COLUMBIA | ENGINEERING
The Fu Foundation School of Engineering and Applied Science

Applied Physics

MS Degree

The program of study leading to the degree of Master of Science, while emphasizing continued work in basic physics, permits many options in several applied physics specialties. The program may be considered simply as additional education in areas beyond the bachelor's level, or as preparatory to doctoral studies in the applied physics fields of plasma physics, laser physics, or solid-state physics. All degree requirements must be completed within five years. A candidate is required to maintain at least a 2.5 grade point average. M.S. students must complete the Professional Development and Leadership Course, ENGI E4000, as a graduation requirement.

Core Courses

APPH E4100: Quantum physics of matter (3 pts)
Basic theory of quantum mechanics, well and barrier problems, the harmonic oscillator, angular momentum identical particles, quantum statistics, perturbation theory and applications to the quantum physics of atoms, molecules, and solids.

APPH E4110: Modern optics (3 pts)
Ray optics, matrix formulation, wave effects, interference, Gaussian beams, Fourier optics, diffraction, image formation, electromagnetic theory of light, polarization and crystal optics, coherence, guided wave and fiber optics, optical elements, photons, selected topics in nonlinear optics.

APPH E4112: Laser physics (3 pts)
Optical resonators, interaction of radiation and atomic systems, theory of laser oscillation, specific laser systems, rate processes, modulation, detection, harmonic generation, and applications.

*APPH E4200**:** Physics of fluids (3 pts)*
An introduction to the physical behavior of fluids for science and engineering students. Derivation of basic equations of fluid dynamics: conservation of mass, momentum, and energy. Dimensional analysis. Vorticity. Laminar boundary layers. Potential flow. Effects of compressibility, stratification, and rotation. Waves on a free surface; shallow water equations. Turbulence.

*APPH E4300**:** Applied electrodynamics (3 pts)*
Overview of properties and interactions of static electric and magnetic fields. Study of phenomena of time dependent electric and magnetic fields including induction, waves, and radiation as well as special relativity. Applications are emphasized.

APPH E4301: Introduction to plasma physics (3 pts)
Definition of a plasma. Plasmas in laboratories and nature, plasma production. Motion of charged particles in electric and magnetic fields, adiabatic invariants. Heuristic treatment of collisions, diffusion, transport, and resistivity. Plasma as a conducting fluid. Electrostatic and magnetostatic equilibria of plasmas. Waves in cold plasmas. Demonstration of laboratory plasma behavior, measurement of plasma properties. Illustrative problems in fusion, space, and nonneutral or beam plasmas.

COLUMBIA | ENGINEERING
The Fu Foundation School of Engineering and Applied Science

Applied Mathematics

MS Degree

This 30-point program leads to a Master of Science degree. Students must complete five core courses and five electives. All degree requirements must be completed within five years. A candidate is required to maintain at least a 2.5 grade point average. M.S. students must complete the Professional Development and Leadership Course, ENGI E4000, as a graduation requirement. If a student admitted to the Applied Mathematics M.S. only program is interested in the Ph.D. program, the student must re-apply for admission.

Core Courses

- *APMA E4001: Principles of applied mathematics*

Review of finite-dimensional vector spaces and elementary matrix theory. Linear transformations, change of basis, eigenspaces. Matrix representation of linear operators and diagonalization. Applications to difference equations, Markov processes, ordinary differential equations, and stability of nonlinear dynamical systems..

- *APMA E4101: Introduction to dynamical systems*

An introduction to the analytic and geometric theory of dynamical systems; basic existence, uniqueness and parameter dependence of solutions to ordinary differential equations; constant coefficient and parametrically forced systems; Fundamental solutions; resonance; limit points, limit cycles and classification of flows in the plane (Poincare-Bendixson Therem); conservative and dissipative systems; linear and nonlinear stability analysis of equilibria and periodic solutions; stable and unstable manifolds; bifurcations, e.g. Andronov-Hopf; sensitive dependence and chaotic dynamics; selected applications.

- *APMA E4150: Applied functional analysis*

Introduction to modern tools in functional analysis that are used in the analysis of deterministic and stochastic partial differential equations and in the analysis of numerical methods: metric and normed spaces.

