Department of Physics

(DIVISION OF SCIENCE)

Professor V. Parameswaran Nair, Chair • Department Office: MR 419 • Tel: 212-650-6832

GENERAL INFORMATION

The City College offers the following undergraduate degree in Physics:

B.S.

PROGRAMS AND OBJECTIVES

The Department of Physics provides a comprehensive program designed to enable students to acquire a basic understanding of the laws of nature and their application, and to prepare them for a career either in physics or in one of the many science and technology oriented professions for which physics is a basic component. The various introductory courses are therefore designed to meet a variety of student needs, including general knowledge, preparation for professional work (engineering, materials science, photonics, premedical, biomedical physics, architecture, teaching, etc.) and preparation for advanced work in physics. A sequence of advanced courses is provided primarily for Physics majors but is also open to other interested students. The aim of these courses is to train students for technical employment in industry or government and for graduate work.

In addition to the Standard Physics Option the Department offers an Applied Physics Option, a Secondary Education Option and a Biomedical Physics Option. The Applied Physics Option has two tracks: Materials Science or Optics/Photonics.

The Department cooperates in the Program in Premedical Studies (PPS), a program of the Division of the College of Liberal Arts and Science. This allows the student to major in Physics while participating in PPS. The program features a curriculum which integrates a variety of learning experiences specifically preparing participants to meet medical, dental and veterinary school admission requirements as well as those for physician's assistant and physical therapy advanced degree programs.

Honors
The Research Honors Program is one of several ways for undergraduate students to participate in faculty research projects. Such projects, if judged to be of sufficient quality and quantity, may lead to a degree with honors.

Physics Scholar Program
The Physics Department accepts students into the Physics Scholar Program. This program provides research opportunities and summer research employment. More information about this very successful and competitive program can be obtained directly from the Department.

Research
The large active research faculty provides undergraduate research opportunities in many fields of experimental and theoretical physics. Modern laboratories provide excellent training facilities in the areas of laser physics, low temperature physics, biophysics and semiconductor physics. Off-site research in atomic physics takes place at Lawrence Berkeley National Laboratory. Some students also participate in theoretical physics research, primarily in the areas of condensed matter physics and high energy. Academic credit can be earned for participation in such research projects.

Graduate Courses
Physics majors in their senior year sometimes enroll in beginning graduate courses.

Electives for Non-Majors
Engineering majors may take as electives Physics 32100, 32300, 42200, 45200, 45300, 55400, 55500, 56100, 58000 and 58100. Biology and premedical students may elect Physics 31500 and 42200. Mathematics and Chemistry majors may elect Physics 35100 and 35300. All physical science students with an interest in astronomy should consider Physics 45400. Chemists should consider Physics 55400.

Exemption Credit
Qualified students may take exemption examinations for all courses offered by the Department upon application to the Department. Exemption examinations are given at several specified times during the year. In general, a grade of B+ or better is required for exemption with credit and a grade of B- or better for exemption without credit. For some courses, it will be necessary to complete the laboratory component before full credit is given.

TUTORING

Each faculty member designates two office hours per week when she or he will be available to tutor students. In addition, all faculty members teaching multiple section introductory or intermediate courses are available for tutoring of students in all sections of the particular course(s) they are teaching. Detailed tutoring schedules are distributed early in each semester. For the introductory courses there is also a tutoring lab, open about 25 hours per week, staffed by qualified graduate and undergraduate students, where a student in these courses may seek assistance.

DEPARTMENT ACTIVITIES

Colloquia and Seminars
The Physics Department holds a weekly colloquium in a field of general or current interest in physics, usually given by a distinguished outside speaker. All Physics graduate students and Physics majors are invited to attend. In addition there are weekly seminars of a more specialized nature in such areas as high-energy physics, condensed matter physics and biophysics and frequent seminars in such areas as astrophysics and light scattering.

