Physics majors may also satisfy Lifelong Learning by completing COMP 106/L or 110/L.

Total Units in the Major	61
General Education Units	36
Additional Units	23
Total Units Required for a B.A. Degree	120

Requirements for Bachelor of Science Degree in Physics

To enroll in the first courses in Mathematics and Chemistry the student must obtain a satisfactory score on the Mathematics Placement Test (MPT) and the Chemistry Placement Test (CPT). Without satisfactory scores the student may be required to take additional courses in preparation for the required courses. The student must complete all courses listed under Lower- Division Required Courses as well as those listed under one of the 2 options. In addition, all students are required to take 2 comprehensive exams – one on general physics upon completion of PHYS 227 or its equivalent and one on advanced physics just before they graduate. The dates of these exams will be posted in the department office. For more information, consult the department undergraduate advisor.

Lower Division Required Courses (39 Units)

MATH	150A	Calculus I (5)
MATH	150B	Calculus II (5)
MATH	250	Calculus III (3)
MATH	262	Introduction to Linear Algebra (3)
MATH	280	Applied Differential Equations (3)
PHYS	225/220AL	Physics I and Mechanics Lab (4/1)
PHYS	226/220BL	Physics II and Electricity and Magnetism Lab (4/1)
PHYS	227/L	Physics III and Lab (4/1)
CHEM	101/L	General Chemistry I and Lab (4/1)

A. Option I: Physics

1. Upper Division Required Courses (31 Units)

PHYS	301	Analytical Mechanics I (3)
PHYS	311	Electromagnetism I (3)
PHYS	365	Experimental Physics I (2)
PHYS	366	Experimental Physics II (2)
PHYS	375	Quantum Physics I (3)
PHYS	402	Analytical Mechanics II (3)
PHYS	410	Electromagnetism II (3)
PHYS	431	Thermodynamics and Statistical Mechanics (4)
PHYS	451	Quantum Physics II (3)
PHYS	465	Experimental Physics III (2)
PHYS	466	Experimental Physics IV (2)
PHYS	493	Physics and Astronomy Colloquium (1)

2. Upper Division Electives (9 Units)

A minimum of 9 units of upper division electives chosen with the approval of the department undergraduate advisor from the following:

PHYS	420	Modern Optics (3)
PHYS	421	Laser Physics (3)
PHYS	470	Introduction to Nuclear and Elementary Particle Physics (3)
PHYS	480	Introduction to Solid State Physics (3)
PHYS	489	Mathematical Physics (3)
PHYS	490	Computer Applications in Physics (3)
PHYS	495	Directed Undergraduate Research (1-3)
ASTR	301	The Dynamical Universe (3)
ASTR	401	The Radiative Universe (3)

or other courses, including mathematics or engineering, if approved by the department undergraduate advisor.

General Education: Basic Skills Mathematics is satisfied by MATH 150A. Natural Sciences is satisfied by CHEM 101/L and PHYS 225/220AL. Physics majors may also satisfy Lifelong Learning by completing COMP 106/L or 110/L.

Total Units in the Major Option I	79
General Education Units	36
Additional Units	5
Total Units Required for the. B.S.Degree, Option I	120

B. Option II: Astrophysics

1. Upper Division Required Courses (37 Units)

PHYS	301	Analytical Mechanics I (3)
PHYS	311	Electromagnetism I (3)
PHYS	365	Experimental Physics I (2)
PHYS	366	Experimental Physics II (2)
PHYS	375	Quantum Physics I (3)
PHYS	402	Analytical Mechanics II (3)
PHYS	410	Electromagnetism II (3)
PHYS	431	Thermodynamics and Statistical Mechanics (4)
PHYS	465	Experimental Physics III (2)
PHYS	466	Experimental Physics IV (2)
PHYS	493	Physics and Astronomy Colloquium (1)
PHYS	495	Directed Undergraduate Research (3)
ASTR	301	The Dynamical Universe (3)
ASTR	401	The Radiative Universe (3)

