DEPARTMENT OF PHYSICS

College of Arts and Sciences
Department of Physics
103 Smith Hall
Kent Campus
330-672-2246
physics-web@kent.edu
www.kent.edu/physics

Undergraduate Programs
• Physics - B.A.
• Physics - B.S.

Minors
• Physics

Graduate Programs
• Physics - M.A.
• Physics - M.S.
• Physics - Ph.D.

Department of Physics Faculty
• Almasan, Carmen C. (1995), Professor, Ph.D., University of South Carolina, 1989
• Antocheviz Dexheimer Strickland, Veronica A. (2013), Assistant Professor, Ph.D., Goethe Universitat, 2009
• Balci, Hamza (2009), Associate Professor
• Barrick, John M. (1988), Associate Lecturer, Ed.S., Kent State University, 1988
• Cheng, Haw (2018), Assistant Professor, Ph.D., University of North Carolina, Chapel Hill, 2014
• Driscoll, Donald D. (2007), Associate Professor
• Dzero, Maxim (2010), Associate Professor
• Ellman, Brett D. (1997), Associate Professor, Ph.D., University of Chicago, 1993
• Fregoso, Benjamin (2017), Assistant Professor
• Gleeson, James T. (1997), Professor and Department Chair, Ph.D., Kent State University, 1991
• Katramatou, A. Mina T. (1996), Professor, Ph.D., American University, 1988
• Keane, Declan F. (1988), Professor
• Li, Ran (2007), Associate Professor, Ph.D., Southern Illinois University, Carbondale, 2007
• Lussem, Bjorn (2014), Associate Professor
• Manley, D.M. (1986), Professor, Ph.D., University of Wyoming, 1981
• Mann, Elizabeth K. (1998), Professor, Ph.D., University of Paris, 1992
• Margitis, Spyridon (1997), Professor
• Minnick, Stephen A. (2003), Professor, Ph.D., Pennsylvania State University, 2003
• Montgomery, Timothy E. (1985), Associate Lecturer
• Petratos, Gerassimos G. (1994), Professor
• Portman, John J. (2003), Professor, Ph.D., University of Illinois, Urbana, 2000
• Quader, Khandker F. (1990), Professor, Ph.D., State University of New York-Stony Brook, 1983
• Schmidt, Thorsten-Lars (2019), Assistant Professor
• Schroeder, Almut (2001), Associate Professor
• Secaur, Jonathan M. (1980), Associate Professor, Ph.D., Kent State University, 1994
• Selinger, Robin L. (2005), Professor, Ph.D., Harvard College, 1989
• Sprunt, Samuel N. (1995), Professor, Ph.D., Massachusetts Institute of Technology, 1989
• Strickland, Michael (2013), Professor, Ph.D., Duke University, 1997
• Vanfossen, Joseph A. (2004), Assistant Professor
• Wei, Qi-Huo (2006), Professor
• Yokoyama, Hiroshi (2009), Professor

Physics (PHY)

PHY 11030 SEVEN IDEAS THAT SHOOK THE UNIVERSE (KBS) 3 Credit Hours
Description of major revolutionary physical concepts and their implications for understanding the physical universe. Not counted toward requirements for physics major.
Prerequisite: None.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter
Attributes: Kent Core Basic Sciences, Transfer Module Natural Sciences

PHY 12000 INTRODUCTORY PHYSICS SEMINAR (ELR) 1 Credit Hour
To provide a nurturing course for new physics majors, ideally to be taken in their first semester as majors. The course includes a journal club component, informational talks by industrial physicists and training in a select group of essential skills and tools for future work in the physics program.
Prerequisite: None.
Schedule Type: Seminar
Contact Hours: 1 other
Grade Mode: Standard Letter
Attributes: Experiential Learning Requirement

PHY 12111 PHYSICS FOR HEALTH TECHNOLOGIES 3 Credit Hours
Basic physics applied to health technologies: measurement techniques, force and motion of solids and fluids, energy, heat wave phenomena, electricity. Students taking this course should be in a health technologies major.
Prerequisite: None.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter

PHY 12201 TECHNICAL PHYSICS I (KBS) (KLAB) 3 Credit Hours
Introduction to principles of physics: mechanics.
Prerequisite: MATH 11010.
Pre/corequisite: MATH 11022.
Schedule Type: Combined Lecture and Lab
Contact Hours: 2 lecture, 2 lab
Grade Mode: Standard Letter
Attributes: Kent Core Basic Sciences, Kent Core Basic Sciences Lab
PHY 12202  TECHNICAL PHYSICS II (KBS) (KLAB)  4 Credit Hours
Introduction to principles of physics, including fluids, thermodynamics, electricity and magnetism.
Prerequisite: PHY 12201.
Schedule Type: Combined Lecture and Lab
Contact Hours: 3 lecture, 2 lab
Grade Mode: Standard Letter
Attributes: Kent Core Basic Sciences, Kent Core Basic Sciences Lab

