# Physics (PHYS)

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Department of Physics Website (https://fulbright.uark.edu/departments/physics/)

**Degrees Conferred:**
M.S., Ph.D. (PHYS)

**Primary Areas of Faculty Research:** Astronomy/astrophysics, biophysics/neuro-physics, computational/theoretical physics, condensed matter/nano-physics, non-linear and quantum optics.

**Prerequisites to M.S. and Ph.D. Degree Programs:** Prospective students must satisfy the requirements of the Graduate School as described in this catalog and have the approval of the Graduate Admissions Committee of the Department of Physics. In addition, to be admitted to graduate study in physics without deficiency, candidates should have an undergraduate degree with the equivalent of a 30-hour major in physics including intermediate-level courses in mechanics, electricity and magnetism, quantum physics and thermal physics, and mathematics through differential equations. Students who present less than the above may be admitted with deficiency dependent on degree track subject to the approval of the department's Graduate Admissions Committee. Students may eliminate deficiencies while concurrently enrolling in graduate courses, provided prerequisites are met. While submission of Graduate Record Examination scores is not required for admission, students who have taken the GRE advanced physics test are urged to submit their test scores to the physics department to facilitate advising and placement.

## M.S. in Physics

**Requirements for the Master of Science Degree:** Students may choose between two Master of Science degrees in the physics department. These are the M.S. Physics (30-hour thesis path); and the M.S. Physics (36-hour non-thesis path). Both M.S. degree curricula prepare a student for the Physics Ph.D. degree.

Incoming graduate students will be advised by a departmental graduate adviser for the first two years. Students must form their thesis or advisory committees by the end of their third academic semester and file the appropriate forms with the Graduate School. The thesis committee (thesis-path students) consists of the research adviser as chair, two members of the physics faculty, and one member of the graduate faculty not from the Physics Department. The advisory committee (for non-thesis-path students) consists of the individual study project adviser as chair and two members of the physics faculty. Students in this degree program can choose either a 30-semester-hour thesis path or a 36-semester-hour non-thesis path.

Both the thesis and non-thesis M.S. degrees share the following academic requirements: Completion of:

| | | |
|---|---|---|
| PHYS 5011 | Introduction to Current Physics Research Seminar | 1 |
| PHYS 5073 | Mathematical Methods for Physics | 3 |
| PHYS 5413 | Quantum Mechanics I | 3 |
| PHYS 5313 | Advanced Electromagnetic Theory I | 3 |
| PHYS 5323 | Advanced Electromagnetic Theory II | 3 |
| PHYS 5111 | Research Techniques Through Laboratory Rotations | 1 |
| PHYS 5041 | Journal Club Seminar | 1 |

Students who have had similar courses at another institution may substitute up to 12 credit hours of other courses in lieu of those listed above, on a course-by-course basis, upon petitioning the Graduate Affairs Committee.

Elective courses will be used for the remaining required degree hour. The minimum number of physics elective hours, the maximum number of non-physics technical elective hours, and the minimum number of total elective hours are shown in the table.

| Degree | Physics Electives | Technical Electives | Total Electives |
|---|---|---|---|
| M.S. Physics Thesis | 9 | 0 | 9 |
| M.S. Physics Non-Thesis | 18 | 0 | 18 |

Students will select electives from courses listed in the graduate catalog as appropriate to their field of specialization, with course selection approved by their thesis committee. For the purposes of this degree requirement, any Astronomy (ASTR) graduate course listed in the Graduate Catalog and taught through the physics department will be considered a Physics elective.

No more than one 4000-level course may be counted toward the 30-hour requirement for the thesis option, and no more than two 4000-level courses may be counted toward the 36-hour requirement for the non-thesis option.

**Requirements for Thesis-Path M.S. Degrees:** Completion of six master's thesis hours under PHYS 600V and a written thesis successfully defended in a comprehensive oral exam given by the student's thesis committee.

**Requirements for Non-thesis Path M.S. Degrees:** Completion of three hours under PHYS 502V Individual Study in Advanced Physics and a written project report successfully defended in a comprehensive oral exam given by the student's advisory committee. Students who pass the Physics Ph.D. candidacy examination will be considered to have satisfied the PHYS 502V requirement of the non-thesis path M.S. degrees.

