

# DEPARTMENT OF PHYSICS

## College of Arts and Sciences

Department of Physics  
103 Smith Hall  
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## 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

- Antocheviz Dexheimer Strickland, Veronica A. (2013), Associate Professor, Ph.D., Goethe Universitat, 2009
- Balci, Hamza (2009), Professor, Ph.D., University of Maryland, 2004
- Bos, Philip J. (1994), Professor, Ph.D., Kent State University, 1978
- Driscoll, Donald D. (2007), Associate Professor, Ph.D., Case Western Reserve University, 2004
- Dzero, Maxim (2010), Professor
- Ellman, Brett D. (1997), Associate Professor, Ph.D., University of Chicago, 1993
- Fregoso, Benjamin (2017), Associate Professor, University of Illinois-Urbana, 2010
- Gleeson, James T. (1997), Professor, Ph.D., Kent State University, 1991
- Jakli, Antal I. (1989), Professor, Ph.D., University Of Budapest, 1988
- Katramatou, A. Mina T. (1996), Professor, Ph.D., American University, 1988
- Keane, Declan F. (1988), Professor, Ph.D., University College of Dublin
- Lavrentovich, Oleg D. (1992), Trustees Research Professor, Kiev University, 1990
- Li, Ran (2007), Associate Professor, Ph.D., Southern Illinois University, Carbondale, 2007
- Mann, Elizabeth K. (1998), Professor, Ph.D., University of Paris, 1992
- Margetis, Spyridon (1997), Professor, Ph.D., Goethe Universitat, 1991
- Minnick, Stephen A. (2003), Professor, Ph.D., Pennsylvania State University, 2003
- Petratos, Gerassimos G. (1994), Professor, Ph.D., American University, 1988
- Polak, Robert D. (2022), Associate 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), Associate Professor
- Schroeder, Almut (2001), Associate Professor
- Selinger, Jonathan V. (2005), Professor, Ph.D., Harvard College, 1989
- Selinger, Robin L. (2005), Professor, Ph.D., Harvard College, 1989
- Sprunt, Samuel N. (1995), Professor, Ph.D., Massachusetts Institute of Technology, 1989
- Vanfossen, Joseph A. (2004), Associate Professor, Ph.D., Kent State University, 2017
- Yang, Deng-Ke (1989), Professor, Ph.D., University of Hawaii at Manoa, 1989
- Yokoyama, Hiroshi (2009), Professor, Ph.D., Tokyo International University, 1987

## 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:** Minimum C grade in MATH 11022 or in MATH 12011; or pre/corequisites MATH 12002 or MATH 12012 or MATH 12021.

**Corequisite:** PHY 13021.

**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 13022.

**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 13012 COLLEGE PHYSICS II (KBS) 2 Credit Hours**

Principles of classical physics, primarily electricity and magnetism.

**Prerequisite:** PHY 13001 or PHY 23101.

**Schedule Type:** Lecture, Recitation

**Contact Hours:** 2 lecture

**Grade Mode:** Standard Letter

**Attributes:** Kent Core Basic Sciences, Transfer Module Natural Sciences

**PHY 13021 GENERAL COLLEGE PHYSICS LABORATORY I (KBS) (KLAB) 1 Credit Hour**

Introductory lab to accompany PHY 13001.

**Corequisite:** PHY 13001.

**Schedule Type:** Laboratory

**Contact Hours:** 2 lab

**Grade Mode:** Standard Letter

**Attributes:** Kent Core Basic Sciences, Kent Core Basic Sciences Lab, TAG Science, Transfer Module Natural Sciences, TAG Natural Science Lab

**PHY 13022 GENERAL COLLEGE PHYSICS LABORATORY II (KBS) (KLAB) 1 Credit Hour**

Introductory lab to accompany PHY 13002 or PHY 13012.