PHY 13001  GENERAL COLLEGE PHYSICS I (KBS)  4 Credit Hours
Principles of mechanics, heat and sound.
Prerequisite: MATH 11022 with a minimum C grade.
Pre/corequisite: MATH 12002 or MATH 12012 or MATH 12021.
Corequisite: PHY 13001.
Schedule Type: Lecture, Recitation
Contact Hours: 3 lecture, 1 other
Grade Mode: Standard Letter
Attributes: Kent Core Basic Sciences, TAG Science, Transfer Module Natural Sciences

PHY 13002  GENERAL COLLEGE PHYSICS II (KBS)  4 Credit Hours
Principles of electricity and magnetism, optics and modern physics. Three hours lecture and one hour recitation weekly.
Prerequisite: PHY 13001 or PHY 23101.
Corequisite: PHY 13002.
Schedule Type: Lecture, Recitation
Contact Hours: 3 lecture, 1 other
Grade Mode: Standard Letter
Attributes: Kent Core Basic Sciences, TAG Science, Transfer Module Natural Sciences

PHY 13001 or PHY 13011 or PHY 23101.

PHY 13002 or PHY 13012.

PHY 21040  PHYSICS IN ENTERTAINMENT AND THE ARTS (KBS)  3 Credit Hours
Descriptive introduction to physics underlying selected forms of art and entertainment. Examples are drawn from music, visual arts and communications media. Not counted toward requirements for physics major.
Prerequisite: None.
Schedule Type: Lecture
Contact Hours: 1-3 lecture
Grade Mode: Standard Letter

PHY 21040.

PHY 13002 or PHY 13012.

PHY 21430  FRONTIERS IN ASTRONOMY (KBS)  3 Credit Hours
Modern description of astrophysical observations, the results of these observations and the physical principles based on them. Not counted toward requirements for physics major.
Prerequisite: None.
Schedule Type: Laboratory
Contact Hours: 2 lab
Grade Mode: Standard Letter
Attributes: Kent Core Basic Sciences, TAG Science, Transfer Module Natural Sciences

PHY 20095  SPECIAL TOPICS  1-3 Credit Hours
(Repeatable for credit) Topic announced when scheduled.
Prerequisite: None.
Schedule Type: Lecture
Contact Hours: 1-3 lecture
Grade Mode: Standard Letter

PHY 20096  INDIVIDUAL INVESTIGATION IN PHYSICS  1-6 Credit Hours
(Repeatable for credit) Individual projects in physics.
Prerequisite: Special approval.
Schedule Type: Individual Investigation
Contact Hours: 1-6 other
Grade Mode: Standard Letter-IP

PHY 21040.
PHY 21431  FRONTIERS IN ASTRONOMY LABORATORY (KBS) (KLAB)  
1 Credit Hour  
Laboratory component of PHY 21430.  
Pre/corequisite: PHY 21430.  
Schedule Type: Laboratory  
Contact Hours: 3 lab  
Grade Mode: Standard Letter  
Attributes: Kent Core Basic Sciences, Kent Core Basic Sciences Lab, TAG Science  

PHY 22564  INTRODUCTION TO MATERIALS PHYSICS  
3 Credit Hours  
Survey of mechanical and electronic properties of materials with application in science and technology. Metals, semiconductors, ceramics, polymers and liquid crystals, and other special materials will be addressed.  
Prequisite: PHY 23102.  
Schedule Type: Lecture  
Contact Hours: 3 lecture  
Grade Mode: Standard Letter  

PHY 23101  GENERAL UNIVERSITY PHYSICS I (KBS) (KLAB)  
5 Credit Hours  
Principles of mechanics, heat and sound at calculus level.  
Pre/corequisite: MATH 12002.  
Schedule Type: Laboratory, Lecture  
Contact Hours: 4 lecture, 3 lab  
Grade Mode: Standard Letter  
Attributes: Kent Core Basic Sciences, Kent Core Basic Sciences Lab, TAG Science  

PHY 23102  GENERAL UNIVERSITY PHYSICS II (KBS) (KLAB)  
5 Credit Hours  
Principles of electricity, magnetism, light and modern physics at calculus level.  
Pre/corequisite: PHY 13001 or PHY 23101.  
Schedule Type: Laboratory, Lecture  
Contact Hours: 4 lecture, 3 lab  
Grade Mode: Standard Letter  
Attributes: Kent Core Basic Sciences, Kent Core Basic Sciences Lab, TAG Science  

