GAANN administrative team:

- Project Co-Directors (Christopher Gould, Mohamed Bourham, and David Shafer);
- The NSE GAANN Executive Committee (Project Co-directors plus Nam Dinh, John Mattingly, Carla Frohlich, Gail McLaughlin, and Paul Huffman)

Sample Academic Plans for NSE GAANN Fellows

PHYSICS	NUCLEAR ENGINEERING
Thesis: Ultracold Neutron Physics	Thesis: Radiation Transport and Detection
Minor: Nuclear Engineering	Minor: Nuclear Physics
Yr.1: PY501 Quantum Physics I PY506 Nuclear and Subatomic Physics PY507 Elementary Particle Physics PY525 Computational Physics PY721 Statistical Physics I PY730 Nuclear Structure Physics I NE521 Nuclear Measurements NE726 Radioisotopes Measurement Applications PY801 Physics Seminar NSE Seminar Series Participation in APS/ANS Conference	Yr.1: NE504 Radiation Safety & Shielding NE528 Intro Plasma Physics & Fusion Energy NE521 Nuclear Measurements and Instrumentation NE761 Radiation Detection NE727 Nuclear Engineering Analysis NE726 Radioisotopes Measurement Applications PY501 Quantum Physics I NE801 Nuclear Engineering Seminar NE893 Doctoral Supervised Research NSE Seminar Series Participation in APS/ANS Conference
Yr.2: MA584 Numerical Solution of PDE's PY711 Advanced Quantum Mechanics I PY722 Statistical Physics II PY781 Quantum Mechanics I PY810 Special Topics In Physics NE761 Radiation Detection NE770 Nuclear Radiation Attenuation PY801 Physics Seminar NSE Seminar Series PY895 Dissertation Research Participation in APS/ANS Conference	Yr.2: MA584 Numerical Solution of PDE's NE727 Nuclear Engineering Analysis NE746 Fusion Energy Engineering NE757 Rad. Effects On Materials NE762 Radioisotope Applications NE770 Nuclear Radiation Attenuation PY514 Electromagnetism I PY730 Nuclear Structure Physics NE801 Nuclear Eng. Seminar NSE Seminar Series
Yr.3: PY895:Dissertation Research PY801 Nuclear Engineering Seminar Preparing the Professoriate (1 semester of supervised teaching experience) Participation in APS/ANS Conference	Yr.3: NE895 Dr Dissertation Research NE801 Nuclear Engineering seminar Preparing the Professoriate (1 semester of supervised teaching experience) Participation in APS/ANS Conference
Yr.4: PY895 Dissertation Research 1 peer-reviewed publication (e.g., J. Nuclear Instruments and Methods in Physics Research) Participation in APS/ANS Conference	Yr.4: PY895 Dissertation Research 1 peer-reviewed publication (e.g., J. Nuclear Instruments and Methods in Physics Research) Participation in APS/ANS Conference
Yr.5: PY895 Dissertation Research PY899 Doctoral Dissertation 1 peer-reviewed publication Participation in APS/ANS Conference	Yr.5: PY895 Dissertation Research PY899 Doctoral Dissertation 1 peer-reviewed publication Participation in APS/ANS Conference

Supervised training instruction

Each GAANN fellow in nuclear science and engineering will participate in a two- semester, supervised teaching experience through our Preparing the Professoriate program. This program provides GAANN fellows with an extensive mentored experience in teaching, comparable to their mentored experience in research. This program goes far beyond the typical teaching assistantship experience. Fellows will be paired for two semesters with outstanding teacher- researchers in their disciplines. Each pair will develop an individualized program that involves extensive observation and teaching components. During the first-semester, fellows will observe the entire process of teaching an undergraduate course, from textbook selection and syllabus preparation to the final student evaluations of the course. Fellows will participate in tutoring, examination development, and grading, and will develop materials for the courses they will teach. A fellow may teach any year after completing 18 hours of graduate coursework, depending on department requirements and dissertation committee advice.