Planetarium
The Physics Department maintains a fully equipped planetarium. Programs and shows on an appropriate level are given for elementary schools, junior and senior high schools and the college community as well as other groups upon request. Programs and shows are available both in English and in Spanish.

Job Placement
The Physics Department maintains an up-to-date file of employment opportunities at all levels.

Computer Facilities
Computation facilities include a general purpose Science Computer Lab with 40 Dell workstations, projectors, printer and network equipment for classes and assigned course work, internet and e-mail access. Licensed software such as MS Office, Matlab, Mathmetica, SPSS, SAS, Gaussian 98W and ArcView are available in all the workstations. Teaching and research laboratories have a variety of dedicated computer workstations, servers, cluster, software and applications for data acquisition, processing, simulation and scientific computation.

AWARDS

The Physics Department annually awards one or more Ward medals and the Sidney Millman Scholarship Award for academic excellence, and a Sonkin medal for the best achievement in experimental physics. Physics students may also compete, along with students in the other science departments, for the annual Marshak award and Zemansky Introductory Physics Prize. All awards are presented at a special Science Honors Convocation.

ADVISEMENT

Undergraduate Majors
Professor Joseph L. Birman
MR 424; 212-650-6871

Professor Fredrick W. Smith
MR 423A, 212-650-6963

Graduate Students
Professor Timothy Boyer
MR 331; 212-650-5585

All other students
Contact the Physics Office (MR-419; 212-650-6832), to be put in touch with an appropriate advisor.

REQUIREMENTS FOR MAJORS

All Physics majors must complete "Basic Courses for Physics Majors" and either the "Standard Physics Concentration" or one of the "Alternative Concentrations". These courses are in addition to the Science core curriculum requirements:

Basic Courses for Physics Majors
Physics:
35300: Electricity and Magnetism I 3
37100: Advanced Physics Laboratory I 2
45100: Thermodynamics and Statistical Physics 3

Total Credits for Basic Courses 8

Standard Physics Concentration
Required Courses
Physics:
35100: Intermediate Mechanics 4
35400: Electricity and Magnetism II 3
45200: Optics 3
47100: Advanced Physics Laboratory II 2
55100: Quantum Physics I 4
55200: Quantum Physics II 4
55600: Current Topics in Physics 1
Physics Elective: Physics 31500, 42200, 45300, 55400 3

Mathematics:
39100: Methods of Differential Equations 3
39200: Linear Algebra and Vector Analysis 3

Total Credits for Standard Physics Concentration 38

Alternative Physics Concentration
(Materials Science and Optics/Photonics Concentrations)

Required Courses
Physics:
32300: Quantum Mechanics 3
35100: Intermediate Mechanics 3
35400: Electricity and Magnetism II 3
Applied Physics Electives: 15
Materials Science concentration requires Physics 554000, 55500 and 56100. Additional electives may be selected from Physics 42200, Chemistry 26100, 32500, Chem Engr 46700 and EE 44100. Optics/Photonics concentration requires Physics 45200, 47100, 45300 and 58000. Additional electives may be selected from Physics 55400, 58100 and EE 59801

Mathematics:
39100: Methods of Differential Equations 3
39200: Linear Algebra and Vector Analysis 3

Total Credits for Applied Physics Concentration 38

Biomedical Physics Concentration

Required Courses
Physics:
42200: Biophysics 3
52200: Biomedical Physics 3
One of the following: 3-4
32300: Quantum Mechanics 3
55100: Quantum Physics I 4

Mathematics:
39100: Methods of Differential Equations 3
39200: Linear Algebra and Vector Analysis 3

Chemistry:
45900: Biochemistry I 4

Total Credits for Biomedical Physics Concentration 27-28

Secondary Education Concentration
Major requirements are listed below. Pedagogical requirements are listed in the Department of Education section of this *Bulletin*.