2. Upper Division Electives (3 Units)

A minimum of 3 units chosen from the following:

PHYS	420	Modern Optics (3)
PHYS	421	Laser Physics (3)
PHYS	451	Quantum Physics II (3)
PHYS	470	Introduction to Nuclear and Elementary Particle Physics (3)
PHYS	480	Introduction to Solid State Physics (3)
PHYS	489	Mathematical Physics (3)
PHYS	490	Computer Applications in Physics (3)

General Education: Basic Skills Mathematics is satisfied by MATH 150A. Natural Sciences is satisfied by CHEM 101/L and PHYS 225/220AL. Physics majors may also satisfy Lifelong Learning by completing COMP 106/L or 110/L.

Total Units in the Major, Option	79
General Education Units	36
Additional Units	5
Total Units Required for the B.S. Degree, Option II	120

B.S. Honors Program

The program leading to a B.S. degree in Physics with Honors provides the opportunity to selected physics majors for intensive study under individual faculty guidance. Admission to the Honors Program is granted by approval of the department undergraduate advisor. Students in either of the two B.S. options are eligible provided they have:

1. completed 90 units of college work;
2. maintained a grade point average of 3.0 overall and in the physics major; and
3. obtained the approval of a faculty sponsor who will supervise their research. Students interested in the honors program should contact the department undergraduate advisor. Honors candidates will be required to complete one of the two B.S. options of the physics major and in addition the following course:

   PHYS 498 Undergraduate Thesis (3)

Graduation with Honors in Physics will require the following:

1. Admission to the Honors Program.
2. Grade point average of 3.25 for all upper division units in the major including PHYS 498. There shall be no individual grades below a C. A grade of C- is not acceptable.
3. Approval of the undergraduate thesis by a faculty committee.

Minor in Physics

1. Lower Division Required Courses (32-34 Units)

MATH	150A	Calculus I (5)
MATH	150B	Calculus II (5)
MATH	250	Calculus III (3)
MATH	262	Introduction to Linear Algebra (3)
MATH	280	Applied Differential Equations (3)
PHYS	225/220AL	Physics I/ Mechanics Lab (4/1)
or PHYS	220A/L	Mechanics/ Lab (3/1)
PHYS	226/220BL	Physics II/ Electricity and Magnetism Lab (4/1)
or PHYS	220B/L	Electricity and Magnetism/ Lab (3/1)
PHYS	227/L	Physics III/ Lab (4/1)

2. Upper Division Required Courses (9 Units)

A minimum of 9 units chosen from the following, with the approval of the department undergraduate advisor.

PHYS	301	Analytical Mechanics I (3)
PHYS	311	Electromagnetism I (3)
PHYS	365	Experimental Physics I (2)
PHYS	366	Experimental Physics II (2)
PHYS	375	Quantum Physics I (3)
PHYS	431	Thermodynamics and Statistical Mechanics (4)
PHYS	493	Physics and Astronomy Colloquium (1)

Total Units Required for the Minor	41-43

Requirements for the Master of Science Degree in Physics

For admission to the program: Applicants must meet general University admission requirements. In addition, if the applicant has a bachelor's degree in physics, then a grade point average of at least 2.5 in all upper division physics lecture classes is required. If the bachelor's degree is in a related field, then a grade point average of at least 2.5 in all upper division lecture classes in the major is required.

A. For Classified Status

1. A bachelor's degree in physics. If the major is in a related field, completion of prescribed prerequisites with grades of B or better is required.
2. General University requirements for classified status.

B. For the Degree

1. Completion, with a B average (3.0) or higher, of 30 units of approved graduate study, including a minimum of 21 units of 500 and 600-level courses.

   Required core courses (14 units)

PHYS	600	Classical Mechanics (4)
PHYS	610	Electromagnetic Theory (4)
PHYS	630	Statistical Physics (3)
PHYS	650	Quantum Mechanics I (3)

   The four core courses must be completed with a B average (3.0) or higher, and at least 3 of these courses must be taken in residence at CSUN. Students are strongly advised to complete the graduate core courses early in their studies.