During the second semester, fellows will teach or co-teach the courses they observed during the previous semester. Each fellow will develop a Professional Teaching Portfolio documenting the academic experience gained through teaching. The portfolio may include such items as student evaluations of instruction, letters of recommendation that specifically address teaching, evidence of course planning and preparation,

videotapes of teaching, and statements of teaching philosophy

Instruction on effective teaching techniques

All fellows will participate in teaching effectiveness seminars to improve their teaching skills. Fellows must participate in eight seminars (16 hours). Seminars address three broad categories: Core Fundamentals introduces students to basic skills in teaching, and these workshops are offered multiple times each semester. Advanced Strategies addresses more complex teaching concepts that build on the core fundamentals. Special Topics allow student to explore challenging current issues facing higher education. Fellows learn the fundamental components of pedagogy, enriching their personal growth and professional development.
Examples of seminars are as follows:

Examples of Teaching Seminars Offered by the Graduate School	
Examples of Core Fundamentals:	**Examples of Advanced Strategies:**
Active Learning	Collaborative Learning and Group Work
Classroom Assessment Techniques	Effective Classroom Discussion: Conversation with a Purpose
Classroom Management	Emotional Intelligence: A Tool for Teaching
Effective Questioning Techniques	Responding to Student Writing: Encouraging Reflection and Revision
Establishing Credibility and Authority in the Classroom	Incorporating Active Learning Strategies into your Online Teaching Environment
Evaluation and Grading	**Examples of Special Topics:**
Learning Styles	Controversy in the Classroom: How to Handle It
Managing Disruptive Classroom Behaviors	Current Issues in Teaching: Moral Development and the Shadow Scholar
Motivational Teaching Strategies	Current Issues in Teaching: Using Games in the Classroom
Writing Learning Outcomes	Surviving the Academic Job Search

Supervision of teaching performance

During the Preparing the Professoriate experience, GAANN fellows will receive written guidelines addressing such matters as grading, test security, office-hour requirements, classroom and laboratory safety procedures, and the philosophy of teaching adopted by the departments they serve. In addition to direction and feedback from the teaching assistant supervisors in their respective departments, fellows will also receive regular guidance from their teaching mentors throughout the teaching experience.

Evaluation of teaching performance

GAANN fellows in nuclear science and engineering will be evaluated by the students in the courses they teach, as well as by their Preparing the Professoriate teaching mentors. They will also work with their mentors to prepare teaching portfolios, including materials they develop for the courses they teach, and student and faculty evaluations of their teaching. At the end of the Preparing the Professoriate program, these portfolios will be submitted to the director of graduate student teaching programs for evaluation. Each teaching portfolio is a personal representation of what the fellow teaches, how he/she teaches, why he/she teaches in that way, what the fellow has done to improve his/her teaching, and evidence that the fellow's teaching style makes a difference. In addition to ongoing face-to-face evaluation and improvement discussions with the student, each teaching mentor will complete a written evaluation and forward it to the NSE GAANN Executive Committee.

Monitoring progress toward degree

At NCSU, graduate plans of study are formally documented and approved by the student's graduate committee. For GAANN fellows, these plans of study will also be reviewed by the NSE GAANN Executive Committee. The Executive Committee will review fellows' academic performance each year, as evaluated by their advisors, teaching mentors, and directors of graduate programs. They will communicate findings, where appropriate, to the student's advisor, who will further mentor the student. If a program adjustment seems indicated, they will work with the relevant NSE faculty to effect the change. Fellowships will be renewed as long as students maintain a minimum 3.5 GPA and make reasonable progress toward the degree.

Timeline of Fellowship Project and Evaluation Activities					
	2012-2013	Yr. 1 (2013-14)	Yr. 2 (2014-15)	Yr. 3 (2015-16)	2016-17
August		Reception; orientation; academic advising	Fellows begin supervised teaching year.	Same as Aug. 2013	(2017) Closing reception for fellows.
September		Fellows select research advisors, dissertation committees.			
October					
November	Receive award notification	Fellows develop plan of work.	Fellows update plan of work	Fellows update plan of work	Fellows update plan of work

December	Assemble GAANN Exec. Committee To plan for next yr.	Assemble GAANN Exec. Committee To plan for next yr.	Assemble GAANN Exec. Committee To plan for next yr.	Assemble GAANN Exec. Committee To plan for next yr.	Assemble GAANN Exec. Committee To plan for next yr.
January	Prepare recruiting materials	GPA review; academic mentoring if necessary.	GPA review; academic mentoring if necessary.	GPA review; academic mentoring if necessary.	GPA review; academic mentoring if necessary.
February	Faculty nominations of fellows.				
March	Interview candidates; Financial need assessments.			Finalize fellows' continued support for 4th & 5th years.	
April		Distribute/analyze evaluation questionnaires; make adjustments.	Distribute/analyze evaluation questionnaires; make adjustments	Distribute/analyze evaluation questionnaires; make adjustments	Distribute/analyze evaluation questionnaires; make adjustments
May	Notify fellows; send written rules	Advisors evaluate fellows' progress; decide renewals; recommend plan of work adjustments	Advisors evaluate fellows' progress; decide renewals; recommend plan of work adjustments	Advisors evaluate fellows' progress; decide renewals; recommend plan of work adjustments	Advisors evaluate fellows' progress; decide renewals; recommend plan of work adjustments. In 2015, most fellows receive PhDs.
June					
July	Recruit/organize mentor pool.	Prepare evaluation report.	Prepare evaluation report.	Prepare evaluation report.	(2017) Most fellows receive PhDs; 5-yr. evaluation continues; adjustments recommended.