Required Courses
35100: Intermediate Mechanics 4
35300: Electricity and Magnetism I 3
35400: Electricity and Magnetism II 3
37100: Advanced Physics Lab I 2
45100: Thermodynamics and Statistical Physics 3

45200: Optics	3
32100: Modern Physics	3
Electives to be chosen in consultation with the advisor	6
Total Credits for Secondary Ed. Concentration	**27**

Elective Courses

Students who intend to go on to graduate work in Physics should choose, in consultation with the departmental advisor, free electives from among the following:

Physics:
31500: Medical Physics (3 cr.)
42200: Biophysics (3 cr.)
45300: Physical Photonics I (Laser Optics) (3 cr.)
45400: Descriptive Astronomy (3 cr.)
52200: Biomedical Physics (3 cr.)
55300: Kinetic Theory and Statistical Mechanics (3 cr.)
55400: Solid State Physics (3 cr.)
55500: The Physics and Chemistry of Materials (3 cr.)
Any graduate course with designation V0100-V2600

Mathematics:
Selected 20000, 30000, or 40000 level courses

Additional Requirements

Students who intend to go on to complete some graduate work during the undergraduate years should see the concentration advisor (Prof. J. L. Birman or Prof. F.W. Smith) concerning possible substitutions for some of the above courses.

Note: all the non-introductory courses in physics required for Physics majors are given only once a year. For a student who has completed the required introductory courses (Physics 20700, 20800, Math 20100, 20200, 20300) the following sequence is therefore recommended for the remaining courses:

	Physics	Math
Spring		39100
Fall	35100, 35300, 37100	
Spring	35400, 47100, 55100	39200
Fall	45200, 55200, 55600	
Spring	45100, elective	

Students who enter this sequence during their sophomore year may thus be free to take physics (or math) electives or graduate courses in their senior year. The latter is especially recommended by the Department.

Students who cannot readily fit into this sequence should consult the concentration advisor. All students intending to major in Physics should see the specialization advisor before entering their junior year. Students who do not intend to do graduate work should see Professors Birman or Smith for an individualized program.

All Physics majors must also complete the following courses:
New Student Seminar (unless exempt) (0 cr.)
English 11000: Freshman Composition (3 cr.)
English 21003 or equivalent: Second Level Writing Course (3 cr.)
Core Curriculum for the intended degree
Speech 11100 (3 cr.) or pass the Speech Proficiency test.

In addition, all students must complete the following:

College Proficiency Examination: Pass the CPE after completing 45 but no more than 60 credits.

Proficiency in a Foreign Language: Students must complete either two years of foreign language in high school or a second semester-level course at City College.

Writing Across the Curriculum: Three elective-level courses that are identified as requiring at least 3,500 words of writing. Courses designated with a (W) at the end of each course description fulfill this requirement.

For more information, please consult the chapter entitled *Degree Requirements* in the introduction to this *Bulletin*.

REQUIREMENTS FOR A MINOR IN PHYSICS

Students in other departments may minor in physics by taking a minimum of 9 credits in Physics beyond the introductory courses (20700, 20800 or 20300, 20400). These courses are in addition to the science core requirements. See an advisor in the Physics Department for guidance.

COURSE DESCRIPTIONS

CORE COURSES

All courses except Astronomy 10000 and 30500 carry a Physics (PHYS) designation, starting with PHYS 10000.

Astronomy 10000: Ideas of Astronomy
Explores the entire realm of the universe, its origins and history, and establishes our time and place and role in it. Our solar system, our galaxy, the expanding universe of many galaxies will be discussed along with more recent discoveries such as quasars, pulsars and black holes. 3 lect., 1 rec. hr./wk., slides, films, planetarium shows; 3 cr.

Physics 10000: Ideas of Physics
A course with two themes: 1. How nature works the interplay of space, time, matter and energy; 2. Structures are born, live out their life cycles, and die. These include us, the stars, and perhaps the universe. This theme may be called the scientific story of genesis. 3 lect., 1 rec. hr./wk., demonstrations, slides, films; 3 cr.