   Electives (16 Units)

   To be selected, with approval of the department graduate advisor, from 400, 500 and 600-level courses including Thesis (PHYS 698—3 to 6 units). At least 10 of these units must be in Physics. Up to 6 units of approved courses may be in related fields: Astronomy, Chemistry, Engineering and Mathematics. Up to 9 units may be at the 400-level, other than PHYS 495, 498 and 499, if approved in advance by the department graduate advisor.
2. Thesis or Comprehensive Examination.
   a. Students electing the thesis option must pass an oral examination in the field of the thesis.
   b. Students not electing the thesis option must pass a written comprehensive examination in PHYS 600, 610, 630, and 650. The exams will be offered during 2 days before the start of the Fall and Spring semesters. The dates will be announced in the preceding semester. (For regulations governing registration for the thesis or comprehensive examination, see the department graduate advisor.)

Total Units Required for the M.S. Degree	30

Course List – Astronomy

ASTR 152. Elementary Astronomy (3)
Introduction to astronomy. Topics to be covered include the historical development of astronomy; the laws that govern the behavior of the Universe; a survey of the properties of stars and galaxies, including their origin and evolution; and the Big Bang theory. This course is also offered on-line as ASTR 152OL. Students using this course to satisfy the General Education requirement in Natural Sciences may satisfy the corresponding lab requirement by completing course ASTR 154L.

ASTR 154L. Observational Astronomy (1)
Recommended Corequisite or Preparatory: ASTR 152. Introduction to the techniques of observational astronomy including data acquisition and interpretation. Testing of astronomical hypotheses by using data from observations of the moon, planets, sun, stars and galaxies. May be used to satisfy the lab requirement in General Education, Natural Sciences provided ASTR 152 has been completed. Three hours per week.

ASTR 301. The Dynamical Universe (3)
Preparatory: MATH 150B; PHYS 220A or 225; and completion of the Lower Division Writing Requirement. Applications of Newtonian and relativistic dynamics to astrophysical systems. Planetary and satellite motion, planetary rings, binary and multiple star systems, clusters of stars, dynamics of spiral and elliptical galaxies, missing mass of galaxy clusters, relativistic orbits (Mercury and the binary pulsar), black holes, dynamical fate of the universe.

ASTR 312. Exploring the Solar System (3)
Preparatory: Completion of the Lower Division Writing Requirement. Comprehensive survey of the solar system with emphasis placed upon the results of recent space explorations. Kepler's laws and planetary motion, solar interior and solar atmosphere, planets and their satellites, minor planets, comets, meteors and the interplanetary medium.

ASTR 312L. Exploration Of the Solar System Laboratory (1)
Preparatory: Completion of the Lower Division Writing Requirement. Recommended Corequisite or Preparatory: ASTR 312. Use of observational and laboratory facilities, and published data, to explore the Solar System. One three-hour lab period per week.

ASTR 352. Current Developments in Astronomy (3)
Preparatory: Completion of the Lower Division Writing Requirement. In-depth examination and interpretation of astronomical discoveries occurring at the time the course is taught. Reading includes both background material and current periodicals accessible to upper division, General Education students. Likely areas of discussion: spacecraft exploration of the solar system, satellite observations of high energy radiation from space, exotic astronomical objects (e.g., double quasars, black hole candidates), and new cosmological data. Students using this course to satisfy the General Education requirement in Natural Sciences may satisfy the corresponding lab requirement by completing course ASTR 352L. (IC)

ASTR 352L. Current Developments in Astronomy Lab (1)
Preparatory: Completion of the Lower Division Writing Requirement. Recommended Corequisite or Preparatory: ASTR 352. Use of observational and laboratory facilities, and published data, to explore current developments in astronomy. May be used to satisfy the lab requirement in Natural Sciences, General Education provided ASTR 352 is also completed. Three hours per week. (IC)

ASTR 401. The Radiative Universe (3)
Preparatory: PHYS 227. Application of the laws of radiation, atomic and subatomic structure to astrophysical systems. Cosmic magnetic fields, and energy sources, analysis of radiation from stars, nebulae, supernovae, active galaxies and quasars, the early universe, origin of the elements.