PHY 30020  INTERMEDIATE PHYSICS LABORATORY (WIC)  
2 Credit Hours  
(Repeatable for credit) Experiments in classical and modern physics are selected to accompany and to supplement junior-level physics courses.  
Prequisite: PHY 36001 and 10 hours of additional physics courses.  
Schedule Type: Laboratory  
Contact Hours: 3 lab  
Grade Mode: Standard Letter  
Attributes: Writing Intensive Course  

PHY 30095  SPECIAL TOPICS  
1-3 Credit Hours  
(Repeatable for credit) Topic announced when scheduled.  
Prequisite: Permission.  
Schedule Type: Lecture  
Contact Hours: 1-3 lecture  
Grade Mode: Standard Letter  

PHY 30041  SYSTEMS IN ASTRONOMY  
1-3 Credit Hours  
"Hands-on" course to give the student a working knowledge of analog electronics and of AC and DC circuits typically used by the scientist.  
Prequisite: MATH 12002 and; PHY 13002 or PHY 23102.  
Schedule Type: Combined Lecture and Lab  
Contact Hours: 6 other  
Grade Mode: Standard Letter  

PHY 32511  ELECTRONICS  
4 Credit Hours  
"Hands-on" course to give the student a working knowledge of analog electronics and of AC and DC circuits typically used by the scientist.  
Prequisite: MATH 12002 and; PHY 13002 or PHY 23102.  
Schedule Type: Combined Lecture and Lab  
Contact Hours: 6 other  
Grade Mode: Standard Letter  

PHY 33000  COSMOLOGY  
3 Credit Hours  
This course will provide a quantitative introduction to modern cosmology, from the Big Bang to the formation of the first stars. Subjects include the evolution of the geometry and temperature of the universe its composition and select aspects of general relativity.  
Prequisite: PHY 36001.  
Schedule Type: Lecture  
Contact Hours: 3 lecture  
Grade Mode: Standard Letter  

PHY 35101  CLASSICAL MECHANICS  
4 Credit Hours  
Modern description of mechanics including both LaGrangian and Hamilton formulations, with applications to central force, motion, coupled oscillations, rigid body motion and motion in non-inertial reference frames.  
Prequisite: PHY 23102 and MATH 32052.  
Schedule Type: Lecture  
Contact Hours: 4 lecture  
Grade Mode: Standard Letter  

PHY 36001  INTRODUCTORY MODERN PHYSICS  
3 Credit Hours  
Special theory of relativity, Rutherford-Bohr model of atom, quantization of light, matter waves, Schroedinger equation, hydrogen atom, electron spin, multi-electron atoms.  
Prequisite: MATH 12003 and PHY 23102.  
Schedule Type: Lecture  
Contact Hours: 3 lecture  
Grade Mode: Standard Letter  

PHY 36002  APPLICATIONS OF MODERN PHYSICS  
3 Credit Hours  
Survey of applications of twentieth century physics. Topics include molecular bonding, conducting and insulating solids, degenerate matter, quantum condensates, subatomic and sub-nuclear particle physics, cosmology.  
Prequisite: PHY 36001.  
Schedule Type: Lecture  
Contact Hours: 3 lecture  
Grade Mode: Standard Letter  

PHY 40020  ADVANCED PHYSICS LABORATORY (WIC)  
2 Credit Hours  
(Repeatable for credit) Advanced experiments in classical and modern physics are selected to accompany and to supplement senior-level physics courses.  
Prequisite: PHY 30020.  
Schedule Type: Laboratory  
Contact Hours: 3 lab  
Grade Mode: Standard Letter  
Attributes: Writing Intensive Course  

PHY 40060  PHYSICAL LITERATURE  
1-3 Credit Hours  
Study of current or topical literature.  
Prequisite: Permission.  
Schedule Type: Lecture  
Contact Hours: 1-3 lecture  
Grade Mode: Standard Letter
PHY 4092  INTERNSHIP IN PHYSICS (ELR)  1-3 Credit Hours  
(Repeatable for credit) Supervised capstone experience in physics at a 
national laboratory, a research university in industry or at a local research 
site. No more than 3 credit hours may be applied toward the major 
electives for physics majors.  
Prerequisite: Permission.  
Schedule Type: Practicum or Internship  
Contact Hours: 1-3 other  
Grade Mode: Satisfactory/Unsatisfactory  
Attributes: Experiential Learning Requirement  

PHY 4095  SPECIAL TOPICS  1-3 Credit Hours  
(Repeatable for credit) Topic announced when scheduled.  
Prerequisite: Permission.  
Schedule Type: Lecture  
Contact Hours: 1-3 lecture  
Grade Mode: Standard Letter  

PHY 4096  INDIVIDUAL INVESTIGATION (ELR)  1-6 Credit Hours  
(Repeatable for credit) Individual projects for physics majors.  
Prerequisite: 20 hours of physics; and special approval of department 
chairperson.  
Schedule Type: Individual Investigation  
Contact Hours: 1-6 other  
Grade Mode: Standard Letter-IP  
Attributes: Experiential Learning Requirement  