Astronomy 30500: Methods in Astronomy
Designed to fulfill the 30000-level core science requirement, the course covers the fundamental physical laws that underlie the motions of heavenly bodies, including Newtonian mechanics and Einstein's theory of relativity, planetary, stellar and galactic evolution; the methods, techniques and instruments used by modern astronomy, including the Hubble Space Telescope and planetary space probes. 3 lect., 1 rec. hr./wk., slides, films, planetarium shows, field trips; 3 cr.

INTRODUCTORY COURSES

20300-20400: General Physics
For majors in the life sciences (biology, medicine, dentistry, psychology, physical therapy) and for liberal arts students. Fundamental ideas and laws of physics from mechanics to modern physics. Included are Newton's laws of motion, electricity and magnetism, heat, optics, relativity, quantum mechanics and nuclear physics. Emphasis is on the basic principles and general laws. Use of mathematics is restricted to elementary algebra and some trigonometry. Physics 20300 is prereq. for Physics 20400 (required for Premed., Predent., Bio-Med., and all Life Science students). 3 lect., 1 rec. hr./wk., 3 lab. hr. alt. wks.; 4 cr./sem.

20305-20405: Laboratory Sections for 20300 and 20400
Department permission required for registration, which is limited to students having passed lecture part via exemption

exam or via equivalent course elsewhere. Not open to students who have previously taken or are planning to register for 20300 or 20400. 3 lab. hr. alt. wks.; 1 cr./sem.

20700-20800: General Physics
Vectors, equilibrium, rectilinear motion. Newton's laws, gravitation, motion in a plane, work and energy, impulse and momentum, rotation and angular momentum, simple harmonic motion, fluids, heat and thermodynamics, waves and acoustics, electrostatics, magnetism and electromagnetism, direct and alternating current, geometrical and physical optics. Pre- or coreq.: Math 20200 for Physics 20700. Physics 20700 is prereq. for Physics 20800. Math 20300 is pre- or coreq. for Physics 20800. (Required for all students in the Physical Sciences, Engineering and Computer Science.) 3 lect., 2 rec. hr./wk., 2 lab/wrkshp. hrs (20700), 2 lab. hrs. alt. wks. (20800); 4 cr./sem.

21900: Physics for Architecture Students
A one-semester course for students of Architecture. Translational and rotational equilibrium. Newton's laws of motion and vibrations. Work, energy and power. Fluids and temperature. Heat and energy transfer. Prereq.: completion of all mathematics requirements through trigonometry or be eligible for Math 20500. 3 lect., 2 rec. hr./wk.; 4 cr.

30000: Elementary Physics
For students in the School of Education. Survey of physics emphasizing the meanings of physical laws, concepts of motion and energy, and physical properties of matter. Topics include concepts of velocity and acceleration; Newton's laws of motion, mass and weight, circular motion, gravitation, work, energy, momentum, electromagnetic properties of matter, and atomic theory (required for students in Elementary Education). 3 lect., 2 lab. or discussion hr./wk.; 3 cr.

32100: Modern Physics for Engineers
Introductory historical background, elementary quantum theory, application to one-electron atoms, atomic shell structure and periodic table; nuclear physics, relativity and statistical mechanics. Concepts, quantitative work and problem sets are emphasized. Prereq.: Physics 20800 or equivalent, Math 20300 or 20900 (elective for Engineering students). 3 lect. hr./wk.; 3 cr.

ELEMENTARY ELECTIVES

31500: Medical Physics
Physical aspects of the skeletal, circulatory, nervous, muscular, respiratory, and renal systems; diagnostic imaging including EKG, EEG, x-rays, CAT, MRI, lasers and fiber optical probes; radiation therapy and safety; nuclear medicine; artificial organs. Prereq.: Physics 20400 or 20800. 3 hr./wk.; 3 cr.