**Corequisite:** PHY 13002 or PHY 13012.

**Schedule Type:** Laboratory

**Contact Hours:** 2 lab

**Grade Mode:** Standard Letter

**Attributes:** Kent Core Basic Sciences, Kent Core Basic Sciences Lab, TAG Science, Transfer Module Natural Sciences, TAG Natural Science Lab

**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 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:** 3 lecture

**Grade Mode:** Standard Letter

**Attributes:** Kent Core Basic Sciences, Transfer Module Natural Sciences

**PHY 21041 PHYSICS IN ENTERTAINMENT AND THE ARTS LABORATORY (KBS) (KLAB) 1 Credit Hour**

Laboratory component of PHY 21040, two hours weekly.

**Pre/corequisite:** PHY 21040.

**Schedule Type:** Laboratory

**Contact Hours:** 2 lab

**Grade Mode:** Standard Letter

**Attributes:** Kent Core Basic Sciences, Kent Core Basic Sciences Lab, Transfer Module Natural Sciences, TAG Natural Science Lab

**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:** Lecture

**Contact Hours:** 3 lecture

**Grade Mode:** Standard Letter

**Attributes:** Kent Core Basic Sciences, Transfer Module Natural Sciences

**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, Transfer Module Natural Sciences, TAG Natural Science Lab

**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.

**Prerequisite:** 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.

**Prerequisite:** PHY 13001 or PHY 23101.

**Pre/corequisite:** MATH 12003.

**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**

Experiments in classical and modern physics are selected to accompany and supplement junior-level physics courses.

**Prerequisite:** PHY 36001; and 10 credit hours of additional Physics (PHY) courses.

**Schedule Type:** Laboratory

**Contact Hours:** 4 lab

**Grade Mode:** Standard Letter

**Attributes:** Writing Intensive Course

**PHY 30095 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 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.

**Prerequisite:** MATH 12002 and; PHY 13002 or PHY 23102.

**Schedule Type:** Combined Lecture and Lab

**Contact Hours:** 6 other

**Grade Mode:** Standard Letter

**PHY 34000 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.

**Prerequisite:** 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.

**Prerequisite:** 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.

**Prerequisite:** 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.

**Prerequisite:** PHY 36001.

**Schedule Type:** Lecture

**Contact Hours:** 3 lecture

**Grade Mode:** Standard Letter

**PHY 40020 ADVANCED PHYSICS LABORATORY (WIC) 2 Credit Hours**

(Slashed with PHY 50020) Advanced experiments in classical and modern physics are selected to accompany and supplement senior-level physics courses.

**Prerequisite:** PHY 30020.

**Pre/corequisite:** 6 credit hours of 40000-level Physics (PHY) courses.

**Schedule Type:** Laboratory

**Contact Hours:** 4 lab

**Grade Mode:** Standard Letter

**Attributes:** Writing Intensive Course

**PHY 40060 PHYSICAL LITERATURE 1-3 Credit Hours**

Study of current or topical literature.

**Prerequisite:** Permission.

**Schedule Type:** Lecture

**Contact Hours:** 1-3 lecture

**Grade Mode:** Standard Letter

**PHY 40092 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:** Practical Experience

**Contact Hours:** 1-3 other

**Grade Mode:** Satisfactory/Unsatisfactory

**Attributes:** Experiential Learning Requirement

**PHY 40095 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 40096 INDIVIDUAL INVESTIGATION (ELR) 1-3 Credit Hours**  
(Slashed with PHY 50096)(Repeatable for credit) Individual projects for physics majors and minors.

**Prerequisite:** PHY 23102; and special approval.

**Schedule Type:** Individual Investigation

**Contact Hours:** 3-9 other

**Grade Mode:** Standard Letter

**Attributes:** Experiential Learning Requirement

**PHY 40099 SENIOR HONORS THESIS (ELR) 1-10 Credit Hours**  
(Repeatable for credit) 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

**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**

(Slashed 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 LABORATORY 2 Credit Hours**

(Slashed with PHY 40020) Advanced experiments in classical and modern physics are selected to accompany and supplement graduate-level physics courses.

