GRADUATE ELECTIVES 2018-2019

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

FALL 2018

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 (J. Engel)

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 822 Field Theory I

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

PHYS 829 Magnetic Resonance (Y. Wu)

PHYS 832 General Relativity (C. Evans)

Permission of the instructor for students lacking the prerequisite. Differential geometry of space-time. Tensor fields and forms. Curvature, geodesics, Einstein's gravitational field equations. Tests of Einstein's theory. Applications to astrophysics and cosmology.

Prerequisite: PHYS 831

PHYS 871 Solid State I (D. Khveshchenko)

Equivalent experience for students lacking the prerequisite. Topics considered include those of PHYS 573, but at a more advanced level, and in addition a detailed discussion of the interaction of waves (electromagnetic, elastic, and electron waves) with periodic structures, e.g. x-ray diffraction, phonons, band theory of metals and semiconductors.

Pre-requisites: PHYS 321

ASTR 703 Galaxies (S. Kannappan)

Overview of the structure and evolution of galaxies, with emphasis on learning and applying modern research methods such as scientific literature review and computational astrostatistics. Includes galaxy morphology and dynamics, star formation, active galactic nuclei, galaxy interactions, large-scale clustering, environment-dependent physical processes, and the evolution of the galaxy population over cosmic time.

SPRING 2019

PHYS 415 Optics (A. Oldenburg)

This is intended to be a first optics course for advanced undergraduates or beginning graduate students in STEM fields. It is designed as a survey course aiming to expose students to a broad array of topics in optics, with an emphasis on understanding over-arching concepts, general physical principles that dictate the behavior of light, as well as practical knowledge about common optical components and devices, and analytical tools for engineering simple optical systems. Because this is a mixed undergraduate-graduate course, I will attempt to present both basic concepts and advanced reasoning behind the principles in the same lecture; in many cases, the textbook reading jumps around in order to provide multiple levels of insight about the same topic. We will do a mixture of analytical and numerical problems, emphasizing topics of most interest to an experimentalist wishing to apply knowledge from this course to his/her laboratory.

Pre-requisites: Undergraduate EM I & II

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 581 Renewable Electric Power Systems (R. Lopez)

Broad and quantitative study of renewable electric power systems: wind systems, photovoltaic cells, distributed generation (concentrating solar power, microhydro, biomass), and the economics of these technologies.

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 (D. Khveshchenko)

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 824 Group Theory and Applications (L. Dolan)

Required preparation: knowledge of matrices, mechanics, and quantum mechanics. Discrete and contiuous groups. Representation theory. Application to atomic, molecular, solid state, nuclear, and particle physics.

PHYS 862 Nuclear Physics I (A. Champagne)

The intent of the course is to provide an overview of fundamental symmetries and neutrinos in nuclear physics. Many of the topics of interest are aimed at probing for physics beyond the standard model of fundamental interactions, often using the nucleus as a laboratory to make precision tests. The course will be enriched by selected readings from foundation papers in the published literature. These examples will prove interesting while motivating the underlying nuclear and particle physics. The plan is to on average cover a foundations related topic every week, either in class or as part of the homework.

Pre-requisites: PHYS 543 (or equivalent undergraduate nuclear physics course), PHYS 721

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.

Pre-requisites: None

ASTR 704 Cosmology (A. Erickcek)

General relativity and cosmological models; thermal history of the early universe, nucleosynthesis, and the cosmic microwave background; growth of structure through cosmic time.

ASTR 705 Interstellar Medium (F. Heitsch)

The interstellar medium (ISM) is the “recycling bin” of our Galaxy, taking up the “refuse” of old stars while providing fuel for the next generation of stars. The goal is to provide a physical understanding of the processes regulating the Galactic gas budget – from stellar explosions to the formation of the solar system, and of the corresponding observational diagnostics. It draws on several sub-fields of physics and chemistry, such as atomic and nuclear physics, electromagnetism, hydrodynamics, molecular chemistry, and gravitational physics. Emphasis will be laid on class projects, offering opportunities for small research projects in the field of astrophysics.

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