32300: Quantum Mechanics for Applied Physicists
Basic experiments, wave-particle duality, uncertainty; Wave functions and Schroedinger equation; 1-d problems: (a) bound states: square well, harmonic oscillator, Kronig-Penny model, (b) scattering from barriers, tunneling; QM formalism: Dirac notation, operators & eigenvalues, angular momentum; Hydrogen atom; Peturbation theory; time independent – first order nondegenerate, level splitting; time dependent – Golden rule; Identical particles, spin & statistics; Quantum communication, Bell's theorem. Prereq.: Physics 20700 and 20800, Math 39100 and 39200 (required for Physics majors in the Applied Physics Option). 3 hr./wk.; 3 cr.

33100: Intelligent Life in the Universe
Problems concerning the existence of and contact with other intelligent life forms. The physical conditions necessary for development and evolution of such forms. The physical limitations on contact with them. 4 hr./wk.; 4 cr.

33200: Physics of Science Fiction
The physical basis for the many imaginative and speculative schemes encountered in science fiction: anti-matter, space warps, black holes, anti-gravity, time travel, multi-dimensional universes, parallel universes, quarks, robots, flying saucers, Star Trek, etc. Every lecture is accompanied by a color slide show. No prereq. 3 hr./wk.; 3 cr.

ADVANCED COURSES

35100: Mechanics
Newton's laws; Systems of particles; Small oscillations; Central forces and planetary motion; Rotations and rotating coordinate system; Introduction to rigid body motion; Lagrangian dynamics; Introduction to Hamiltonian dynamics. Prereq.: Physics 20800; pre- or cor-req.; Math 39100 (required for Physics majors). 4 hr./wk.; 4 cr.

35300: Electricity and Magnetism I
Review of vector calculus; Electrostatics in vaccum, work & energy, conductors; Laplace's equation and its solution; Electric fields in matter, currents, circuits and dielectrics; magnetostatics, vector potential. Prereq.: Physics 20800; pre- or coreq.: Math 39100 and Physics 35100 or equivalent (required for Physics majors). 3 hr./wk.; 3 cr.

35400: Electricity and Magnetism II
Magnetic fields in matter; Electrodynamics, induction, Makwell's equations; Electromagnetic waves in vacuum and in matter; Guided waves – transmission lines and waveguides; Electromagnetic potentials and radiation; Special relativity. Prereq.: Physics 35300; pre- or coreq.: Math 39100 and Math 39200 (required for Physics majors, except those in the Biomedical Option). 3 hr./wk.; 3 cr.

37100: Advanced Physics Laboratory I
Experiments in electricity, magnetism and electronics. Prereq.: Physics 20800; coreq.: Physics 35300 (required for Physics majors). 3 lab., 1 conf. hr./wk.; 2 cr.

42200: Biophysics
Introduction to the structure, properties, and function of proteins, nucleic acids, lipids and membranes. In depth study of the physical basis of selected systems including vision, nerve transmission, photosynthesis, enzyme mechanism, and cellular diffusion. Introduction to spectroscopic methods for monitoring reactions and determining structure including light absorption or scattering, fluorescence, NMR and X-ray diffraction. The course emphasizes reading and interpretation of the original literature. Prereq.: 1 yr. of Math, 1 yr. of Physics (elective for Physics Majors and Biomedical Engineering students). 3 hr./wk.; 3 cr.

45100: Thermodynamics and Statistical Physics
Temperature; equations of state; work, heat and the First Law; irreversibility, entropy and the Second Law; introduction to kinetic theory and statistical mechanics; low-temperature physics; the Third Law. Prereq.: Physics 35100 and 35300; coreq.: Math 39100 (required for all Physics majors). 3 hr./wk.; 3 cr.

45200: Optics
Dispersion, reflection and refraction, interference, diffraction, coherence, geometrical optics, interaction of light with matter. Prereq.: Physics 35400, or similar engineering courses; pre- or coreq.: Math 39200 (required for all Physics majors, except those in the Biomedical Option). 3 hr./wk.; 3 cr.

