Physics (PHYS)

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226 Physics Building
479-575-7932

Department of Physics Website (http://www.uark.edu/depts/physics)

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

Primary Areas of Faculty Research: Atomic and molecular physics; biophysics; condensed matter physics; laser physics; nanoscience; physics education; quantum optical physics; space and planetary sciences; surface physics; and theoretical physics.

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 in 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:

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<tr>
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</tr>
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<td>3</td>
</tr>
<tr>
<td>PHYS 5413</td>
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<td>3</td>
</tr>
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<td>PHYS 5323</td>
<td>Advanced Electromagnetic Theory II</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 5111</td>
<td>Research Techniques Through Laboratory Rotations</td>
<td>1</td>
</tr>
<tr>
<td>PHYS 5041</td>
<td>Journal Club Seminar</td>
<td>1</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Degree</th>
<th>Physics Electives</th>
<th>Technical Electives</th>
<th>Total Electives</th>
</tr>
</thead>
<tbody>
<tr>
<td>M.S. Physics Thesis</td>
<td>9</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>M.S. Physics Non-Thesis</td>
<td>18</td>
<td>0</td>
<td>18</td>
</tr>
</tbody>
</table>

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/#mastersdegreecontent).

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.

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

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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.

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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.
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:

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<tr>
<th>Course</th>
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<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTR 5033</td>
<td>Astrophysics I: Stars and Planetary Systems</td>
<td>3</td>
</tr>
<tr>
<td>ASTR 5043</td>
<td>Astrophysics II: Galaxies and the Large-Scale Universe</td>
<td>3</td>
</tr>
</tbody>
</table>

Nine additional hours in elective coursework appropriate to the student’s field of specialization and approved by the student’s research thesis advisory committee.

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/degerequirements/#phdandedddegreeextext).

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.

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<td>PHYS 5111</td>
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A minimum grade of B is required in the following core courses:

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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:

<table>
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<tr>
<th>Course</th>
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<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOL 4793</td>
<td>Introduction to Neurobiology</td>
<td>3</td>
</tr>
<tr>
<td>PSYC 4183</td>
<td>Behavioral Neuroscience</td>
<td>3</td>
</tr>
</tbody>
</table>
Nine additional hours in elective coursework appropriate to the student’s field of specialization and approved by the student’s research thesis advisory committee.

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/degrequi requirements/#phdandeddegree).  

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.

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

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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:

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Nine additional hours in elective coursework appropriate to the student’s field of specialization and approved by the student’s research thesis advisory committee.

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/degrequi requirements/#phdandeddegree).  

Graduate Faculty

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

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

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

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

Gea-Banacloche, Julio R., Ph.D. (University of New Mexico), Licenciado en Ciencias Fisicas (Universidad Autonoma de Madrid), Professor, 1989.

Hamad, Bothina, Ph.D. (University of Jordan), Research Associate Professor, 2016.
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.

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.

PHYS 5083. Mathematical Methods of Physics II. 3 Hours.
Applications of matrices, tensors, and linear vector spaces to problems in physics. Introduction to groups and their representations, and symmetry principles in modern physics. Prerequisite: PHYS 5073.

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.

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.

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.

PHYS 5213. Statistical Mechanics. 3 Hours.
Classical and quantum mechanical statistical theories of matter and radiation. Prerequisite: PHYS 4333 and (PHYS 4073 or PHYS 5413).

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. Pre- or Corequisite: PHYS 5423. Prerequisite: Graduate standing or instructor consent.

PHYS 5313. Advanced Electromagnetic Theory I. 3 Hours.
Electrostatics, boundary-value problems in electrostatics, electrostatics in a medium, magnetostatics, and Faraday’s Law.

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.

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.
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. Prerequisite: PHYS 4073.

PHYS 5423. Quantum Mechanics II. 3 Hours.
Continuation of PHYS 5413 Prerequisite: PHYS 5413.

PHYS 5513. Atomic and Molecular Physics. 3 Hours.
Survey of atomic and molecular physics with emphasis on the electronic structure and spectroscopy of 1 and 2 electron atoms and diatomic molecules. Includes fine and hyperfine structure, Zeeman and Stark mixing of states, collision phenomena, radiative lifetimes, and experimental techniques. Prerequisite: PHYS 5413.
PHYS 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.

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.

PHYS 5653. Subatomic Physics. 3 Hours.

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.

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.

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.

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.

PHYS 5763. Experimental Methods for Nanoscience. 3 Hours.
Fundamentals of the selected techniques suitable for characterization on the nanoscale. Focus on diverse methods such as x-ray and neutron spectroscopy, scanning probe microscopies, optical methods, electron diffraction methods and more.

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.

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. Corequisite: PHYS 5413.

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

PHYS 590V. Master of Arts Research. 1-6 Hour.

PHYS 600V. Master of Science Thesis. 1-6 Hour.
Master of Science Thesis. May be repeated for degree credit.

PHYS 6413. Quantum Mechanics III. 3 Hours.
Relativistic quantum mechanics, second quantization, with applications to quantizing electromagnetic fields and to many-body theory. Introduction to Feynman diagrams. Prerequisite: PHYS 5423.

PHYS 6513. Advanced Topics in Complexity. 3 Hours.
The goal of the course is to give students tools to investigate the behavior of complex systems and to analyze the relationship of non-linear dynamics and chaos theory to complex biological and non-biological systems. A special emphasis will be given to understanding the way neurons work as biological computing elements.

PHYS 6613. Quantum Optics. 3 Hours.
Properties of light and its interaction with atoms, particular attention given to the laser and recent experiments. Classical theory of resonance; Optical Bloch Eqs.; 2 level atoms in steady fields; pulse propagation; semiclassical theory of the laser, coherent states and coherent functions; gas, solid, and dye lasers; photon echoes and superradiance; quantum electrodynamics and spontaneous emission. Prerequisite: PHYS 5413 or equivalent.

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.

PHYS 700V. Doctoral Dissertation. 1-18 Hour.
Doctoral Dissertation. May be repeated for degree credit.