PHY 4099  SENIOR HONORS THESIS (ELR)  1-10 Credit Hours  
Thesis for departmental, general or university honors must be 1-10 hours 
with continuous registration throughout the senior year beginning in the 
summer prior to the senior year. Students taking this course must consult 
with their department and the Honors College and receive approval prior 
to the first semester of the senior year.  
Prerequisite: Honors senior standing; and special approval.  
Schedule Type: Senior Project/Honors Thesis  
Contact Hours: 1-10 other  
Grade Mode: Standard Letter-IP  
Attributes: Experiential Learning Requirement  

PHY 40195  SPECIAL TOPICS  1-3 Credit Hours  
(Repeatable for credit) (Slashed with PHY 50195) Topic announced when 
scheduled.  
Prerequisite: Special approval.  
Schedule Type: Lecture  
Contact Hours: 1-3 lecture  
Grade Mode: Standard Letter  

PHY 41010  BIOPHOTONICS  3 Credit Hours  
(Slashed with PHY 51010; Cross-listed with BSCI 41110 and BSCI 51110 
and CHEM 41010 and CHEM 51010) Interdisciplinary overview of 
the basics of biophotonics; application of biophotonic techniques to 
probe biological samples. Introduction to the foundations of optics 
and photonics and how the molecular structure of organic molecules 
translates into unique photonic properties and targeting in biological cells 
or tissue. Preparation of fluorescent materials, advanced spectroscopy 
and cell visualization using regular and confocal fluorescence 
microscopy.  
Prerequisite: Special approval.  
Schedule Type: Combined Lecture and Lab  
Contact Hours: 1 lecture, 6 lab  
Grade Mode: Standard Letter  

PHY 44600  INTRODUCTION TO BIOLOGICAL PHYSICS  3 Credit Hours  
Introduces ideas essential to physical understanding of biological 
systems. Topics include: introduction to molecular components of the 
cell; statistical mechanics and transport in biological systems; selected 
topics in biophysics.  
Prerequisite: PHY 23102.  
Schedule Type: Lecture  
Contact Hours: 3 lecture  
Grade Mode: Standard Letter  

PHY 44802  ASTROPHYSICS  3 Credit Hours  
Galactic structure, stellar formation and evolution, origin of the elements 
(or nucleosynthesis), nonoptical astronomies, and description of various 
cosmological theories.  
Prerequisite: MATH 12003.  
Schedule Type: Lecture  
Contact Hours: 3 lecture  
Grade Mode: Standard Letter  

PHY 45201  ELECTROMAGNETIC THEORY  4 Credit Hours  
Properties of electric and magnetic fields developed by vector methods. 
Treatment on static fields in vacuum and matter. Theory of classical 
electromagnetic fields with emphasis on dynamic fields.  
Prerequisite: MATH 32052 and PHY 23102.  
Schedule Type: Lecture  
Contact Hours: 4 lecture  
Grade Mode: Standard Letter  

PHY 45301  THERMAL PHYSICS  3 Credit Hours  
An introduction to thermodynamics and statistical mechanics, with 
applications in material science and engineering.  
Prerequisite: PHY 36001.  
Schedule Type: Lecture  
Contact Hours: 3 lecture  
Grade Mode: Standard Letter  

PHY 45401  MATHEMATICAL METHODS IN PHYSICS  4 Credit Hours  
Consolidation of vector analysis, curvilinear coordinate systems, tensors, 
matrix algebra, vector spaces, common groups in physics, calculus of 
residues, contour integration, methods for differential equations in 
physics; additional topics important for physics selected from special 
functions, integral equations, calculus of variations.  
Prerequisite: MATH 32052.  
Schedule Type: Lecture  
Contact Hours: 4 lecture  
Grade Mode: Standard Letter  

PHY 45403  DATA ANALYSIS AND COMPUTATIONAL PHYSICS TECHNIQUES  3 Credit Hours  
(Slashed with PHY 55403) Study of uncertainties in physical 
measurements. Data reduction and error analysis techniques. Monte 
Carlo simulation method. Least-squares fits to data. Basic computational 
physics techniques.  
Prerequisite: MATH 12003 and PHY 23102.  
Schedule Type: Lecture  
Contact Hours: 3 lecture  
Grade Mode: Standard Letter  

Department of Physics
PHY 45501 ELECTROMAGNETIC WAVES AND MODERN OPTICS 3 Credit Hours
Interactions between light and matter from both a macroscopic and microscopic perspective; producing and controlling light devices and spectroscopic techniques based on modern optics.
Prerequisite: PHY 45201.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter

PHY 46101 QUANTUM MECHANICS 4 Credit Hours
Systematic introduction to the principles and solution techniques of quantum mechanics, including the Schroedinger equation in one and three dimensions. Topics include: angular momentum formalism, introductory Dirac notation and vector space formalism, intrinsic spin, identical particle systems and perturbation theory.
Prerequisite: PHY 36001.
Pre/corequisite: MATH 32052.
Schedule Type: Lecture
Contact Hours: 4 lecture
Grade Mode: Standard Letter

PHY 46301 INTRODUCTION TO NUCLEAR AND PARTICLE PHYSICS 4 Credit Hours
(Cross-listed with PHY 56301) Introduction to nuclear and particle physics including particle detectors and accelerators, experimental techniques, nuclear fission and fusion, nuclear reactors, medical applications, and connections to astrophysics and cosmology.
Prerequisite: PHY 36001.
Pre/corequisite: MATH 32052.
Schedule Type: Lecture
Contact Hours: 4 lecture
Grade Mode: Standard Letter

PHY 46401 INTRODUCTION TO SOLID STATE PHYSICS 3 Credit Hours
Fundamental unifying concepts and experimental techniques needed to understand thermal, electrical and optical properties of ions and electrons in solids. Special topics of current research.
Prerequisite: PHY 36002.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter

PHY 50020 ADVANCED PHYSICS LAB 2 Credit Hours
(Repeatable for credit) Advanced experiments in classical and modern physics are selected to accompany and to supplement graduate-level physics courses.
Prerequisite: Graduate standing.
Schedule Type: Laboratory
Contact Hours: 3 lab
Grade Mode: Standard Letter

PHY 50093 VARIABLE TITLE WORKSHOP IN PHYSICS 1-6 Credit Hours
(Repeatable for credit) Workshops individually designed to provide instruction and training in specific areas of physics.
Prerequisite: Graduate standing; and special approval.
Schedule Type: Workshop
Contact Hours: 1-6 other
Grade Mode: Satisfactory/Unsatisfactory

PHY 50095 SPECIAL TOPICS 1-3 Credit Hours
(Repeatable for credit) Topic announced when scheduled.
Prerequisite: Graduate standing; and special approval.
Schedule Type: Lecture
Contact Hours: 1-3 lecture
Grade Mode: Standard Letter

PHY 50096 INDIVIDUAL INVESTIGATION 1-3 Credit Hours
(Repeatable for credit) Individual projects for physics graduate students.
Prerequisite: Graduate standing.
Schedule Type: Individual Investigation
Contact Hours: 1-3 other
Grade Mode: Standard Letter-IP

PHY 50195 SPECIAL TOPICS 1-3 Credit Hours
(Repeatable for credit) (Slashed with PHY 40195) Topic announced when scheduled.
Prerequisite: Graduate standing; and special approval.
Schedule Type: Lecture
Contact Hours: 1-3 lecture
Grade Mode: Standard Letter

PHY 51010 BIOPHOTONICS 3 Credit Hours
(Slashed with PHY 41010; Cross-listed with BSCI 41110 and BSCI 51110 and CHEM 41010 and CHEM 51010) Interdisciplinary overview of the basics of biophotonics; application of biophotonic techniques to probe biological samples. Introduction to the foundations of optics and photonics and how the molecular structure of organic molecules translates into unique photonic properties and targeting in biological cells or tissue. Preparation of fluorescent materials, advanced spectroscopy and cell visualization using regular and confocal fluorescence microscopy.
Prerequisite: Graduate standing; and special approval.
Schedule Type: Combined Lecture and Lab
Contact Hours: 1 lecture, 6 lab
Grade Mode: Standard Letter

PHY 54600 INTRODUCTION TO BIOLOGICAL PHYSICS 3 Credit Hours
Introduces ideas essential to physical understanding of biological systems. Topics include: introduction to molecular components of the cell; statistical mechanics and transport in biological systems; selected topics in biophysics.
Prerequisite: Graduate standing; and special approval.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter

PHY 54802 ASTROPHYSICS 3 Credit Hours
Galactic structure, stellar formation and evolution, origin of the elements (or nucleosynthesis), non optical astronomies, and a description of various cosmological theories. Graduate standing.
Prerequisite: MATH 12003.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter

PHY 55201 ELECTROMAGNETIC THEORY 4 Credit Hours
Properties of electric and magnetic fields developed by vector methods. Treatment of static fields in vacuum and matter. Theory of classical electromagnetic fields with emphasis on dynamic fields.
Prerequisite: Graduate standing.
Schedule Type: Lecture
Contact Hours: 4 lecture
Grade Mode: Standard Letter
PHY 55301  THERMAL PHYSICS  3 Credit Hours
An introduction to thermodynamics and statistical mechanics, with applications in material science and engineering.
**Prerequisite:** PHY 36001; and graduate standing.
**Schedule Type:** Lecture
**Contact Hours:** 3 lecture
**Grade Mode:** Standard Letter