Courses Available to GAANN Fellows in the Nuclear Science and Engineering

NE 500 Nuclear Reactor Energy Conversion NE 500 Nuclear Reactor Energy Conversion: Introduction to the concepts and principles of heat generation and removal in reactor systems. Power cycles, reactor heat sources, analytic and numerical solutions to conduction problems in reactor components and fuel elements, heat transfer in reactor fuel bundles and heat exchangers. Problem sets emphasize design principles. Heat transfer lab included.

NE 502 Reactor Engineering A course in thermal-hydraulic design and analysis of nuclear systems. Single and two-phase flow, boiling heat transfer, modeling of fluid systems. Design constraints imposed by thermal-hydraulic considerations are discussed. A thermal-hydraulics laboratory included.

NE 504 Radiation Safety and Shielding 3(3-0-0) F Preq: NE 401 or NE 520 Radiation safety and environmental aspects of nuclear power generation. Radiation interaction, photon attenuation, shielding theory and design project, external and internal dose evaluation, reactor effluents and release of radioactivity into the environment, transportation and disposal of radioactive waste; and environmental impact of nuclear power plants

NE 505 Reactor Systems 3(3-0-0) F Preq: NE 401 Nuclear power plant systems: PWR, BWR and advanced concepts. Design criteria, design parameters, economics, primary and secondary loops, safety systems, reactor control and protection systems, containment, accident and transient behaviors, core design, and reactivity control mechanisms. Term- long project. Credit for both NE 405 and NE 505 is not allowed

NE (MSE) 509 Nuclear Materials 3(3-0-0) S Preq: MSE201 Structure and Properties of Engineering Materials. Properties and selection of materials for nuclear steam supply systems, radiation effects on materials, implications of radiation damage to reactor materials, crystal structure and defects, dislocation theory, mechanical properties, radiation damage, hardening and embrittlement.

NE 512 Nuclear Fuel Cycles 3(3-0-0) S Preq: NE 401 Processing of nuclear fuel with description of mining, milling, conversion, enrichment, fabrication, irradiation, shipping, reprocessing and waste disposal. Fuel cycle economics and fuel cost calculation. In-core and out-of-core nuclear fuel management, engineering concepts and methodology. Term- long project. Credit for both NE 412 and NE 512 is not allowed

NE 520 Radiation and Reactor Fundamentals 3(3-0-0) F Preq: MA 341 abd PY 208 Basics of nuclear physics and reactor physics that are needed for graduate studies in nuclear engineering. Concepts covered include, atomic and nuclear models, nuclear reactions, nuclear fission, radioactive decay, neutron interactions, nuclear reactors, neutron diffusion in non-multiplying and multiplying systems, and basic nuclear reactor kinetics.

NE 521 Measurements and Instrumentation 3(3-0-0) F Preq: MA 341 abd PY 208 or NE520

Basics of nuclear measurements and instrumentation, fundamental concepts of neutron production, interaction and detection. Laboratories covered include, radiation detection and instrumentation, laboratory experiments in radiation measurements, neutron interactions and detection.

NE (PY) 528 Introduction to Plasma Physics and Fusion Energy 3(3-0-0) F Preq: MA 401 and PY 208 Concepts in plasma physics, basics of thermonuclear reactions; charged particle collisions, single particle motions and drifts, radiation from plasmas and plasma waves, fluid theory of plasmas, formation and heating of plasmas, plasma confinement, fusion devices and other plasma applications.

NE 591Special Topics In Nuclear Engineering I 3(3-0-0) F,S Preq: Consent of Instructor Credits Arranged

NE 592 Special Topics In Nuclear Engineering II 3(3-0-0) F,S Preq: Consent of Instructor Credits Arranged

NE 721 Nuclear Laboratory Fundamentals 3(2-3-0) F Preq: MA 401 and NE 401 Introduction to nuclear instrumentation and experimental techniques used in nuclear engineering research. Topics include radiation detection and spectroscopy, neutron instrumentation, statistical analysis, use of microcomputers and nuclear reactor operations.

