GRADUATE ELECTIVES 2019-2020

COURSES IN *ITALICS* ARE REQUIRED ("CORE") COURSES FOR THE DOCTORAL WRITTEN EXAM I.

FALL 2019

PHYS 405 Biophysics (M. Falvo)

Biology succeeds in defining architecture, motion, response and replication through the generation of order and force from biochemistry. We will explore the fundamental thermodynamic and physical processes that underlie biological phenomena such as diffusion, entropy at the molecular and system level, electrostatics and hydrophobicity. These will form the basis for an understanding of self assembly and force generation that are responsible for molecular and cellular processes such as DNA replication and repair, intracellular transport and cell division. At the higher level of macromolecular assemblies, molecular machines are responsible for the construction of flagella and cilia, and for the manner in which these structures generate torque and force to propel organisms and fluid flow. We will explore the imaging technologies that have elucidated molecular and cellular structure such as electron, optical and atomic force microscopy. Measuring single molecule forces has been accomplished using atomic force microscopy, laser and magnetic tweezers and fluid flow. The overlying goal of the course is for us to understand the cell as a physical entity, and insist on understanding through principled mathematical models and precision measurements.

PHYS 631 Math Methods (J. Drut)

Linear vector spaces and matrices, curvilinear coordinates, functions of complex variables, ordinary and partial differential equations, Fourier series, integral transforms, special functions, differential forms.

PHYS 660 Fluid Dynamics (A. Scotti)

This course represents an advanced introduction to the fascinating problem of characterizing the motion of fluid substances. Over the last century and a half, the study of fluid dynamics has spurred a large number of ideas that have found application in different areas of science. For example, in the late 1960's, Ed Lorentz, while studying the properties of a "simple" flow confined between two plates kept at different temperatures, made the discovery that lies at the heart of chaos theory. Moreover, knowledge concerning the flows of fluids is fundamental in many areas of engineering (aerodynamics, turbomachinery, chemical reactors, etc.), medicine and applied sciences (oceanography, geology, meteorology,...). Finally, the equations that govern the motion of flu- ids pose fundamental mathematical problems that have not, so far, found an answer. Hence, fluid dynamics lies at a crossroad where many different paths converge. In this class the goal is to provide an introduction to the theoretical tools necessary to obtain a quantitative description of the motion of fluid substances under a variety of conditions.

PHYS 701 Classical Dynamics (C. Evans)

Variational principles, Lagrangian and Hamiltonian Mechanics. Symmetries and conservation laws. Two-body problems, perturbations, and small oscillations, rigid-body motion. Relation of classical and quantum mechanics.

PHYS 721 Quantum Mechanics I (L. Mersini)

Review of nonrelativistic quantum mechanics. Spin, angular momentum, perturbation theory, scattering, identical particles, Hartree-Fock method, Dirac equation, radiation theory.

PHYS 821 Advanced Quantum Mechanics (D. Khveshchenko)

Advanced angular momentum, atomic and molecular theory, many-body theory, quantum field theory.

PHYS 822 Field Theory (D. Khveshchenko)

Quantum field theory, path integrals, gauge invariance, renormalization group, Higgs mechanism, electroweak theory, quantum chromodynamics, Standard Model, unified field theories

SPRING 2020

PHYS 543 Nuclear Physics (R. Janssens)

Structure of nucleons and nuclei, nuclear models, forces and interactions, nuclear reactions. Prerequisite: PHYS 321, permission of instructor for students lacking the prerequisite.

PHYS 594 Nonlinear Dynamics (J.P. Lu)

Interdisciplinary introduction to nonlinear dynamics and chaos. Fixed points, bifurcations, strange attractors, with applications to physics, biology, chemistry, finance.
Requisites: Prerequisite, MATH 383; permission of the instructor for students lacking the prerequisite.

PHYS 632 Advanced Research Techniques: Statistics, Data Analysis, Numerics (J. Wilkerson)

Methods required for the analysis, interpretation, and evaluation of physics measurements and theory. Error analysis, statistical tests, model fitting, parameter estimation, Monte Carlo methods, Bayesian inference, noise mitigation, experimental design, big data, selected numerical techniques including differential equations and Fourier techniques.

Pre-requisites: Students are expected to be able to program in a high-level computer language. Students lacking or uncertain about this prerequisite should contact the instructor for permission.

PHYS 712 Electromagnetic Theory (C. Evans)

Maxwell's equations, time-varying fields, and conservation laws. Plane EM waves, polarization, propagation, dispersive media. Wave guides and resonant cavities. Radiation from slow-moving charges. Special theory of relativity. Radiation from relativistic charges. Interaction between radiation and matter.

PHYS 722 Quantum Mechanics II (L. Mersini)

Review of non-relativistic quantum mechanics. Spin, angular momentum, perturbation theory, scattering, identical particles, Hartree-Fock method, Dirac equation, radiation theory.

PHYS 741 Statistical Mechanics (Y. Wu)

Classical and quantal statistical mechanics, ensembles, partition functions, ideal Fermi and Bose gases.

PHYS 823 Field Theory II (G. Basar)

Quantum field theory, path integrals, gauge invariance, renormalization group, Higgs mechanism, electroweak theory, quantum chromodynamics, Standard Model, unified field theories.

ASTR 701 Stellar Interiors, Evolution, and Populations (G. Cecil)

This lecture/seminar examines the structure and evolution of stars from Main Sequence youth to death, as individuals and as a population. Earlier events, including the collapse of constituent gas clouds into accretion disks, are covered in other courses, as are rare relativistic end-products such as neutron stars and black holes whose study benefits from a course on general relativity. Thermonuclear fusion and atmospheric energy transfer bound stellar volumes; information from these regions comes to us directly as neutrinos and photons, respectively. The course will genera- lize power input and gas opacity sources to treat current exoplanet atmospheres illuminated and viewed from above, but heated both above and below.

ASTR 719 Astronomical Data (N. Law)

The course is designed as an introduction to astronomical observing, with a focus on optical / infrared telescopes. The course is based on a practical approach to learning astronomical observing and data reduction, with hands-on experience. We will analyze existing astronomical datasets from large world-class observatories like UNC's SOAR. Every student will use the PROMPT array to observe several objects (including attempting to detect an exoplanet transit).

Pre-requisites: an undergraduate course in general astronomy and some programming experience