45300: Physical Photonics I/Laser Optics
Theory and applications of lasers and masers. Physical principles underlying the design of lasers, coherent optics, and non-linear optics. Pre- or coreq.: a course in modern physics (Physics 55100 or Physics 32100), a course in electricity and magnetism (Physics 35400 or EE 33200). Optics (Physics 45200) is desirable but not required (elective for Physics and Engineering majors). 3 hr./wk.; 3 cr.

45400: Descriptive Astronomy
Astronomy for science majors. Stellar astronomy, galactic astronomy, cosmology, and earth and planetary science. Recent discoveries and topics such as pulsars, black holes, radio astronomy, interstellar medium, radio galaxies, quasars, spiral density waves in disc galaxies, black body radiation, intelligent life beyond the earth. Lectures are supplemented by observations and planetarium shows. Prereq.: Physics 20800 (elective for Physics majors). 3 hr./wk.; 3 cr.

47100: Advanced Physics Laboratory II
Experiments in optics, quantum physics and atomic physics. Prereq.: Phys 35400; pre or coreq.: Physics 55100 (required for Physics majors). 3 lab., 1 conf. hr./wk.; 2 cr.

52200: Biomedical Physics
Methods used in the study of biophysics and biomedical physics. Study of the physical basis of spectroscopic methods including light absorption or scattering, fluorescence, NMR and X-ray diffraction for the study of biomolecules. Biomedical imaging including sonogram, MRI, and tomography will be discussed. Prereq: 42200 or the consent of the instructor. 3 hr./wk.; 3cr.

55100: Quantum Physics I
Introductory material: 2-slit experiment, matter waves and addition of amplitudes – superposition principle; Uncertainty principle, properties of matter waves: Boundary conditions and energy level quantization and Schrödinger interpretation – wave equation, application to one dimensional problems, barrier penetration, Bloch states in solids and how bands form in solids; The universality of the Harmonic potential – Simple Harmonic oscillator and applications; One electron atoms, spin, transition rates; Identical particles and quantum statistics; Beyond the Schrödinger equation: Variational methods and WKB. Prereq.: Math 39100 and Math 39200. Pre- or coreq.: Physics 35100, Physics 35400 (required for Physics majors). 4 hr./wk.; 4 cr.

55200: Quantum Physics II
Review of Schrödinger equation, Uncertainty principle. Formalism: Observables, Operators etc.; Application to simple case: 2 level systems, electron in a magnetic field; Angular momentum – Bohr model revisited; Magnetic properties of solids; Time independent perturbation theory and applications; Time dependent perturbation theory: Lasers, Masers etc.; Adiabatic processes: Berry's phase, when does phase matter?; Quantum entanglement, Bell's theorem and recent experiments. Prereq.: Physics 55100 or equivalent Math 39100, and Math 39200 (required for Physics majors). 4 hr./wk.; 4 cr.

55400: Solid State Physics
(Same as Physics U4500) Crystal structure and symmetry; crystal diffraction; crystal binding; phonons and lattice vibrations; thermal properties of insulators; free electron theory of metals; energy bands; Fermi surfaces; semiconductors, selected topics in superconductivity, dielectric properties, ferro-electricity, magnetism. Prereq.: Physics 55100 or equivalent, e.g. Chem 33200 or Physics 32100 (elective for Physics and Engineering majors). 3 hr./wk.; 3 cr.

55500: The Physics and Chemistry of Materials
(Same as Physics U4600) Examples, characteristic properties, and applications of important classes of materials (semiconductors, ceramics, metals, polymers, dielectrics and ferroelectrics, super-conductors, magnetic materials); surfaces and interfaces of solids; selected topics in the synthesis, processing and characterization of materials. Prereq.: Phys 55400 or equivalent, e.g. EE 45400 or ChE 46400 (required of Physics majors in the Applied Physics/Material Science Option; and elective for other Physics majors and for Engineering majors). 3 hr./wk.; 3 cr.