ASTR 499A-C. Independent Study (1-3)

Course List – Physics

PHYS 100A. General Physics I (3)
Prerequisite: MATH 104 or 105 or a score on the Mathematics Placement Test (MPT) sufficient for entry into MATH 255A. Introductory course in physics. Topics covered: mechanics, heat and sound. Students using this course to satisfy the Natural Sciences requirement in General Education may satisfy the corresponding lab requirement by completing course PHYS 100AL.

PHYS 100AL. General Physics I Lab (1)
Recommended Corequisite or Preparatory: PHYS 100A. May be used to satisfy the lab requirement in Natural Sciences, General Education, provided PHYS 100A is also completed. Three hours per week.

PHYS 100AR. General Physics I Recitation (1)
Corequisite: PHYS 100A. Recitation-discussion of topics introduced in PHYS 100A. Optional class emphasizing problem-solving. Problems solved are directly related to topics introduced in the lecture class. One hour per week.

PHYS 100B. General Physics II (3)
Prerequisite: PHYS 100A. Continuation of PHYS 100A. Topics covered: electricity and magnetism, light, and modern physics. Students using this course to satisfy the Natural Sciences requirement in General Education may satisfy the corresponding lab requirement by completing course PHYS 100BL.

PHYS 100BL. General Physics II Lab (1)
Recommended Corequisite or Preparatory: PHYS 100B. May be used to satisfy the lab requirement in Natural Sciences, General Education, provided PHYS 100B is also completed. Three hours per week.

PHYS 100BR. General Physics II Recitation (1)
Corequisite: PHYS 100B. Recitation-discussion of topics introduced in Physics 100B. Optional class emphasizing problem-solving. Problems solved are directly related to topics introduced in the lecture class. One hour per week.

PHYS 101. Introduction to Faculty Research (1)
Preparatory: Instructor consent. Designed to introduce prospective or current physics majors to the department. Each week, a different member of the department conducts the class and the specialty and expertise of that faculty member is presented to the class. Enables students to find out what it is that physicists do and thereby make informed decisions about their career objectives. (Credit/No Credit Only)

PHYS 220A. Mechanics (3)
Prerequisite: MATH 150A. Recommended Corequisite or Preparatory: MATH 150B. Dynamics and statics of particles and rigid bodies, harmonic vibrations, and fluid mechanics. Students using this course to satisfy the Natural Sciences requirement in General Education may satisfy the corresponding lab requirement by completing course PHYS 220AL.

PHYS 220AL. Mechanics Lab (1)
Recommended Corequisite or Preparatory: PHYS 220A or 225. May be used to satisfy the lab requirement in Natural Sciences, General Education, provided PHYS 220A is also completed. Three hours per week.

PHYS 220AR. Mechanics Recitation (1)
Corequisite: PHYS 220A. Recitation-discussion of topics introduced in PHYS 220A. Optional course emphasizes problem-solving. Problems solved are directly related to topics introduced in the lecture class. One hour per week.

PHYS 220B. Electricity and Magnetism (3)
Prerequisites: PHYS 220A; MATH 150B. Recommended Corequisite or Preparatory: MATH 250. Electric and magnetic fields, circuit theory and electromagnetic induction. Students using this course to satisfy the Natural Sciences requirement in General Education may satisfy the corresponding lab requirement by completing course PHYS 220BL.

PHYS 220BL. Electricity and Magnetism LAB (1)
Recommended Corequisite or Preparatory: PHYS 220B or 226. May be used to satisfy the lab requirement in Natural Sciences, General Education, provided PHYS 220B is also completed. Three hours per week.

PHYS 220BR. Electricity and Magnetism Recitation (1)
Corequisite: PHYS 220B. Recitation-discussion of topics introduced in Physics 220B. Optional class emphasizing problem-solving. Problems solved are directly related to topics introduced in the lecture class. One hour per week.