Students should also be aware of Graduate School requirements with regard to master's degrees (http://catalog.uark.edu/graduatecatalog/degreerequirements/#mastersdegreestext).

## Requirements for Ph.D. in Physics

**Requirements for the Doctor of Philosophy Degree:** To be admitted to candidacy for the Ph.D. degree the student must:

1. Form a dissertation committee
2. Pass the research-based candidacy exam
3. Obtain a minimum of B-grade in core physics courses and
4. File a Declaration of Intent with the Graduate School.

Incoming graduate students will be advised by a departmental adviser for the first year. Students must form their dissertation committees by the end of their second academic semester and file the appropriate forms with the Graduate School. The dissertation committee consists of the research adviser as chair and two other members of the graduate faculty.

The research-based candidacy examination, also known as the Ph.D. qualifier, consists of a written proposal and oral presentation. All students entering the Ph.D. graduate program in the fall semester must take their qualifier no later than the end of their fifth semester of graduate studies. Students entering the Ph.D. graduate program in the spring semester must take their qualifier no later than the end of their sixth semester of graduate studies. Especially well-prepared students are encouraged to take their qualifier earlier. A candidate failing the research-based qualifier in a first attempt, will have one additional semester (two if they change adviser) for a second and final attempt.

Ph.D. students must complete a minimum of 33 semester-hours in 5000- and/or 6000-level courses beyond their Bachelor of Science degrees. Courses taken to fulfill the requirements for the University of Arkansas M.S. physics degrees can be included in this 33 semester-hour requirement. Students who have had similar courses as part of an M.S. physics program at another institution may obtain a waiver, on a course-by-course basis, upon petitioning to the Physics Graduate Affairs Committee.

Ph.D. students must take:

| | | |
|---|---|---|
| PHYS 5011 | Introduction to Current Physics Research Seminar | 1 |
| PHYS 5111 | Research Techniques Through Laboratory Rotations | 1 |
| PHYS 5041 | Journal Club Seminar | 1 |
| PHYS 5073 | Mathematical Methods for Physics | 3 |
| PHYS 5103 | Advanced Mechanics | 3 |
| PHYS 5213 | Statistical Mechanics | 3 |
| PHYS 5313 | Advanced Electromagnetic Theory I | 3 |
| PHYS 5413 | Quantum Mechanics I | 3 |

A minimum grade of B is required in the following core courses:

| | |
|---|---|
| PHYS 5073 | Mathematical Methods for Physics |
| PHYS 5103 | Advanced Mechanics |
| PHYS 5213 | Statistical Mechanics |
| PHYS 5313 | Advanced Electromagnetic Theory I |
| PHYS 5413 | Quantum Mechanics I |

If a minimum grade of B is not obtained, the course may be repeated once. If the student cannot obtain a minimum of B on two attempts, the student will not be allowed to continue in the Ph.D. program.

Fifteen additional semester hours in elective physics graduate courses will be required, and they must be selected from the 5000- or 6000-level courses listed in the graduate catalog appropriate to the student's field of specialization and approved by the student's dissertation advisory committee. For the purposes of this degree requirement, any Astronomy (ASTR) graduate course listed in the Graduate Catalog and taught through the physics department will be considered a physics elective. Additional elective courses outside of the physics department may be taken with dissertation committee approval.

Physics Ph.D. students may also choose one of the following concentrations by meeting its requirements: Astrophysics, Biophysics, or Neuroscience. Students who do not choose one of the three concentrations will pursue the general Physics Ph.D. requirements by default.

## Requirements for Ph.D. in Physics with Astrophysics Concentration

**Requirements for the Doctor of Philosophy Degree:** To be admitted to candidacy for the Ph.D. degree the student must:

1. Form a dissertation committee
2. Pass the research-based candidacy exam
3. Obtain a minimum of B-grade in core physics courses and
4. File a Declaration of Intent with the Graduate School.

Incoming graduate students will be advised by a departmental adviser for the first year. Students must form their dissertation committees by the end of their second academic semester and file the appropriate forms with the Graduate School. The dissertation committee consists of the research adviser as chair and two other members of the graduate faculty.