NE 722 Reactor Dynamics and Control 3(3-0-0) F Preq: NE 401 or NE 520 Methods of describing and analyzing dynamic behavior of systems. These methods applied to reactor systems and the effects of feedbacks studies. Methods of measuring the behavior of reactor systems and development of logic systems for control and safety.

NE 723 Reactor Analysis 3(3-0-0) F Preq: NE 401 or NE 520 Basic models of neutron motion and methods of calculating neutron flux distributions in nuclear reactors. Emphasis on multigroup diffusion theory. Criticality search, neutron slowing down models, resonance absorption, thermalization and heterogeneous cell calculations. Objective is to enable students to read literature and perform relevant analysis in reactor physics.

NE 724 Reactor Heat Transfer3(3-0-0) S Preq: NE 402 and NE 401 or NE 520 Consideration of heat generation and transfer in nuclear power reactors. Topics include reactor heat generation, steady-state and transient heat combustion in reactor fuel elements, boiling heat transfer and single and two-phase flow.

NE 726 Radioisotopes Measurement Applications 3(3-0-0) S Preq: NE 401 or 520 Introduction the student to measurement applications using radioisotopes and radiation. Discussion of all major tracing, gauging and analyzer principles and treatment of several specific applications in detail. Objective is to familiarize student with design and analysis of industrial measurement systems using radioisotopes and/or radiation.

NE 727 Nuclear Engineering Analysis 3(3-0-0) S Preq: NE 401 or NE 520 Fundamental material on: (1) numerical methods for solving the partial differential equations pertinent to nuclear engineering problems, (2) Monte Carlo simulation of radiation transport and (3) data and error analysis techniques including estimation of linear and nonlinear model parameters from experimental data. Reactor Theory and Analysis

NE 730 Radiological Assessment 3(3-0-0) S Preq: NE 404 or 504 Principles of analyzing environmental radiation transport and resulting human exposure and dose and dose management. Sources term of radiation exposure, the radon problem, transport or radionuclides in the atmosphere, surface water, and groundwater, pathways modeling, radiation dosimetry, probabilistic models for environmental assessment, uncertainty analysis, and radiation risk management. A package of computer codes is developed as a class project.

NE 732 Principles of Industrial Plasmas 3(3-0-0) S Preq: NE/PY 528 Theory and fundamental physical principles of industrial plasmas. Applications in plasma processing, plasma

manufacturing technology, arcs and torches, plasma sprayers, high-voltage high-current switching devices, plasma-driven devices and plasma-aided technology. Emphasis on particle transport and plasma flow.

NE 740 Laboratory Projects in Nuclear Engineering 3(3-0-0) F Preq: NE 721 Enhancement of laboratory skills pertinent to nuclear engineering research through projects that requiring student to design the experiment, assemble equipment, carry out the measurements and analyze and interpret data. Students work in groups of two and perform to completion two laboratory projects.

NE 745 Plasma Laboratory 3(2-3-0) F. Alt. yrs. Preq: NE 528 or PY 508 or PY 509 Experimental plasma generation and plasma diagnostic techniques. Lecture topics include high vacuum techniques, perturbing and non-perturbing probe techniques, and laser and emission spectroscopy. Laboratories utilize various methods of measuring plasma parameters discussed in lectures. Fusion Energy Engineering

NE 751 Nuclear Reactor Design Calculations 3(3-0-0) S. Alt. yrs. Preq: NE 723 Application of digital computer to problems in reactor core nuclear design. Study and exercise of available reactor core physics computer modules. Description of systems and programs used by industry for power reactor core design and core follow. A review of relevant analytic and numerical methods facilitates computer program development by students.

NE 752 Thermal Hydraulic Design Calculations 3(3-0-0) F. Alt. yrs. Preq: NE 724 Advanced presentation of thermal-hydraulic analysis of nuclear power systems. Topics including development of single phase and two-phase fluid flow equations, subchannel analysis, interphase phenomena and numerical solution methods relevant to design and safety analysis codes.

NE 755 Reactor Theory and Analysis 3(3-0-0) S, Alt yrs Preq: NE 723, 727 Theoretical aspects of neutron diffusion and transport related to the design computation and performance analysis of nuclear reactors. Principal topics: a unified view of the neutron cycle including slowing down, resonance capture and thermalization; reactor dynamics and control; fuel cycle studies; and neutron transport methods. Background provided for research in power and test reactor analysis.