- *APMA E4200: Partial differential equations*

Techniques of solution of partial differential equations. Separation of the variables. Orthogonality and characteristic functions, nonhomogeneous boundary value problems.

- *APMA E4204: Functions of a complex variable*

Complex numbers, functions of a complex variable, differentiation and integration in the complex plane. Analytic functions, Cauchy integral theorem and formula, Taylor and Laurent series, poles and residues, branch points, evaluation of contour integrals. Conformal mapping, Schwarz-Christoffel transformation. Applications to physical problems.

- *APMA E4300: Introduction to numerical methods*

Introduction to fundamental algorithms and analysis of numerical methods commonly used by scientists, mathematicians and engineers. Designed to give a fundamental understanding of the building blocks of scientific computing that will be used in more advanced courses in scientific computing and numerical methods for PDEs (e.g. APMA E4301, E4302).

- *APMA E4301: Numerical methods for partial differential equations*

Numerical solution of differential equations, in particular partial differential equations arising in various fields of application. Presentation emphasizes finite difference approaches to present theory on stability, accuracy, and convergence with minimal coverage of alternate approaches (left for other courses).

- *APMA E6301: Analytic methods for partial differential equations*

Introduction to analytic theory of PDEs of fundamental and applied science; wave (hyperbolic), Laplace and Poisson equations (elliptic), heat (parabolic) and Schroedinger (dispersive) equations; fundamental solutions, Green's functions, weak/distribution solutions, maximum principle, energy estimates, variational methods, method of characteristics; elementary functional analysis and applications to PDEs; introduction to nonlinear PDEs, shocks; selected applications.

- *APMA E6302: Numerical analysis for partial differential equations*

Numerical analysis of initial and boundary value problems for partial differential equations. Convergence and stability of the finite difference method, the spectral method, the finite element method and applications to elliptic, parabolic, and hyperbolic equations.

Students must also take a required Research Seminar course, APMA E6100 x or y. Students attend at least three Applied Mathematics research seminars within the Department of Applied Physics and Applied Mathematics and submit reports on each.

Materials Science & Engineering

Materials science and engineering is concerned with synthesis, processing, structure, and properties of metals, ceramics, polymers, and other materials, with emphasis on understanding and exploiting relationships among structure, properties, and applications requirements. Our graduate research programs encompass projects in areas as diverse as polycrystalline silicon, electronic ceramics grain boundaries and interfaces, microstructure and stresses in microelectronics thin films, oxide thin films for novel sensors and fuel cells, optical diagnostics of thin-film processing, ceramic nanocomposites, electrodeposition and corrosion processes, structure, properties, and transmission electron microscopy and crystal orientation mapping, magnetic thin films for giant and colossal magnetoresistance, chemical synthesis of nanoscale materials, nanocrystals, carbon nanotubes, nanostructure analysis using X-ray and neutron diffraction techniques, and electronic structure calculation of materials using density functional and dynamical mean-field theories.

MS Degree

M.S. students must complete the Professional Development and Leadership Course, ENGI E4000, as a graduation requirement. Candidates for the Master of Science degree in Materials Science and Engineering will follow a program of study formulated in consultation with and approved by a faculty adviser. Thirty points of credit are required at a minimum. Students interested in a specific focus should consult their faculty advisor for relevant course listings. The following six courses (18 points) are required for the degree:

- *MSAE E4100: Crystallography*

A first course on crystallography. Crystal symmetry, Bravais lattices, point groups, space groups. Diffraction and diffracted intensities. Exposition of typical crystal structures in engineering materials, including metals, ceramics, and semiconductors. Crystalline anisotropy.

- *MSAE E4200: Theory of crystalline materials: phonons*

Theoretical understanding of vibrational behavior of crystalline materials; introducing all key concepts at classical level before quantizing the Hamiltonian. Basic notions of Group Theory introduced and exploited: irreducible representations, Great Orthogonality Theorem, character tables, degeneration, product groups, section rules, etc.

- *MSAE E4201: Materials thermodynamics and phase diagrams*

Review of laws of thermodynamics, thermodynamic variables and relations, free energies and equilibrium in thermodynamic system. Statistical thermodynamics. Unary, binary, and ternary phase diagrams, compounds and intermediate phases, solid solutions and Hume-Rothery rules, relationship between phase diagrams and metastability, defects in crystals. Thermodynamics of surfaces and interfaces, effect of particle size on phase equilibria, adsorption isotherms, grain boundaries, surface energy, electrochemistry.