The research-based candidacy examination, also known as the Ph.D. qualifier, consists of a written proposal and oral presentation. All students entering the Ph.D. graduate program in the fall semester must take their qualifier no later than the end of their fifth semester of graduate studies. Students entering the Ph.D. graduate program in the spring semester must take their qualifier no later than the end of their sixth semester of graduate studies. Especially well-prepared students are encouraged to take their qualifier earlier. A candidate failing the research-based qualifier in a first attempt, will have one additional semester (two if they change adviser) for a second and final attempt.

Ph.D. students must complete a minimum of 33 semester-hours in 5000- and/or 6000-level courses beyond their Bachelor of Science degrees. Courses taken to fulfill the requirements for the University of Arkansas M.S. physics degrees can be included in this 33 semester-hour requirement. Students who have had similar courses as part of an M.S. physics program at another institution may obtain a waiver, on a course-by-course basis, upon petitioning to the Physics Graduate Affairs Committee.

Ph.D. students must take:

| | | |
|---|---|---|
| PHYS 5011 | Introduction to Current Physics Research Seminar | 1 |
| PHYS 5111 | Research Techniques Through Laboratory Rotations | 1 |
| PHYS 5041 | Journal Club Seminar | 1 |
| PHYS 5073 | Mathematical Methods for Physics | 3 |
| PHYS 5103 | Advanced Mechanics | 3 |
| PHYS 5213 | Statistical Mechanics | 3 |
| PHYS 5313 | Advanced Electromagnetic Theory I | 3 |
| PHYS 5413 | Quantum Mechanics I | 3 |

A minimum grade of B is required in the following core courses:

| | |
|---|---|
| PHYS 5073 | Mathematical Methods for Physics |
| PHYS 5103 | Advanced Mechanics |
| PHYS 5213 | Statistical Mechanics |
| PHYS 5313 | Advanced Electromagnetic Theory I |
| PHYS 5413 | Quantum Mechanics I |

If a minimum grade of B is not obtained, the course may be repeated once. If the student cannot obtain a minimum of B on two attempts, the student will not be allowed to continue in the Ph.D. program.

Fifteen additional semester hours in elective physics graduate courses will be required, and they must be selected from the 5000- or 6000-level courses listed in the graduate catalog appropriate to the student's field of specialization and approved by the student's dissertation advisory committee. For the purposes of this degree requirement, any Astronomy (ASTR) graduate course listed in the Graduate Catalog and taught through the physics department will be considered a physics elective. Additional elective courses outside of the physics department may be taken with dissertation committee approval.

Physics Ph.D. students may also choose one of the following concentrations by meeting its requirements: Astrophysics, Biophysics, or Neuroscience. Students who do not choose one of the three concentrations will pursue the general Physics Ph.D. requirements by default.

**Requirements for Astrophysics Concentration:** Students must also take:

| | | |
|---|---|---|
| ASTR 5033 | Astrophysics I: Stars and Planetary Systems | 3 |
| ASTR 5043 | Astrophysics II: Galaxies and the Large-Scale Universe | 3 |
| Nine additional hours in elective coursework appropriate to the student's field of specialization and approved by the student's research thesis advisory committee. | | 9 |

Ph.D. students must also earn 18 hours of credit in Doctoral Dissertation, submit a dissertation, and defend it successfully in a comprehensive oral examination given by the dissertation committee. The doctoral degree will be awarded to students who complete a minimum of 72-graduate semester credit hours beyond the bachelor's degree.

Students should also be aware of Graduate School requirements with regard to doctoral degrees (http://catalog.uark.edu/graduatecatalog/degreerequirements/#phdandedddegreestext).

## Requirements for Ph.D. in Physics with Biophysics Concentration

**Requirements for the Doctor of Philosophy Degree:** To be admitted to candidacy for the Ph.D. degree the student must:

1. Form a dissertation committee
2. Pass the research-based candidacy exam
3. Obtain a minimum of B-grade in core physics courses and
4. File a Declaration of Intent with the Graduate School.

Incoming graduate students will be advised by a departmental adviser for the first year. Students must form their dissertation committees by the end of their second academic semester and file the appropriate forms with the Graduate School. The dissertation committee consists of the research adviser as chair and two other members of the graduate faculty.