PHYS 225. Physics I (4)
Prerequisite: MATH 150A. Recommended Corequisite or Preparatory: MATH 150B. First course of a sequence intended primarily for physical science majors. Calculus-based course on mechanics, fluids, waves and acoustics.

PHYS 226. Physics II (4)
Prerequisites: PHYS 225; MATH 150B. Recommended Corequisite or Preparatory: MATH 250. Second course of a sequence of courses intended primarily for physical science majors. Calculus-based course on Electricity and Magnetism and Optics.

PHYS 227. Physics III (4)
Prerequisites: PHYS 226 or 220B, and MATH 250. Recommended Corequisite or Preparatory: MATH 280. Third course of a sequence of courses intended primarily for physical science majors. Calculus-based course on Thermodynamics, Waves and Modern Physics.

PHYS 227L. Physics III LAB (1)
Recommended Corequisite or Preparatory: PHYS 227. Three hours per week.

Upper Division

PHYS 301. Analytical Mechanics I (3)
Preparatory: MATH 250, 280; PHYS 227. Newtonian mechanics of a single particle, oscillations, systems of particles, central force motion, calculus of variations, Lagrangian and Hamiltonian mechanics.

PHYS 305/L. Physics Of Music and Laboratory (3/1)
Corequisite: PHYS 305L. Preparatory: Completion of the Lower Division Writing Requirement. This course is currently taught entirely and only online. History and development of the science of sound and music, physical concepts necessary for the study of wave motion, mechanics of the construction of sound and musical tones, basic physical principles involved in the production of sound in instruments and the human voice, including studies of the production of language. A good understanding of the composition of sounds and musical tones is obtained without detailed mathematics through experiments carried out in the home or other locations using the student's computer with installed software. A final project is required. (Available for General Education, Natural Sciences) (IC)

PHYS 311. Electromagnetism I (3)
Preparatory: MATH 250, 280; PHYS 227. Vector calculus, electrostatics, magnetostatics, Faraday's Law and introduction to Maxwell's equations.

PHYS 365. Experimental Physics I (2)
Preparatory: MATH 250, 262, 280; PHYS 227/L. Advanced experimental techniques in physics with topics including optics, nuclear physics, thin-film characteristics, microwaves, data acquisition via computer interface, computer simulations, solar observations, or other topics chosen by the instructor. This course includes a module on computer analysis in physics using Matlab. Students are trained in advanced experimental techniques and complete two experimental modules for two units of credit. Six hours per week.

PHYS 366. Experimental Physics II (2)
Preparatory: MATH 250, 262, 280; PHYS 227/L. Advanced experimental techniques in physics with topics including optics, nuclear physics, thin-film characteristics, microwaves, data acquisition via computer interface, computer simulations, solar observations, or other topics chosen by the instructor. Students are trained in advanced experimental techniques and complete two experimental modules for two units of credit. Six hours per week.

PHYS 375. Quantum Physics I (3)
Preparatory: MATH 262, PHYS 301. Classical background, the wave function,Schrodinger equation, time development and stationary states, one-dimensional problems, harmonic oscillator, formalism of quantum mechanics.

PHYS 376. Radiologic Physics (3)
Preparatory: PHYS 100A/L, 100B/L or instructor consent. Specialized course devoted to the nature and production of x-radiation. Topics include the interaction of radiation with matter, attenuation of x-rays and the principles behind radiographic equipment and components.

PHYS 402. Analytical Mechanics II (3)
Preparatory: MATH 262; PHYS 301. Noninertial reference frames, rigid body motion, coupled oscillations, nonlinear mechanics, scattering, vibrating string, Fourier analysis. Available for graduate credit

PHYS 410. Electromagnetism II (3)
Preparatory: MATH 262; PHYS 301; 311. Maxwell's equations and applications, electromagnetic waves, radiation, and special relativity. Available for graduate credit.