- *MSAE E4202: Kinetics of transformations in materials*

Review of thermodynamics, irreversible thermodynamics, diffusion in crystals and noncrystalline materials, phase transformations via nucleation and growth, overall transformation analysis and time-temperature-transformation (TTT) diagrams, precipitation, grain growth, solidification, spinodal and order-disorder transformations, martensitic transformation.

- *MSAE E4206: Electronic & magnetic properties of solids (3 pts)*

A survey course on the electronic and magnetic properties of materials, oriented towards materials for solid state devices. Dielectric and magnetic properties, ferroelectrics and ferromagnets. Conductivity and superconductivity. Electronic band theory of solids: classification of metals, insulators, and semiconductors. Materials in devices: examples from semiconductor lasers, cellular telephones, integrated circuits, and magnetic storage devices. Topics from physics are introduced as necessary.

- *MSAE E4215: Mechanical behavior of structural materials (3 pts)*

Recommended preparation: a course in mechanics of materials. Review of states of stress and strain and their relations in elastic, plastic, and viscous materials. Dislocation and elastic-plastic concepts introduced to explain work hardening, various materials-strengthening mechanisms, ductility, and toughness. Macroscopic and microstructural aspects of brittle and ductile fracture mechanics, creep and fatigue phenomena. Case studies used throughout, including flow and fracture of structural alloys, polymers, hybrid materials, composite materials, ceramics, and electronic materials devices. Materials reliability and fracture prevention emphasized.

The remaining 12 points will be chosen from elective courses, available on department website

COLUMBIA | ENGINEERING
The Fu Foundation School of Engineering and Applied Science

Medical Physics

Medical Physics is an applied branch of physics concerned with the application of the concepts and methods of physics to the diagnosis and treatment of human disease. Medical Physicists are concerned with clinical service and consultation, research and development, and teaching. Our CAMPEP-accredited Program is designed to prepare students for professional careers in the field of Medical Physics. It is registered with the State of New York, is administered by faculty from the Fu Foundation School of Engineering and Applied Science in collaboration with faculty from the College of Physicians and Surgeons and the Mailman School of Public Health, leads to a Master of Science (M.S.) degree, and provides preparation toward certification by the American Board of Radiology.

Specializations:

Radiation Therapy Physicists perform acceptance testing and commissioning of new equipment, calibrate radiotherapy units and maintain their clinical information, contribute to the development of therapeutic techniques, design treatment plans, and assure the safe and effective delivery of radiation as prescribed in patient care.

Diagnostic Radiology Physicists contribute to the advancement and effectiveness of radiological imaging exams and procedures by helping to develop improved imaging techniques and using them for the diagnosis of disease in patients.

Nuclear Medicine Physicists ensure correct and safe application of radioactive molecular-agents used in the diagnosis and treatment of disease, assist in the introduction of new agents including their dosimetry, assess the performance of Nuclear Medicine equipment, and contribute to the development of quality assurance programs.

Medical Health Physicists contribute to the protection of patients and the public from excessive radiation by establishing and monitoring radiation safety procedures and ensuring compliance with applicable federal and state regulations.

Core Curriculum

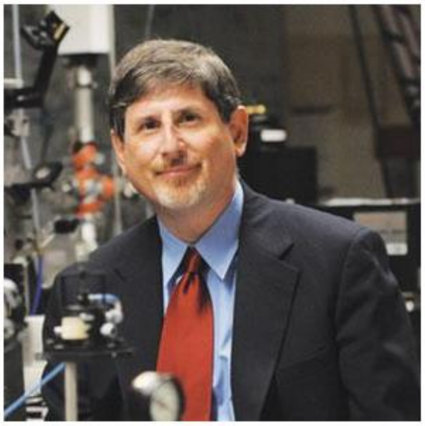
The Program consists of a core curriculum of medical and nuclear physics courses, a laboratory course, anatomy, two practicums, a tutorial, one elective, and a seminar. Specific course requirements are:

APPH E4010 Introduction to nuclear science
APPH E4330 Radiobiology for medical physicists
APPH E4710 Radiation instrumentation lab, I
APPH E4550 Medical physics seminar
APPH E4500 Health physics
APPH E4501 Medical health physics tutorial

APPH E4600 Fundamentals of radiological physics & radiation dosimetry
APBM E4650 Anatomy for physicists & engineers
APPH E6319 Clinical nuclear medicine physics
APPH E6330 Diagnostic radiology physics
APPH E6335 Radiation therapy physics

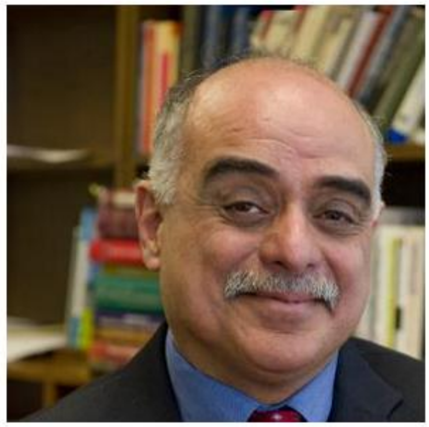
COLUMBIA | ENGINEERING
The Fu Foundation School of Engineering and Applied Science

Applied Physics and Mathematics Faculty



IRVING P. HERMAN

EDWIN HOWARD ARMSTRONG PROFESSOR AND CHAIR OF APPLIED PHYSICS;



CEVDET NOYAN

CHAIR OF APPLIED PHYSICS AND APPLIED MATHEMATICS AND PROFESSOR OF MATERIALS SCIENCE AND ENGINEERING AND OF EARTH AND ENVIRONMENTAL ENGINEERING

WILLIAM E. BAILEY

ASSOCIATE PROFESSOR OF MATERIALS SCIENCE AND OF APPLIED PHYSICS AND APPLIED MATHEMATICS

ANDREW COLE

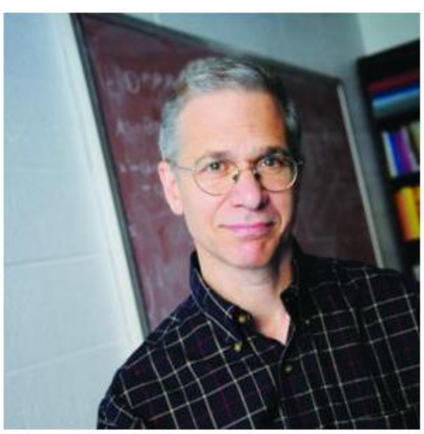
ASSOCIATE PROFESSOR OF APPLIED PHYSICS

QIANG DU

FU FOUNDATION PROFESSOR OF APPLIED MATHEMATICS; CHAIR OF APPLIED MATHEMATICS PROGRAM; AFFILIATED FACULTY OF DATA SCIENCE

ALEXANDER GAETA

DAVID M. RICKEY PROFESSOR OF APPLIED PHYSICS AND OF MATERIALS SCIENCE (JOINT APPOINTMENT IN ELECTRICAL ENGINEERING)

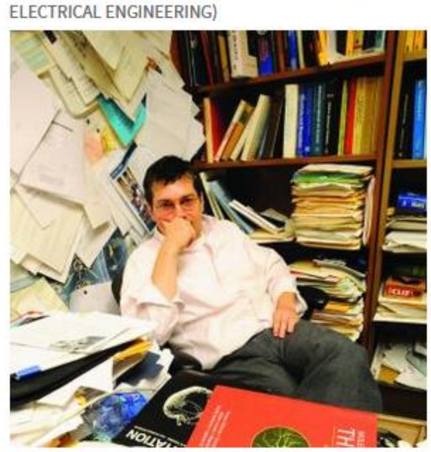


MICHAEL I. WEINSTEIN

PROFESSOR OF APPLIED MATHEMATICS AND PROFESSOR OF MATHEMATICS

RENATA M. WENTZCOVITCH

PROFESSOR OF MATERIALS SCIENCE AND ENGINEERING, AND EARTH AND ENVIRONMENTAL SCIENCE



CHRIS H. WIGGINS

ASSOCIATE PROFESSOR OF APPLIED MATHEMATICS