NE 757 Radiation Effects on Materials 3(3-0-0) F Preq: NE 509 Interactions of radiation with matter, with emphasis on physical effects. Discussion of current theories and experimental techniques. Annealing of defects, radiation induced changes in physical properties and effects in reactor materials.

NE 761 Radiation Detection 3(3-0-0) F Preq: NE 726 Advanced aspects of radiation detection such as computer methods applied to gamma-ray spectroscopy, absolute detector efficiencies by experimental and Monte Carlo techniques, the use and theory of solid state detectors, time-of-flight detection experiments and M÷ssbauer and other resonance phenomena.

NE 762 Radioisotope Applications 3(3-0-0) F Preq: NE 726 Presentation of advanced principles and techniques of radioisotope applications. Topics include radiotracer principles; radiotracer applications to engineering processes; radioisotope gauging principles; charged particle, gamma ray and neutron radioisotope gauges.

NE 770 Nuclear Radiation Attenuation 3(3-0-0) F. Alt. yrs. Preq: NE 727 Physical theory and mathematical analysis of the penetration of neutrons, gamma-rays and charged particles.
Analytical techniques including point kernels, transport theory, Monte Carlo and numerical methods. Digital computers employed in the solution of practical problems.

NE 771 Advanced Nuclear Waste Management 3(2-1-0) F,Alt yrs(even) Preq: NE 531 Course covers advanced technical issues in nuclear waste management with emphasis on developing better predictive models and technologies for safe disposal of nuclear waste.
The course proveeds as a combination of eminars and lectures.

NE (MAT) (MSE) 773Computer Experiments In Materials and Nuclear Engineering 3(3-0-0) S Monte Carlo and dynamical computer experiments covered from standpoint of how to design and use them in materials and nuclear engineering work.

NE (MA)777 Exact and Approximate Solutions In Particle Transport Theory 3(3-0-0) S Preq: MA 501 or MA 511 Method of elementary solutions used to solve exactly basic problems in neutron-transport theory and related topics. In addition, development and usage of FN method to establish concise approximate solutions in the realm of particle transport theory.

NE 780 Magnetohydrodynamics & Transport in Plasmas 3(3-0-0) F, Alt. Yrs. (Odd) Preq: NE 528, NE/PY 414 and 415 Advanced fluid description of plasmas for magnetic fusion, space and industrial plasmas, and other applications. Emphasis on a first principles approach to transport, equilibria, and stability.

NE 781 Kinetic Theory, Waves, & Non-Linear Effects in Plasmas 3(3-0-0) F, Alt yrs(even) Preq: NE 528, NE/PY 414 and 415 Coreq: MA 775 Kinetic theory, waves, and non-linear phenomena in magnetized plasmas. First principles approach to the treatment of instabilities and other collective effects.

NE 795 Advanced Topics In Nuclear Engineering I 3(3-0-0) F,S Preq: Consent of Instructor A study of recent developments in nuclear engineering theory and practice.

NE 796 Advanced Topics In Nuclear Engineering II 3(3-0-0) F,S Preq: Consent of Instructor A study of recent developments in nuclear engineering theory and practice.

NE 801 Seminar 1(1-0-0) F,S Discussion of selected topics in nuclear engineering.

NE 885 Doctoral Supervised Teaching 1-3 F, S, Sum Preq: Doctoral student Teaching experience under the mentorship of faculty who assist the student in planning for the teaching assignment, observe and provide feedback to the student during the teaching assignment, and evaluate the student upon completion of the assignment.

NE 890 Doctoral Preliminary Examination 1-9 F, S, Sum Preq: Doctoral student For students who are preparing for and taking written and/or oral preliminary exams.

NE 893 Doctoral Supervised Research 1-9 F, S, Sum Preq: Doctoral student Instruction in research and research under the mentorship of a member of the Graduate Faculty.

NE 895 Doctoral Dissertation Research 1-9 F, S, Sum Preq: Doctoral student Dissertation research.

NE 896 Summer Dissertation Research 1(1-0-0) Sum Preq: Doctoral student For graduate students whose programs of work specify no formal course work during a summer session and who will be devoting full time to thesis research.

NE 899 Doctoral Dissertation Preparation 1-3 F, S, Sum Preq: Doctoral student For students who have completed all credit hour, full-time enrollment, preliminary examination, and residency requirements for the doctoral degree, and are writing and defending their dissertations.