55600: Current Topics in Physics
A seminar course on current topics in experimental and theoretical physics, with oral reports by students and faculty (required for Physics majors). 1 hr./wk.; 1 cr.

56100: Materials Science Laboratory
Introduction to some of the basic methods for sample preparation and characterization relevant to materials science. Topics include synthesis of semiconductor thin films and high temperature superconductors, contact preparation, measurements of transport properties as a function of temperature, Raman spectroscopy, electron spin resonance (ESR), X-ray diffraction, absorption measurements in UV-visible range. Prereq.: Physics 32300; coreq.: Physics 55400 or permission of the instructor. 4 lect. hr./wk. for the first three wks., then 7 lab. hr./wk.; 4 cr.

58000: Physical Photonics II
(Same as Physics U6800) Three-level and four-level solid state lasers: ion-doped laser crystals and glasses. Solid-state laser engineering: end-pumping techniques. Laser characterization: limiting slope efficiency. Femtosecond pulse generation: synchronous pumping, active mode-locking of tunable solid-state lasers. Regenerative amplification of ultrashort pulses. Photons in semiconductors: light-emitting diodes and semiconductor lasers. Semiconductor-laser-pumped solid-state lasers; microchip lasers. Photon detectors; noise in photodectors. Polarization and crystal optics: reflection and refraction; optics of anisotropic media; optical activity and Faraday's effect; optics of liquid crystals; polarization devices. Electro-optics: Pockel's and Kerr effects; electro-optic modulators and switches; spatial modulators; photo-refractive materials. Nonlinear optics: frequency mixing and harmonic generation; optical solutions. Acousto-optics: interactions of light and sound; acousto-optic devices. Prereq.: Phys 45300. 3 hr./wk.; 3 cr.

58100: Physical Photonics III/Wave Transmission Optics
(Same as Physics U8100) Waves and Maxwell's equations. Field energetics, dispersion, complex power. Waves in dielectrics and in conductors. Reflection and refraction. Oblique incidence and total internal reflection. Transmission lines and conducting waveguides. Planar and circular dielectric wave-guides; integrated optics and optical fibers. Hybrid and linearly polarized modes. Graded index fibers. Mode coupling; wave launching. Fiber-optic communications: modulation, multiplexing, and coupling; active fibers: erbium-doped fiber lasers and amplifiers. Prereq.: Phys 35300 and 35400. 3 hr./wk.; 3 cr.

HONORS AND SPECIAL COURSES

30100-30300: Honors I-III
Approval of Dean and Department Honors Supervisor required. Apply not later than December 10 in Fall term or May 1 in the Spring term (elective for Physics majors). Variable cr., usually 3 cr./sem.

31000: Independent Study
The student will pursue a program of independent study under the direction of a member of the Department with the written approval of the faculty sponsor and the Department Chair. Credit may be from 1-4 credits, as determined in the semester before registration by the instructor with the approval of the Department Chair. Students must have completed at least nine credits with a GPA of 2.5 or higher. A maximum of nine credits of independent study may be credited toward the degree. Independent study is to be used to meet special student needs that are not covered in regular course offerings.

31100-32000: Selected Topics in Physics
Courses on contemporary topics to be offered according to the interest of faculty members and students. Consult Department for courses to be offered each academic year. 3 hr./wk.; 3 cr.

GRADUATE COURSES OPEN TO UNDERGRADUATES

Qualified students may take, with Departmental approval, any course available in the Master's Program in Physics or the first year of the Doctoral Programs in Physics. These courses are described in their appropriate catalogs.