The research-based candidacy examination, also known as the Ph.D. qualifier, consists of a written proposal and oral presentation. All students entering the Ph.D. graduate program in the fall semester must take their qualifier no later than the end of their fifth semester of graduate studies. Students entering the Ph.D. graduate program in the spring semester must take their qualifier no later than the end of their sixth semester of graduate studies. Especially well-prepared students are encouraged to take their qualifier earlier. A candidate failing the research-based qualifier in a first attempt, will have one additional semester (two if they change adviser) for a second and final attempt.

Ph.D. students must complete a minimum of 33 semester-hours in 5000- and/or 6000-level courses beyond their Bachelor of Science degrees. Courses taken to fulfill the requirements for the University of Arkansas M.S. physics degrees can be included in this 33 semester-hour requirement. Students who have had similar courses as part of an M.S. physics program at another institution may obtain a waiver, on a course-by-course basis, upon petitioning to the Physics Graduate Affairs Committee.

Ph.D. students must take:

| | | |
|---|---|---|
| PHYS 5011 | Introduction to Current Physics Research Seminar | 1 |
| PHYS 5111 | Research Techniques Through Laboratory Rotations | 1 |
| PHYS 5041 | Journal Club Seminar | 1 |
| PHYS 5073 | Mathematical Methods for Physics | 3 |
| PHYS 5103 | Advanced Mechanics | 3 |
| PHYS 5213 | Statistical Mechanics | 3 |
| PHYS 5313 | Advanced Electromagnetic Theory I | 3 |
| PHYS 5413 | Quantum Mechanics I | 3 |

A minimum grade of B is required in the following core courses:

| | |
|---|---|
| PHYS 5073 | Mathematical Methods for Physics |
| PHYS 5103 | Advanced Mechanics |
| PHYS 5213 | Statistical Mechanics |
| PHYS 5313 | Advanced Electromagnetic Theory I |
| PHYS 5413 | Quantum Mechanics I |

If a minimum grade of B is not obtained, the course may be repeated once. If the student cannot obtain a minimum of B on two attempts, the student will not be allowed to continue in the Ph.D. program.

Fifteen additional semester hours in elective physics graduate courses will be required, and they must be selected from the 5000- or 6000-level courses listed in the graduate catalog appropriate to the student's field of specialization and approved by the student's dissertation advisory committee. For the purposes of this degree requirement, any Astronomy (ASTR) graduate course listed in the Graduate Catalog and taught through the physics department will be considered a physics elective. Additional elective courses outside of the physics department may be taken with dissertation committee approval.

Physics Ph.D. students may also choose one of the following concentrations by meeting its requirements: Astrophysics, Biophysics, or Neuroscience. Students who do not choose one of the three concentrations will pursue the general Physics Ph.D. requirements by default.

**Requirements for Biophysics Concentration:** Students must also take:

| | | |
|---|---|---|
| BIOL 4793 | Introduction to Neurobiology | 3 |
| PSYC 4183 | Behavioral Neuroscience | 3 |
| Nine additional hours in elective coursework appropriate to the student's field of specialization and approved by the student's research thesis advisory committee. | | 9 |

Ph.D. students must also earn 18 hours of credit in Doctoral Dissertation, submit a dissertation, and defend it successfully in a comprehensive oral examination given by the dissertation committee. The doctoral degree will be awarded to students who complete a minimum of 72-graduate semester credit hours beyond the bachelor's degree.

Students should also be aware of Graduate School requirements with regard to doctoral degrees (http://catalog.uark.edu/graduatecatalog/degreerequirements/#phdandedddegreestext).

## Requirements for Ph.D. in Physics with Neuroscience Concentration

**Requirements for the Doctor of Philosophy Degree:** To be admitted to candidacy for the Ph.D. degree the student must:

1. Form a dissertation committee
2. Pass the research-based candidacy exam
3. Obtain a minimum of B-grade in core physics courses and
4. File a Declaration of Intent with the Graduate School.

Incoming graduate students will be advised by a departmental adviser for the first year. Students must form their dissertation committees by the end of their second academic semester and file the appropriate forms with the Graduate School. The dissertation committee consists of the research adviser as chair and two other members of the graduate faculty.