PY 501 Quantum Physics I 3(3-0-0) F Preq: PY 411 Basic principles of quantum physics with emphasis on selected applications to atoms, molecules, solids, nuclei and elementary particles. PY 501 - first semester in two-semester sequence in quantum mechanics; PY 501 - second semester of sequence. Credit for both PY 401 and PY 501 is not allowed

PY 502 Quantum Physics II 3(3-0-0) S Preq: PY 401 Basic principles of quantum physics with emphasis on selected applications to atoms, molecules, solids, nuclei and elementary particles. PY 502 - second semester in two-semester sequence in quantum mechanics; PY 501, first semester of sequence. Credit for both PY 402 and PY 502 is not allowed.

PY 506 Nuclear and Subatomic Physics 3(3-0-0) F Preq: PY 203 or 407; PY 412 Introduction to nuclear and subatomic phenomena: properties of nuclear radiations and detectors, accelerators, nuclear forces and nuclear structure, elementary particles, fundamental symmetries and conservation laws.

PY 507 Elementary Particle Physics 3(3-0-0) S Preq: PY 401 and PY 506 Introduction to fundamental symmetries and dynamics of quarks and leptons. The Standard Model, Dirac equation, Feynman rules in QED and QCD, the Higgs mechanism and electroweak unification.

PY 508 Ion and Electron Physics 3(3-0-0) F Preq: PY 414 Topics: charged particle dynamics, introduction to plasma physics, processes in ionized gases, electron emission and the physics of electron beams.

PY 509 Plasma Physics 3(3-0-0) F Preq: PY 414 Individual and collective motion of charged particles in electric and magnetic fields and through ionized gases.

PY 511 Mechanics I 3(3-0-0) F Preq: PY 203 or 208, MA 341 First semester of two-semester sequence in particle and continuum mechanics at intermediate level. Single-particle dynamics: Elementary Newtonian mechanics, harmonic oscillator, central force motion, conservation laws, motion in non-inertial frames, Coriolis and centrifugal forces, Lagrangian dynamics, Hamilton's equations. Credit for both PY 411 and PY 511 is not allowed.

PY 512 Mechanics II 3(3-0-0) S Preq: PY 511 Second semester of two-semester sequence in particle and continuum mechanics at intermediate level. Dynamics of systems of particles and continua: Center of mass, collisions, rigid bodies, inertia tensor, principla axes, stress and strain tensors, mechanical properties of fluids and solids; waves in discrete and continuum systems, coupled oscillators, normal modes, elements of special relativity. Credit for both PY 412 and PY 512 is not allowed.

PY 514 Electromagnetism I 3(3-0-0) F Preq: PY 203 or PY 208, MA 341 First semester of two- semester sequence. An intermediate course in electromagnetic theory using the methods of vector calculus. Electrostatis field and potential, dielectrics, solution to Laplace's and Poisson's equations, magnetic fields of steady currents. Credit for both PY 414 and PY 514 is not allowed.

PY 515 Electromagnetism II 3(3-0-0) S Preq: PY 514 Continuation of PY 514. Electromagnetic induction, magneticfields in matter, Maxwell'sequations, wave guides, radiation. Credit for both PY 415 and PY 515 is not allowed.

PY 516 Physical Optics 3(3-0-0) F Preq: PY 415 Physical optics with major emphasis on wave properties of light. Boundary conditions, interference and diffraction, optics of thin films, fiber optics and applications to absorption, scattering and laser operation. A background in Maxwell's equations and vector analysis required.

PY 517 Atomic and Molecular Physics 3(3-0-0) S Preq: PY 401, 412 The quantum mechanical treatment of structure and spectra for atoms and molecules. The hydrogen atom, helium atom, multielectron atoms, selection rules, diatomic and simple polyatomic molecules and nuclear magnetic resonance spectroscopy.

PY 525 Computational Physics 3(3-0-0) F Preq: MA 341, PY 411, PY 414 Computational approach to physics problem solving using standard software relevant for physicists. Electrostatic potentials, data analysis, Monte Carlo simulations, Fourier optics, particle orbits, Schrodinger's equation. Examples and assignments for each topic chosen to complement other physics courses.

PY (NE) 528 Introduction to Plasma Physics and Fusion Energy 3(3-0-0) F Preq: MA 401 and PY 208 Concepts in plasma physics, basics of thermonuclear reactions; charged particle collisions, single particle motions and drifts, radiation from plasmas and plasma waves, fluid theory of plasmas, formation and heating of plasmas, plasma confinement, fusion devices and other plasma applications.