**Prerequisite:** Graduate standing.

**Schedule Type:** Laboratory

**Contact Hours:** 4 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**

(Slashed with PHY 40096)(Repeatable for credit) Individual projects for physics graduate students.

**Prerequisite:** Graduate standing.

**Schedule Type:** Individual Investigation

**Contact Hours:** 3-9 other

**Grade Mode:** Standard Letter

**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 55403 DATA ANALYSIS AND COMPUTATIONAL PHYSICS TECHNIQUES 3 Credit Hours**

(Slashed with PHY 45403) 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; and graduate standing.

**Schedule Type:** Lecture

**Contact Hours:** 3 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 56101 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:** Graduate standing; and special approval.

**Schedule Type:** Lecture

**Contact Hours:** 4 lecture

**Grade Mode:** Standard Letter

**PHY 56301 INTRODUCTION TO NUCLEAR AND PARTICLE PHYSICS 4 Credit Hours**

(Slashed 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 60091 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 60093 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 60098 RESEARCH 1-15 Credit Hours**

(Repeatable for credit) Research or individual investigation. Credits earned may be applied toward meeting degree requirements if department approves.

**Prerequisite:** Graduate standing.

**Schedule Type:** Research

**Contact Hours:** 1-15 other

**Grade Mode:** Standard Letter-IP

**PHY 60199 THESIS I 2-6 Credit Hours**

Thesis students must register for total of 6 hours, 2 to 6 hours in a single semester distributed over several semesters if desired.

**Prerequisite:** Graduate standing; and special approval of advisor.

**Schedule Type:** Masters Thesis

**Contact Hours:** 2-6 other

**Grade Mode:** Satisfactory/Unsatisfactory-IP

**PHY 60295 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**

(Slashed with PHY 74101) 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 65101 or PHY 65203 or PHY 66161 or PHY 65301; or graduate standing; and departmental instructor approval.

**Schedule Type:** Lecture

**Contact Hours:** 3 lecture

**Grade Mode:** Standard Letter

**PHY 65101 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 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 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 65203; and graduate standing.

**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**

Fundamental concepts of non-relativistic quantum mechanics. Solution of simple one dimensional problems. Abstract Hilbert-space description. Matrix representations. Quantum dynamics. Extension to three dimensions. Spin and orbital angular momentum.

**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**

Angular momentum theory. Symmetries and conservation laws. Application of approximation methods to realistic problems. Systems of identical particles. Scattering theory. Relativistic single particle wave equations.

**Prerequisite:** PHY 66161; 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 66162; 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 66161; 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:** 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 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 65101 or PHY 65203 or PHY 66161 or PHY 65301; 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, multipoles, 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 65203; 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**

Fundamental concepts of non-relativistic quantum mechanics. Solution of simple one dimensional problems. Abstract Hilbert space description. Matrix representations. Quantum dynamics. Extension to three dimensions. Spin and orbital angular momentum.

**Prerequisite:** Doctoral standing; and special approval.

**Schedule Type:** Lecture

**Contact Hours:** 3 lecture

**Grade Mode:** Standard Letter

**PHY 76162 QUANTUM MECHANICS II 3 Credit Hours**

Angular momentum theory. Symmetries and conservation laws. Application of approximation methods to realistic problems. Systems of identical particles. Scattering theory. Relativistic single particle wave equations.

**Prerequisite:** PHY 66161; 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 66162; 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 66162 or 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 66161 or 76161; and doctoral standing.

**Schedule Type:** Lecture

**Contact Hours:** 3 lecture

**Grade Mode:** Standard Letter

**PHY 76403 ADVANCED CONDENSED MATTER PHYSICS 3 Credit Hours**

(Slashed with PHY 66403) Advanced theories of solids, fluids, superfluids, magnetic, ferroelectric and liquid crystal systems, and the experimental methods that probe them.

**Prerequisite:** 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