The research-based candidacy examination, also known as the Ph.D. qualifier, consists of a written proposal and oral presentation. All students entering the Ph.D. graduate program in the fall semester must take their qualifier no later than the end of their fifth semester of graduate studies. Students entering the Ph.D. graduate program in the spring semester must take their qualifier no later than the end of their sixth semester of graduate studies. Especially well-prepared students are encouraged to take their qualifier earlier. A candidate failing the research-based qualifier in a first attempt, will have one additional semester (two if they change adviser) for a second and final attempt.

Ph.D. students must complete a minimum of 33 semester-hours in 5000- and/or 6000-level courses beyond their Bachelor of Science degrees. Courses taken to fulfill the requirements for the University of Arkansas M.S. physics degrees can be included in this 33 semester-hour requirement. Students who have had similar courses as part of an M.S. physics program at another institution may obtain a waiver, on a course-by-course basis, upon petitioning to the Physics Graduate Affairs Committee.

Ph.D. students must take:

| | | |
|---|---|---|
| PHYS 5011 | Introduction to Current Physics Research Seminar | 1 |
| PHYS 5111 | Research Techniques Through Laboratory Rotations | 1 |
| PHYS 5041 | Journal Club Seminar | 1 |
| PHYS 5073 | Mathematical Methods for Physics | 3 |
| PHYS 5103 | Advanced Mechanics | 3 |
| PHYS 5213 | Statistical Mechanics | 3 |
| PHYS 5313 | Advanced Electromagnetic Theory I | 3 |
| PHYS 5413 | Quantum Mechanics I | 3 |

A minimum grade of B is required in the following core courses:

| | |
|---|---|
| PHYS 5073 | Mathematical Methods for Physics |
| PHYS 5103 | Advanced Mechanics |
| PHYS 5213 | Statistical Mechanics |
| PHYS 5313 | Advanced Electromagnetic Theory I |
| PHYS 5413 | Quantum Mechanics I |

If a minimum grade of B is not obtained, the course may be repeated once. If the student cannot obtain a minimum of B on two attempts, the student will not be allowed to continue in the Ph.D. program.

Fifteen additional semester hours in elective physics graduate courses will be required, and they must be selected from the 5000- or 6000-level courses listed in the graduate catalog appropriate to the student's field of specialization and approved by the student's dissertation advisory committee. For the purposes of this degree requirement, any Astronomy (ASTR) graduate course listed in the Graduate Catalog and taught through the physics department will be considered a physics elective. Additional elective courses outside of the physics department may be taken with dissertation committee approval.

Physics Ph.D. students may also choose one of the following concentrations by meeting its requirements: Astrophysics, Biophysics, or Neuroscience. Students who do not choose one of the three concentrations will pursue the general Physics Ph.D. requirements by default.

**Requirements for Neuroscience Concentration:** Students must also take:

| | | |
|---|---|---|
| BIOL 4793 | Introduction to Neurobiology | 3 |
| PSYC 4183 | Behavioral Neuroscience | 3 |
| Nine additional hours in elective coursework appropriate to the student's field of specialization and approved by the student's research thesis advisory committee. | | 9 |

Ph.D. students must also earn 18 hours of credit in Doctoral Dissertation, submit a dissertation, and defend it successfully in a comprehensive oral examination given by the dissertation committee. The doctoral degree will be awarded to students who complete a minimum of 72-graduate semester credit hours beyond the bachelor's degree.

Students should also be aware of Graduate School requirements with regard to doctoral degrees (http://catalog.uark.edu/graduatecatalog/degreerequirements/#phdandedddegreestext).

## Graduate Faculty

**Barraza-Lopez, Salvador,** Ph.D. (University of Illinois-Urbana-Champaign), B.S. (Instituto Politecnico Nacional de Mexico), Associate Professor, 2011, 2016.

**Bellaiche, Laurent,** Ph.D., M.S., B.S. (University of Paris VI, France), Distinguished Professor, 1999, 2016.

**Churchill, Hugh O.H.,** Ph.D., A.M. (Harvard University), B.A. (Oberlin College), B.M. (Oberlin Conservatory of Music), Associate Professor, 2015, 2021.

**Fu, Huaxiang,** Ph.D., M.S. (Fudan University), B.S. (University of Science and Technology of China), Professor, 2002, 2017.