PHYS 420. Modern Optics (3)
Preparatory: PHYS 311; 375. Propagation of electro-magnetic waves. Geometrical optics. Physical optics: Refraction, reflection, interference, diffraction, and polarization. Atomic spectroscopy. Lasers. Available for graduate credit.

PHYS 421. Laser Physics (3)
Preparatory: PHYS 311; 375. Introduction to the principles of laser operation, properties of laser beams, laser design considerations, and a survey of typical systems that operate at wavelengths having technical applications. Available for graduate credit.

PHYS 431. Thermodynamics and Statistical Mechanics (4)
Preparatory: PHYS 301; 375. Laws of thermodynamics, thermo-dynamic potentials, kinetic theory, phase transitions, equilibrium ensembles and related formalism with applications to classical and quantum systems. Available for graduate credit.

PHYS 451. Quantum Physics II (3)
Preparatory: PHYS 311; 375. Hydrogen atom, angular momentum, spin, matrix representation, quantum statistics, perturbation theory, scattering. Available for graduate credit.

PHYS 465. Experimental Physics III (2)
Preparatory: PHYS 365. Advanced experimental techniques in physics with topics including optics, nuclear physics, thin-film characteristics, microwaves, data acquisition via computer interface, computer simulations, solar observations, or other topics chosen by the instructor. Students are trained in advanced experimental techniques and will complete two experimental modules for two units of credit. Six hours per week.

PHYS 466. Experimental Physics IV (2)
Preparatory: PHYS 365. Advanced experimental techniques in physics with topics including optics, nuclear physics, thin-film characteristics, microwaves, data acquisition via computer interface, computer simulations, solar observations, or other topics chosen by the instructor. Students are trained in advanced experimental techniques and will complete two experimental modules for two units of credit. Six hours per week.

PHYS 470. Introduction to Nuclear and Elementary Particle Physics (3)
Recommended Corequisite or Preparatory: PHYS 451. Production, interactions and structure of subatomic particles: Radioactivity, accelerators, detectors, classification of elementary particles, quark model, nuclear properties, nuclear models, and nuclear reactions. Available for graduate credit.

PHYS 480. Introduction to Solid State Physics (3)
Preparatory: PHYS 311; 375. Structure of crystals, electron theory of metals, theory of semiconductors, and mechanical, electrical, and magnetic behavior of substances in the solid state. Available for graduate credit.

PHYS 489. Mathematical Physics (3)
Preparatory: PHYS 375 (may be taken concurrently) or MATH 380. Topics include complex variables, ordinary and partial differential equations,special functions, and boundary value problems, with physical applications. Available for graduate credit.

PHYS 490. Computer Applications in Physics (3)
*Preparatory: PHYS 301 and 365, or instructor consen*t. Applications of numerical analysis and computer programming to the solution of problems in classical and modern physics. Available for graduate credit.

PHYS 493. Physics and Astronomy Colloquium (1-1-1)
Preparatory: Junior, senior or graduate standing in Physics. Series of lectures presented weekly by faculty members and invited speakers on topics of current interest in physics, astronomy, and related fields. May be repeated twice for credit.

PHYS 495A-C. Directed Undergraduate Research (1-3)
Preparatory: PHYS 365; Senior-standing. Program of original, independent research to be carried out under the direction of one of the physics faculty. May be repeated for credit: maximum six units.

PHYS 496A-Z. Experimental Topics Courses in Physics (1-3)
Experimental courses in Physics with course content to be determined.

PHYS 498. Undergraduate Thesis (3)
Preparatory: Admission to Honors Program in Physics.

PHYS 499. Independent Study (1-3)
See Independent Study under Courses of Study.

PHYS 589. Mathematical Physics Seminar (1)
Preparatory: Senior or graduate-standing in the Department of Mathematics or the Department of Physics and Astronomy. Seminar comprised of a series of weekly lectures in mathematical physics by faculty members and invited speakers. (Crosslisted with MATH 589)

PHYS 595A-Z. Experimental Topics Courses (1-3)

Graduate

PHYS 600. Classical Mechanics (4)
Preparatory: PHYS 402, 410, 451. Advanced course in classical mechanics with topics selected from Lagrangian and Hamiltonian dynamics, continuum mechanics, nonlinear systems and chaos.