PY 543 Astrophysics 3(3-0-0) S Preq: PY 203 or 407; PY 411 Basic physics necessary to investigate, from observational data, internal conditions and evolution of stars. The formation and structure of spectral lines, methods of energy generation and transport, stellar structure, degeneracy, white dwarfs and neutron stars.

PY (ECE) 552 Introduction To the Structure Of Solids 3(3-0-0) S Preq: PY 401 Basic considerations of crystalline solids, metals, conductors and semiconductors.

PY 561 Electronics For Physicists 3(1-4-0) S Preq: Grad. standing Analog and digital electronics laboratory course serving as introduction to use of modern instrumentation required for experimental research in physics. Bipolar and field effect transistors, operational amplifiers, oscillators, power supplies, analog-digital and digital-analog conversion and digital logic circuits.

PY (MA 575 Mathematical Introduction To Celestial Mechanics 3(3-0-0) F Preq: MA 301 Central orbits, N-body problem, 3-body problem, Hamilton-Jacobi theory, perturbation theory, applications to motion of celestial bodies.

PY (MA) 576 Orbital Mechanics 3(3-0-0) S Preq: MA 341, 405, knowledge of elementary mechanics and computer programming Keplerian motion, iterative solutions, numerical integration, differential corrections and space navigation, elements of probability, least squares, sequential estimation, Kalman filter.

PY 590 Special Topics In Physics 1-3 F, S, Sum Preq: Consent of department Investigations in physics under staff guidance. May consist of literature reviews, experimental or theoretical projects or special topics lectures. Credits Arranged

PY 599 Special Topics in Physics 1-3 F, S, Sum Preq: Consent of instructor Investigations in physics under staff guidance. May consist of literature reviews, experimental or theoretical projects or special topics lectures. Credits arranged

PY 610 Special Topics 1-3 F, S Preq: Consent of department Investigations in physics under staff guidance. May consist of literature reviews, experimental or theoretical projects or special topics lectures. Credits Arranged.

PY 615 Advanced Special Topics In Physics 1-3 F, S Preq: Consent of Instructor Advanced study in astrophysics, atomic and molecular physics, condensed matter physics, nuclear physics or plasma physics. Emphasis on new and rapidly developing research areas.

PY 711 Advanced Quantum Mechanics I 3(3-0-0) F Preq: MA 512, PY 782 Introduction to relativistic quantum theory of Dirac particles and the positron. Other topics including second quantization technique and its application to many-body problems, radiation theory and quantization of the electromagnetic field.

PY 712 Advanced Quantum Mechanics II 3(3-0-0) S Preq: PY 601, 711 A general propagator treatment of Dirac particles, photons and scalar and vector mesons. Applications of Feynman graphs and rules illustrating basic techniques employed in treatment of electromagnetic, weak and strong interactions. Renormalization theory, the effects of radiative corrections and aspects of the general Lorentz covariant theory of quantized fields.

PY 721 Statistical Physics I 3(3-0-0) S Preq: PY 401, PY 413 Basic elements of kinetic theory and equilibrium statistical mechanics, both classical and quantum; applications of the techniques developed to various ideal models of noninteracting particles.

PY 722 Statistical Physics II 3(3-0-0) F Preq: PY 721 A continuation of PY 721, with emphasis on the static and dynamic properties of real (interacting) systems. Topics including equilibrium theory of fluids and linear response theory of time-dependent phenomena.

PY (ECE) 727 Semiconductor Thin Film Technology 3(3-0-0) S, Alt yrs. even Preq: ECE 404 Techniques and processes encountered in growth and characterization of epitaxial semiconductor thin films. Interactions of gases at solid interfaces and gas phase dynamics related to epitaxial processes. Example of growth techniques are: solution growth, molecular beam epitaxy and chemical vapor deposition. Film characterization includes electrical, structural, optical, and chemical techniques. Issues involved in epitaxial growth such as: lattice match, critical layer thickness, heterostructures, superlattices and quantum wells.

PY 730 Nuclear Structure Physics I 3(3-0-0) S Preq: PY 782; PY 506 Advanced description of nuclear models and nuclear reactions. Topics including internucleon forces, compound- nucleus processes, shell model, optical model, R-matrix theory, direct reactions, collective model, electromagnetic transitions, isobaric analog states.

PY 753 Introduction To the Structure Of Solids II 3(3-0-0) F Preq: PY 552 The properties of semiconductors, superconductors, magnets, ferroelectrics and crystalline defects and dislocations.