**Gea-Banacloche, Julio R.,** Ph.D. (University of New Mexico), Licenciado en Ciencias Fisicas (Universidad Autonoma de Madrid), Professor, 1989, 2000.
**Harter, William G.,** Ph.D. (University of California-Irvine), B.S. (Hiram College), Professor, 1986.
**Hu, Jin,** Ph.D. (Tulane University), B.S. (University of Science and Technology of China), Assistant Professor, 2017.
**Joffe Minor, Tacy Marie,** Ph.D. (Northwestern University), M.A., B.S. (University of Arkansas), Teaching Assistant Professor, 2011, 2018.
**Kennefick, Daniel John,** Ph.D., M.A. (California Institute of Technology), B.S. (University College Cork, Ireland), Professor, 2003, 2021.
**Kennefick, Julia Dusk,** Ph.D. (California Institute of Technology), B.S. (University of Arkansas), Associate Professor, 2003, 2014.
**Kumar, Pradeep,** Ph.D. (Boston University), M.Sc. (Indian Institute of Technology, Mumbai, India), Associate Professor, 2013, 2019.
**Leftwich, Matthew,** Ph.D., M.S. and B.S. (University of Arkansas), M.B.A. (Webster University), Research Professor, 2021.
**Lehmer, Bret Darby,** Ph.D. (Pennsylvania State University), B.S. (University of Iowa), Associate Professor, 2015, 2021.
**Li, Jiali,** Ph.D., M.S. (The City College of the City University of New York), M.S. (University of Science and Technology of China), B.S. (Hei Long Jiang University), Professor, 2002, 2016.
**Manasreh, Bothina H.,** Ph.D., M.Sc. (University of Jordan), Research Assistant Professor, 2017.
**Nakamura, Hiroyuki,** Ph.D., M.S., B.S. (University of Tokyo), Assistant Professor, 2019.
**Oliver, William,** Ph.D., M.S. (University of Colorado-Boulder), B.S. (University of Arizona), Associate Professor, 1992, 1998.
**Prosandeev, Sergey,** Ph.D., M.S. (Rostov State University), Research Professor, 2005, 2016.
**Salamo, Gregory J.,** Ph.D. (City University of New York), M.S. (Indiana University-Purdue University-Indianapolis), B.S. (City University of New York, Brooklyn College), Distinguished Professor, 1975, 2005.
**Shew, Woodrow L.,** Ph.D. (University of Maryland-College Park), B.A. (College of Wooster), Associate Professor, 2012, 2017.
**Singh, Surendra P.,** Ph.D., M.A. (University of Rochester), M.Sc., B.Sc. (Banaras Hindu University, India), University Professor, 1982, 2016.
**Thibado, Paul M.,** Ph.D. (University of Pennsylvania), B.S. (San Diego State University), Professor, 1996, 2005.
**Vyas, Reeta,** Ph.D. (State University of New York at Buffalo), M.S., B.S. (Banaras Hindu University), Professor, 1984, 2002.
**Wang, Yong,** Ph.D., M.S. (University of California, Los Angeles), B.S. (University of Science and Technology of China), Assistant Professor, 2016.
**Xiao, Min,** Ph.D. (University of Texas at Austin), B.S. (Nanjing University), Distinguished Professor, 1990, 2004.

## Astronomy Courses

**ASTR 5033. Astrophysics I: Stars and Planetary Systems. 3 Hours.**
An introduction to astrophysics covering stellar structure and evolution, the properties of the solar system, and extrasolar planetary systems. (Typically offered: Fall Odd Years)
This course is cross-listed with SPAC 5033.

**ASTR 5043. Astrophysics II: Galaxies and the Large-Scale Universe. 3 Hours.**
An introduction to astrophysics covering the interstellar medium, the Milky Way galaxy, extragalactic astronomy, and introduction to cosmology. Prerequisite: ASTR 5033 or SPAC 5033. (Typically offered: Spring Even Years)

**ASTR 5073. Cosmology. 3 Hours.**
An introduction to modern physical cosmology covering the origin, evolution, and structure of the Universe, based on the Theory of Relativity. (Typically offered: Spring Odd Years)

**ASTR 5083. Data Analysis and Computing in Astronomy. 3 Hours.**
Study of the statistical analysis of large data sets that are prevalent in the physical sciences with an emphasis on astronomical data and problems. Includes computational lab 1 hour per week. Corequisite: Lab component. (Typically offered: Fall Even Years)