FACULTY

Robert R. Alfano, Distinguished Professor
B.S., Fairleigh Dickinson Univ., M.S.; Ph.D., New York Univ.
Joseph L. Birman, Distinguished Professor
B.S., The City College; M.S., Columbia Univ., Ph.D.; Doc-es-Sciences
Timothy Boyer, Professor
B.A., Yale Univ.; M.A., Harvard Univ., Ph.D.
Ngee-Pong Chang, Professor
B.S., Ohio Wesleyan Univ.; Ph.D., Columbia Univ.
Victor Chung, Professor
S.B., M.I.T.; S.M., Univ. of California (Berkeley), Ph.D.
Harold Falk, Professor
B.S., Iowa State Univ.; Ph.D., Univ. of Washington
Swapan K. Gayen, Associate Professor
B.Sc.(Honors), Univ. of Dacca, M.Sc; M.S., Univ. of Connecticut, Ph.D.
Joel Gersten, Professor
B.S., The City College; M.A., Columbia Univ., Ph.D.
Daniel M. Greenberger, Professor
B.S., M.I.T.; M.S., Univ. of Illinois, Ph.D.
Marilyn Gunner, Professor and Acting Dean of Science
B.A., SUNY (Binghamton); Ph.D., Univ. of Pennsylvania
Michio Kaku, Semat Professor
B.A., Harvard Univ.; Ph.D., Univ. of California (Berkeley)
Ronald Koder, Assistant Professor
B.S., Univ. of Missouri-Columbia, Ph.D., John Hopkins Univ.
Joel Koplik, Professor
B.S., Cooper Union; Ph.D., Univ. of California (Berkeley)
Matthias Lenzner, Associate Professor
M.S., Friedrich-Schiller-Univ.; Ph.D., Jena Germany
Michael S. Lubell, Professor
A.B., Columbia Univ.; M.S., Yale Univ., Ph.D.
Hernan Makse, Associate Professor
Licenciatura (Physics), Univ. of Buenos Aires; Ph.D., Boston Univ.
Carlos Andres Meriles, Assistant Professor
B.Sc., FaMAF,Universidad Nacional de Cordoba,Argentina, Ph.D.
V. Parameswaran Nair, Professor and Chair
B.S., Univ. of Kerala; M.Sc., Syracuse Univ., Ph.D.
Vladimir Petricevic, Professor
Dipl. EE., Univ. of Belgrade; M.S. Miami Univ.; Ph.D., CUNY
Alexios P. Polychronakos, Professor
Dip. E.E., National Technological Univ. of Athens; M.Sc., California Institute of Technology, Ph.D.
Alexander Punnoose, Associate Professor
B.S., Indian Institute of Technology; M.S., Indian Institute of Science, Ph.D.
Myriam P. Sarachik, Distinguished Professor
A.B., Barnard College; M.S., Columbia Univ., Ph.D.
David Schmeltzer, Professor
B.Sc., Hebrew Univ.; M.Sc., Technion, D.Sc.
Mark Shattuck, Associate Professor
B.A., Wake Forest Univ., M.S.; Ph.D., Duke Univ.
Frederick W. Smith, Professor
B.A., Lehigh Univ.; Ph.D., Brown Univ.
Jiufeng J. Tu, Associate Professor
A.B., Harvard Univ., A.M.; M.S., Cornell Univ., Ph.D.
Sergey A. Vitkalov, Associate Professor
M.S., Moscow Institute of Physics and Technology; Ph.D., Institute of Solid State Physics, Russian Academy of Sciences

PARTICIPATING FACULTY

Morton M. Denn, Albert Einstein Professor
B.S.E. (Ch.E.), Princeton Univ.; Ph.D., Univ. of Minnesota
Richard N. Steinberg, Professor
B.S., SUNY Binghamton; M.S., Yale Univ., Ph.D.

PROFESSORS EMERITI

Adolf Abrahamson
Michael Arons
Robert Callender
Herman Z. Cummins
Erich Erlbach
Martin Kramer
Seymour J. Lindenbaum
Marvin Mittleman
Peter Tea
Martin Tiersten