PHYS 601. Selected Topics in Astrophysics (3)
Preparatory: PHYS 375; 402, 410. Advanced treatment of the observational and theoretical foundations of astrophysics. Topics may include: Stellar structure, radio sources, relativistic cosmology, the origin of the elements, galaxy formation.

PHYS 610. Electromagnetic Theory (4)
Preparatory: PHYS 410; 489. Advanced theoretical treatment of the electrostatic field with introduction of mathematical techniques. Introduction to electromagnetic waves and radiation from sources.

PHYS 615. Plasma Physics (3)
Preparatory: PHYS 402; 410; 431. Plasma state, motion of isolated charged particles, collisions, plasma statistical mechanics, statistics of collisions, fluid and statistical models, waves in plasmas, instabilities, non-equilibrium statistical mechanics, radiation processes.

PHYS 620. Optics (3)
Preparatory: PHYS 420 or 410. Advanced topics in physical optics- interference and diffraction theory, partial coherence and polarization, conducting thin films, and crystal optics. Introduction to gradient index optics, holography, nonlinear effects and other topics of fundamental or current interest.

PHYS 630. Statistical Physics (3)
Preparatory: PHYS 431; 451; 600. Theoretical foundations of thermodynamics and statistical mechanics for equilibrium and non-equilibrium systems. Applications to Bose and Fermi assemblies, real gases, liquids, solids, solutions, phase transitions, and chemical reactions.

PHYS 640. General Relativity (3)
Preparatory: PHYS 402, 410. Introduction to the mathematics and physics of curved space-time. Gravitational fields as curvature of space-time. Einstein's gravitational field equations, solutions and experimental tests. Application to topics of current interest in relativistic astrophysics, particle physics and field theory.

PHYS 650. Quantum Mechanics I (3)
Preparatory: PHYS 451. Recommended Corequisite or Preparatory: PHYS 600. Mathematical foundation of quantum theory. Scattering theory. Angular momentum and spin. Identical particles. Heisenberg and Schrodinger representations. Perturbation theory.

PHYS 651. Quantum Mechanics II (3)
Preparatory: PHYS 650. Relativistic wave equations. Advanced scattering theory. Selected topics from quantum theory of atoms and molecules.

PHYS 680. Solid State Physics I (3)
Preparatory: PHYS 451 or 480. Advanced treatment of condensed matter physics. Topics: crystal structure, cohesive energy, lattice vibrations, Sommerfeld theory of metals, electronic structure theory, and theory of semiconductors.

PHYS 681. Solid State Physics II (3)
Preparatory: PHYS 480 or 680. Advanced treatment of condensed matter physics. Topics: Magnetic ordering, beyond the independent electron approximation, optical processes and excitons, dielectric properties, superconductivity, defects and surface-interface physics.

PHYS 690. Mathematical Physics (3)
Preparatory: PHYS 489. Selected topics in advanced mathematical physics such as boundary value problems, Green's functions, nonlinear dynamics, approximation methods, numerical analysis, group theory and differential geometry.

PHYS 696A-C. Directed Graduate Research (1-3)

PHYS 697. Directed Comprehensive Studies (3)
Preparatory: Completion of all courses required in the program. May not be used for credit in the program itself.

PHYS 698. Thesis (3-6)
Preparatory: Classified graduate-status, permission of the department, and instructor's consent to serve as thesis advisor. Dissertation of a specialized advanced topic in physics such as a critical evaluation and extension of an existing theoretical treatment, the construction and use of advanced research apparatus, or an original theoretical analysis.

PHYS 699. Independent Study (1-6)
Preparatory: At least one graduate course in physics and instructor consent. Investigation of a special topic in physics with emphasis on advanced theoretical or experimental skills. See Independent Study under Courses of Study.