**ASTR 5523. Theory of Relativity. 3 Hours.**
Conceptual and mathematical structure of the special and general theories of relativity with selected applications. Critical analysis of Newtonian mechanics; relativistic mechanics and electrodynamics; tensor analysis; continuous media; and gravitational theory. (Typically offered: Fall Even Years)

## Physics Courses

**PHYS 500V. Laboratory and Classroom Practices in Physics. 1-3 Hour.**
The pedagogy of curricular materials. Laboratory and demonstration techniques illustrating fundamental concepts acquired through participation in the classroom as an apprentice teacher. (Typically offered: Fall) May be repeated for up to 3 hours of degree credit.

**PHYS 5011. Introduction to Current Physics Research Seminar. 1 Hour.**
This seminar course introduces new Physics graduate students to the faculty of the Physics department and their current research efforts. In addition, the students will be introduced to scientific ethics, and learn communication skills. (Typically offered: Fall)

**PHYS 502V. Individual Study in Advanced Physics. 1-4 Hour.**
Guided study in current literature. (Typically offered: Fall and Spring) May be repeated for up to 4 hours of degree credit.

**PHYS 5041. Journal Club Seminar. 1 Hour.**
In this seminar, the students will present talks based on published research articles. The goal of the course is to develop oral communication skills in the students. Effective literature search techniques will also be covered. (Typically offered: Spring)

**PHYS 5073. Mathematical Methods for Physics. 3 Hours.**
This course merges the mathematics required in classical mechanics, electrostatics, magnetostatics, and quantum mechanics into a single course. The goal is to develop physics problem-solving skills, a strong mathematical foundation, and a more unified picture of physics. (Typically offered: Fall)

**PHYS 5093. Applications of Group Theory to Physics. 3 Hours.**
Application of group theory to topics in physics, especially to atomic/molecular and solid-state physics. Prerequisite: PHYS 5073. (Typically offered: Irregular)

**PHYS 5103. Advanced Mechanics. 3 Hours.**
Dynamics of particles and rigid bodies. Hamilton's equations and canonical variables. Canonical transformations. Small oscillations. Prerequisite: PHYS 5073. (Typically offered: Fall)

**PHYS 5111. Research Techniques Through Laboratory Rotations. 1 Hour.**
Graduate students will be introduced to detailed operational aspects of two Physics research laboratories through extensive observation of those laboratory's operations during a six week rotation through each lab. Planning for starting a research project in the summer will take place in the final three week rotation period. (Typically offered: Spring)

**PHYS 5213. Statistical Mechanics. 3 Hours.**
Classical and quantum mechanical statistical theories of matter and radiation. Prerequisite: PHYS 5413. (Typically offered: Spring)

**PHYS 5263L. Experiment and Data Analysis. 3 Hours.**
This course is devoted to learning some of the frequently used experimental techniques and methods by which experimental data are analyzed to extract quantitative information on physical parameters. Students will perform experiments, analyze data, and write lab reports. Prerequisite: PHYS 5413. (Typically offered: Fall)

**PHYS 5313. Advanced Electromagnetic Theory I. 3 Hours.**
Electrostatics, boundary-value problems in electrostatics, electrostatics in a medium, magnetostatics, and Faraday's Law. (Typically offered: Spring)

**PHYS 5323. Advanced Electromagnetic Theory II. 3 Hours.**
Maxwell equations, conservation laws, wave propagation, waveguides, radiating systems, scattering, special relativity, and radiation by moving charges. (Typically offered: Fall)

**PHYS 5363. Scientific Computation and Numerical Methods. 3 Hours.**
An introduction to numerical methods used in solving various problems in engineering and the sciences. May not earn credit for this course and MATH 4353 or MATH 4363. (Typically offered: Fall Even Years)
This course is cross-listed with MATH 5363.