PY 754 Properties of Surfaces and Interfaces 3(3-0-0) Preq: PY(ECE) 552 Properties of surfaces and interfaces of materials. Relation between electronic properties and atomic structure. (A) Surfaces: thermodynamics, experimental techniques, structure and reconstruction.

PY 755 Dielectric Films and their Interfaces 3(3-0-0) S Preq: PY 552 This course addresses: i) local atomic structure of non-crystalline/amorphous dielectrics - experimental methods and theory; ii) classification of dielectric materials - by bond ionicity, bond density and bonding contraints/atom to discriminate between ideal covalent random networks, disrupted networks, and nano-crystallinity; iii) thermally-grown silicon dioxide and its interface with Si - the standard for alternative dielectrics; iv) electronic structure and bonding in transition metal/lathanide rare earth dielectrics; and v) intrinsic limitations on the performance and reliability of metal-oxide-semiconductor devices.

PY 781 Quantum Mechanics I 3(3-0-0) F, S Preq: MA 512; PY 411 or 414; grad. standing Fundamental concepts and formulations, including interpretation and techniques, and the application of theory to simple physical systems, such as the free particle, the harmonic oscillator, the particle in a potential well and central force problems. Other topics including approximation methods, identical particles and spin, transformation theory, symmetries and invariance, and an introduction to quantum theory of scattering and angular momentum.

PY 782 Quantum Mechanics II 3(3-0-0) F, S Preq: MA 512; PY 411 or 414; grad. standing Fundamental concepts and formulations, including interpretation and

techniques, and the application of theory to simple physical systems, such as the free particle, the harmonic oscillator, the particle in a potential well and central force problems. Other topics including approximation methods, identical particles and spin, transformation theory, symmetries and invariance, and an introduction to quantum theory of scattering and angular momentum.

PY 783 Advanced Classical Mechanics I 3(3-0-0) F Preq: MA 512, PY 412, PY 414; grad. standing Introduction to theoretical physics in preparation for advanced study. Emphasis on classical mechanics, special relativity and the motion of charged particles. Topics including variational principles, Hamiltonian dynamics and canonical transformation theory, structure of the Lorentz group and elementary dynamics of unquantized fields.

PY 785 Advanced Electricity and Magnetism I 3(3-0-0) F, S Preq: PY 415; grad. standing Topics including techniques for solution of potential problems, development of Maxwell's equations; wave equations, energy, force and momentum relations of an electromagnetic field; covariant formulation of electrodynamics; radiation from accelerated charges.

PY 786 Advanced Electricity and Magnetism II 3(3-0-0) F, S Preq: PY 415; grad. standing Topics including techniques for solution of potential problems, development of Maxwell's equations; wave equations, energy, force and momentum relations of an electromagnetic field; covariant formulation of electrodynamics; radiation from accelerated charges.

PY 801 Seminar 1(1-0-0) F, S, Sum Reports on topics of current interest in physics. Several sections offered so that students with common research interests may be grouped together.

PY 810 Special Topics In Physics 1-3 F, S Preq: Consent of department Investigations in physics under staff guidance. May consist of literature reviews, experimental or theoretical projects or special topics lectures. Credits Arranged

PY 815 Advanced Special Topics In Physics 1-3 F, S Preq: Consent of Instructor Advanced study in astrophysics, atomic and molecular physics, condensed matter physics, nuclear physics or plasma physics. Emphasis on new and rapidly developing research areas.

PY 885 Doctoral Supervised Teaching 1-3 F, S, Sum Preq: Doctoral Student Teaching experience under the mentorship of faculty who assist the student in planning for the teaching assignment, observe and provide feedback to the student during the teaching assignment and evaluate the student upon completion of the assignment.

PY 890 Doctoral Preliminary Examination 1-9 F, S, Sum Preq: Doctoral Student For students who are preparing for and taking written and/or oral preliminary exams.

PY 893 Doctoral Supervised Research 1-9 F, S, Sum Preq: Doctoral Student Instruction in research and research under the mentorship of a member of the Graduate Faculty.

PY 895 Doctoral Dissertation Research 1-9 F, S, Sum Preq: Doctoral Student Dissertation Research

PY 896 Summer Dissertation Research 1(1-0-0) Sum Preq: Doctoral student For graduate students whose programs of work specify no formal course work during a summer session and who will be devoting full time to thesis research.

PY 899 Doctoral Dissertation Preparation 1-3 F, S, Sum Preq: Doctoral Student For students who have completed all credit hour requirements, full-time enrollment, preliminary examination, and residency requirements for the doctoral degree, and are writing and defending their dissertations.