PHY 55401  MATHEMATICAL METHODS IN PHYSICS  4 Credit Hours
Consolidation of vector analysis, curvilinear coordinate systems, tensors, matrix algebra, vector spaces, common groups in physics, calculus of residues, contour integration, methods for differential equations in physics; additional topics important for physics selected from special functions, integral equations, calculus of variations.
**Prerequisite:** MATH 32052; and graduate standing.
**Schedule Type:** Lecture
**Contact Hours:** 4 lecture
**Grade Mode:** Standard Letter

PHY 55501  ELECTROMAGNETIC WAVES AND MODERN OPTICS  3 Credit Hours
Interactions between light and matter from both a macroscopic and microscopic perspective; producing and controlling light; devices and spectroscopic techniques based on modern optics.
**Prerequisite:** PHY 55201; and graduate standing.
**Schedule Type:** Lecture
**Contact Hours:** 3 lecture
**Grade Mode:** Standard Letter

PHY 55601  QUANTUM MECHANICS  4 Credit Hours
Systematic introduction to the principles and solution techniques of quantum mechanics, including the Schrödinger equation in one and three dimensions. Topics include: angular momentum formalism, introductory Dirac notation and vector space formalism, intrinsic spin, identical particle systems, and perturbation theory.
**Prerequisite:** Graduate standing; and special approval.
**Schedule Type:** Lecture
**Contact Hours:** 4 lecture
**Grade Mode:** Standard Letter

PHY 55701  INTRODUCTION TO SOLID STATE PHYSICS  3 Credit Hours
Fundamental unifying concepts and experimental techniques needed to understand thermal, electrical and optical properties of ions and electrons in solids. Special topics of current research.
**Prerequisite:** PHY 36002; and graduate standing.
**Schedule Type:** Lecture
**Contact Hours:** 3 lecture
**Grade Mode:** Standard Letter

PHY 56301  INTRODUCTION TO NUCLEAR AND PARTICLE PHYSICS  4 Credit Hours
(Cross-listed with PHY 46301) Introduction to nuclear and particle physics including particle detectors and accelerators, experimental techniques, nuclear fission and fusion, nuclear reactors, medical applications, and connections to astrophysics and cosmology.
**Prerequisite:** Graduate standing.
**Schedule Type:** Lecture
**Contact Hours:** 4 lecture
**Grade Mode:** Standard Letter

PHY 56401  INTRODUCTION TO SOLID STATE PHYSICS  3 Credit Hours
Fundamental unifying concepts and experimental techniques needed to understand thermal, electrical and optical properties of ions and electrons in solids. Special topics of current research.
**Prerequisite:** PHY 36002; and graduate standing.
**Schedule Type:** Lecture
**Contact Hours:** 3 lecture
**Grade Mode:** Standard Letter

PHY 56501  PHYSICS SEMINAR  1 Credit Hour
(Repeatable for credit) Discussion of current literature or of original research in physics. Participation by students, faculty and guests.
**Prerequisite:** Graduate standing.
**Schedule Type:** Seminar
**Contact Hours:** 1 other
**Grade Mode:** Satisfactory/Unsatisfactory-IP

PHY 56603  VARIABLE TITLE WORKSHOP IN PHYSICS  1-6 Credit Hours
(Repeatable for credit) Workshops individually designed to provide instruction and training in specific areas of physics.
**Prerequisite:** Graduate standing.
**Schedule Type:** Workshop
**Contact Hours:** 3 other
**Grade Mode:** Satisfactory/Unsatisfactory

PHY 56704  COLLEGE TEACHING OF PHYSICS  1-3 Credit Hours
(Repeatable for credit) Methodology of teaching in a university, college or junior college. Includes observation of kinds of teaching and practice teaching.
**Prerequisite:** Graduate standing.
**Schedule Type:** Lecture
**Contact Hours:** 1-3 lecture
**Grade Mode:** Satisfactory/Unsatisfactory-IP

PHY 56801  ADVANCED TOPICS  1-3 Credit Hours
(Repeatable for credit) Selected special topics of current research interest.
**Prerequisite:** Graduate standing; and special approval.
**Schedule Type:** Lecture
**Contact Hours:** 3 lecture
**Grade Mode:** Standard Letter-IP
PHY 60299  THESIS II  2 Credit Hours
Thesis students must continue registration each semester until all degree requirements are met.
Prerequisite: PHY 60199; and graduate standing.
Schedule Type: Masters Thesis
Contact Hours: 2 other
Grade Mode: Satisfactory/Unsatisfactory-IP

PHY 64101  ADVANCED PROBLEM SOLVING IN PHYSICS  3 Credit Hours
The course imparts advanced problem-solving skills not acquired in regular courses. Examples from four basic areas of physics (classical mechanics, electricity and magnetism, quantum mechanics and statistical physics) will be emphasized.
Prerequisite: PHY 6/75101 or PHY 6/75203 or PHY 6/76161 or PHY 6/75301; or graduate standing; and departmental instructor approval.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter

PHY 65301  CLASSICAL MECHANICS  3 Credit Hours
Lagrange's equations, variational principles, two-body central force problem and rigid body motion. Hamilton's equations, canonical transformations, Hamilton-Jacobi theory and small oscillations.
Prerequisite: Graduate standing; and special approval.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter

PHY 65204  CLASSICAL ELECTRODYNAMICS II  3 Credit Hours
Plane electromagnetic waves, simple radiating systems, scattering, special theory of relativity, relativistic dynamics, radiation of moving charges, Bremsstrahlung.
Prerequisite: PHY 6/75203; and graduate standing.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter

PHY 65203  CLASSICAL ELECTRODYNAMICS I  3 Credit Hours
Introduction to electrostatics, boundary-value problems, multipoles, electrostatics of macroscopic media, magnetostatics, time-varying fields, Maxwell's equations, conservation laws.
Prerequisite: Graduate standing; and special approval.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter

PHY 65301  STATISTICAL MECHANICS I  4 Credit Hours
An introduction to statistical mechanics, including classical and quantum statistics. Derives thermodynamic quantities from a statistical viewpoint.
Prerequisite: Graduate standing.
Schedule Type: Lecture
Contact Hours: 4 lecture
Grade Mode: Standard Letter

PHY 66161  QUANTUM MECHANICS I  3 Credit Hours
Prerequisite: Graduate standing; and special approval.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter

PHY 66162  QUANTUM MECHANICS II  3 Credit Hours
Prerequisite: PHY 6/76161; and graduate standing.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter

PHY 66201  PARTICLE PHYSICS  3 Credit Hours
Discussion of particle detectors, invariance principles and conservation laws, fundamental interactions, quark model of hadrons, basic concepts of field theory, the Standard Model and selected topics of current interest.
Prerequisite: PHY 6/76162; and graduate standing.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter

PHY 66401  SOLID STATE PHYSICS I  3 Credit Hours
Crystalline state, with emphasis on wave propagation, zone and band theory, phonons. Applications to electrical and thermal conductivities, specific heats, optical, dielectric and magnetic properties.
Prerequisite: PHY 56101 or PHY 6/76161; and graduate standing.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter

PHY 66403  ADVANCED CONDENSED MATTER PHYSICS  3 Credit Hours
(Slashed with PHY 76403) Advanced theories of solids, fluids, superfluids, magnetic, ferroelectric and liquid crystal systems and the experimental methods that probe them.
Prerequisite: PHY 66402 and Graduate standing.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter

PHY 68401  LIQUID CRYSTAL PHYSICS  3 Credit Hours
The molecular structure and properties of liquid crystals and their role in biological systems and industrial applications.
Prerequisite: Graduate standing in physics or chemical physics.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter

PHY 70094  COLLEGE TEACHING OF PHYSICS  1-3 Credit Hours
(Repeatable for credit)Methodology of teaching in a university, college or junior college. Includes observation of kinds of teaching and practice teaching.
Prerequisite: Doctoral standing.
Schedule Type: Lecture
Contact Hours: 1-3 lecture
Grade Mode: Satisfactory/Unsatisfactory-IP
PHY 70095 SPECIAL TOPICS 1-3 Credit Hours
(Repeatable for credit) Topic announced when scheduled.
Prerequisite: Doctoral standing; and special approval.
Schedule Type: Lecture
Contact Hours: 1-3 lecture
Grade Mode: Standard Letter

PHY 74101 ADVANCED PROBLEM SOLVING IN PHYSICS 3 Credit Hours
The course imparts advanced problem-solving skills not acquired in regular courses. Examples from four basic areas of physics (classical mechanics, electricity and magnetism, quantum mechanics and statistical physics) will be emphasized.
Prerequisite: PHY 6/75101 or PHY 6/75203 or PHY 6/76161 or PHY 6/75301; or doctoral standing; and departmental instructor approval.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter

PHY 75101 CLASSICAL MECHANICS 3 Credit Hours
Lagrange's equations, variational principles, two-body central force problems, rigid body motion, Hamilton's equations, canonical transformations, Hamilton-Jacobi theory, small oscillations.
Prerequisite: Doctoral standing; and special approval.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter

PHY 75203 CLASSICAL ELECTRODYNAMICS I 3 Credit Hours
Introduction to electrostatics, boundary value problems, multipole, electrostatics of macroscopic media, magnetostatics, time-varying fields, Maxwell's equations, conservation laws.
Prerequisite: Doctoral standing; and special approval.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter

PHY 75204 CLASSICAL ELECTRODYNAMICS II 3 Credit Hours
Plane electromagnetic waves, simple radiating systems, scattering special theory of relativity, relativistic dynamics, radiation of moving charges, Bremsstrahlung.
Prerequisite: PHY 6/75203; and doctoral standing.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter

PHY 75301 STATISTICAL MECHANICS I 4 Credit Hours
An introduction to statistical mechanics, including classical and quantum statistics. Derives thermodynamic quantities from a statistical viewpoint.
Prerequisite: Doctoral standing.
Schedule Type: Lecture
Contact Hours: 4 lecture
Grade Mode: Standard Letter

PHY 76161 QUANTUM MECHANICS I 3 Credit Hours
Prerequisite: Doctoral standing; and permission.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter

PHY 76162 QUANTUM MECHANICS II 3 Credit Hours
Prerequisite: PHY 6/76161; and doctoral standing.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter

PHY 76163 QUANTUM MECHANICS III 3 Credit Hours
Second quantization and field theory formalism are developed for the many-particle system. Topics include the electron gas and nuclear matter.
Prerequisite: PHY 6/76162; and doctoral standing.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter

PHY 76201 PARTICLE PHYSICS 3 Credit Hours
Discussion of particle detectors, invariance principles and conservation laws, fundamental interactions, quark model of hadrons, basic concepts of a field theory, the Standard Model and selected topics of current interest.
Prerequisite: PHY 6/76162; and doctoral standing.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter

PHY 76303 APPLICATIONS OF QUANTUM CHROMODYNAMICS 3 Credit Hours
Introduces the key attributes and techniques of Quantum Chromodynamics, which is the relativistic quantum field theory of the strong interaction. Topics treated include the properties, structure and interactions of strongly interacting sub-nuclear particles (hadrons) and the physics of hadronic and nuclear matter at finite temperature and density, as applicable to modern nuclear particle physics research.
Prerequisite: PHY 76163.
Corequisite: PHY 66201 or PHY 76201.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter

PHY 76401 SOLID STATE PHYSICS I 3 Credit Hours
Crystalline state, with emphasis on wave propagation zone and band theory phonons. Applications to electrical and thermal conductivities specific heats optical dielectric and magnetic properties.
Prerequisite: PHY 56101 or PHY 6/76161; and doctoral standing.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter

PHY 76403 ADVANCED CONDENSED MATTER PHYSICS 3 Credit Hours
(Flushed with PHY 66403) Advanced theories of solids, fluids, superfluids, magnetic, ferroelectric and liquid crystal systems, and the experimental methods that probe them.
Prerequisite: PHY 66402 or 76402; and doctoral standing.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter
PHY 78401  LIQUID CRYSTAL PHYSICS     3 Credit Hours
The molecular structure and properties of liquid crystals and their role in biological systems and industrial applications.
Prerequisite: Doctoral standing in physics or chemical physics.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter

PHY 80091  PHYSICS SEMINAR     1 Credit Hour
(Repeatable for credit) Discussion of current literature or of original research in physics. Participation by students, faculty and guests.
Prerequisite: Doctoral standing.
Schedule Type: Seminar
Contact Hours: 1 other
Grade Mode: Satisfactory/Unsatisfactory-IP

PHY 80097  PHYSICS COLLOQUIUM     1 Credit Hour
(Repeatable for credit) Presentation by invited speakers of research and other topics on graduate level followed by discussion period. Regular attendance of all physics majors expected. Three or more meetings each semester as arranged.
Prerequisite: Doctoral standing.
Schedule Type: Colloquium
Contact Hours: 1 other
Grade Mode: Satisfactory/Unsatisfactory-IP

PHY 80098  RESEARCH     1-15 Credit Hours
(Repeatable for credit) Research or individual investigation for doctoral students who have not yet passed their candidacy exams. Credit earned may be applied toward the degree if the department approves.
Prerequisite: Doctoral standing; and special approval.
Schedule Type: Research
Contact Hours: 1-15 other
Grade Mode: Satisfactory/Unsatisfactory-IP

PHY 80199  DISSERTATION I     15 Credit Hours
(Repeatable for credit) Doctoral dissertation, for which registration in at least two semesters is required; the first of which will be the semester in which dissertation work is begun, and continuing until the completion of 30 hours.
Prerequisite: Doctoral standing; and special approval.
Schedule Type: Dissertation
Contact Hours: 15 other
Grade Mode: Satisfactory/Unsatisfactory-IP

PHY 80299  DISSERTATION II     15 Credit Hours
(Repeatable for credit) Continuing registration required of doctoral students who have completed the initial 30 hours of dissertation and continuing until all degree requirements are met.
Prerequisite: PHY 80199; and doctoral standing.
Schedule Type: Dissertation
Contact Hours: 15 other
Grade Mode: Satisfactory/Unsatisfactory-IP