**PHYS 5413. Quantum Mechanics I. 3 Hours.**
Non-relativistic quantum mechanics; the Schrodinger equation; the Heisenberg matrix representation; operator formalism; transformation theory; spinors and Pauli theory; the Dirac equation; applications to atoms and molecules; collision theory; and semiclassical theory of radiation. (Typically offered: Fall)

**PHYS 5423. Quantum Mechanics II. 3 Hours.**
Continuation of PHYS 5413 Prerequisite: PHYS 5413. (Typically offered: Spring)

**PHYS 5613. Introduction to Biophysics and Biophysical Techniques. 3 Hours.**
Origins of biophysics, biological polymers and polymer physics, properties of DNA and proteins, techniques to study DNA and proteins, biological membrane and ion channels, biological energy, experimental techniques to study single DNA and proteins. Two experiments are included: (1) DNA Gel electrophoresis; (2) Measurement of double-stranded DNA melting point. (Typically offered: Spring)

**PHYS 5653. Subatomic Physics. 3 Hours.**
Nuclear structure and nuclear reactions. Nature and properties of elementary particles and resonances, their interactions and decays. Phenomenological theory and discussion of experimental evidence. (Typically offered: Fall Odd Years)

**PHYS 5713. Condensed Matter Physics I. 3 Hours.**
The course covers the Drude theory and the Sommerfeld theory of metals, crystal lattices, reciprocal lattices, X-ray diffraction, Bloch's theory of electrons in periodic potential, formation of band gap, lattice vibration, and cohesive energy in solids. Prerequisite: PHYS 5413. (Typically offered: Fall)

**PHYS 5723. Physics at the Nanoscale. 3 Hours.**
This is a cross-disciplinary course that is focused on teaching nanoscience and engineering by studying surface science, the building and analysis of quantum-confined structures, and related nano manufacturing processes. Students will achieve an integrated knowledge of the concepts of surface science, quantum mechanics, nano processing and manipulation, and techniques of materials research. (Typically offered: Irregular)

**PHYS 5734. Laser Physics. 4 Hours.**
A combined lecture/laboratory course covering the theory of laser operation, laser resonators, propagation of laser beams, specific lasers such as gas, solid state, semiconductor and chemical lasers, and laser applications. (Typically offered: Spring Odd Years)

**PHYS 5753. Applied Nonlinear Optics. 3 Hours.**
Topics include: practical optical processes, such as electro-optic effects, acousto-optic effects, narrow-band optical filters, second harmonic generation, parametric amplification and oscillation, and other types of nonlinear optical spectroscopy techniques which are finding current practical applications in industry. (Typically offered: Irregular)

**PHYS 5773. Introduction to Optical Properties of Materials. 3 Hours.**
This course covers crystal symmetry optical transmission and absorption, light scattering (Raman and Brillouin) optical constants, carrier mobility, and polarization effects in semi-conductors, quantum wells, insulators, and other optically important materials. (Typically offered: Spring Even Years)

**PHYS 5783. Physics of 2D Materials. 3 Hours.**
Introduction to the structures of all known layered materials, followed by mechanical, electronic, spin, optical, and topological properties of two-dimensional materials. Discussion of theoretical concepts and examination of experimental manifestations of those concepts are interwoven throughout the semester. Knowledge of solid state physics is required. Pre- or Corequisite: PHYS 5413. (Typically offered: Irregular)

**PHYS 588V. Selected Topics in Physics. 1-3 Hour.**
Selected topics in experimental or theoretical physics at the advanced level. (Typically offered: Irregular) May be repeated for up to 6 hours of degree credit.

**PHYS 600V. Master of Science Thesis. 1-6 Hour.**
Master of Science Thesis. (Typically offered: Fall, Spring and Summer) May be repeated for degree credit.

**PHYS 6513. Theoretical Biophysics. 3 Hours.**
Introduction to biology as a complex system, networks and information theory, negative and positive feedback systems, gene regulation, noise, and noise propagation, cell signaling pathways, intercellular interactions, and emergence of cooperativity in biological systems. Prerequisite: PHYS 5613. (Typically offered: Fall Even Years)

**PHYS 6713. Condensed Matter Physics II. 3 Hours.**
The course covers surface physics, physics of homogeneous and inhomogeneous semiconductors, dielectric and ferroelectric physics, defects in crystals, spin interaction and magnetic properties, superconductivity, and band structure calculation. Prerequisite: PHYS 5713 and PHYS 5413. (Typically offered: Spring Even Years)

**PHYS 700V. Doctoral Dissertation. 1-18 Hour.**
Doctoral Dissertation. (Typically offered: Fall, Spring and Summer) May be repeated for degree credit.