School of Physics, Astronomy, and Computational Sciences

Faculty


Associate professors: Griva*, Klimov*, Marzougui, Rosenberg, Sheng, So, Tian, Weigel, Weingartner, R. Yang*, Zhang, Zoltek

Assistant professors: Camelli, Cressman, Nikolic, Yigit, Zhao

Term associate professor: Djordjevic, Ewell, Geller, Oerter

Term assistant professors: Gliozzi, Vemuru, Wyczalkowski

Term instructors: Ericson

Emeriti: Ceperley, Ehrlich, Evans, Mielczarek

Research faculty: Bilitza, Chung, Dere, Duxbury, Economou, Hoang, Huang, Illipoulos, Mariska, Meier, Mut, Odstrcil, Poland, Richards, Sforza, Shabaev, Shebalin, Titarchuk

*Faculty holding primary appointments in other academic units.

The School of Physics, Astronomy, and Computational Sciences offers undergraduate and graduate degree programs for students with interests and career goals involving physics, computational sciences, data science, and astronomy. In addition, the School provides traditional and interdisciplinary research opportunities at the graduate and undergraduate levels, and benefits from a very high level of external grant funding. Additional information about current faculty research activities is available on the School's website, spacs.gmu.edu.

Course Work

The School of Physics, Astronomy, and Computational Sciences offers all course work designated ASTR, CDS, CSI, and PHYS in the Courses section of this catalog.

Undergraduate Programs

The School offers bachelor's degrees in physics and in astronomy. Minors are available in astronomy, in computational and data sciences, and in physics. An interdisciplinary minor is offered in renewable energy.

Undergraduate Research Opportunities

The School offers many opportunities for undergraduate students to get involved with research. Students should consult with faculty working on research topics of interest to them, based on their exploration of the School's web site.
Bachelor's/Accelerated Master's Degree

Information regarding this program can be found in the Physics, BS/Applied and Engineering Physics, Accelerated MS section of the catalog.

Honors Programs

Physics majors who have maintained an overall GPA of at least 3.50 in physics courses and a GPA of 3.50 in all courses taken at Mason may apply to the physics honors program when they complete the first semester of their junior year. To graduate with honors in physics, a student is required to maintain a minimum GPA of 3.00 in physics courses and successfully complete PHYS 405 and PHYS 406 with a GPA of at least 3.50 and a grade of at least A- in PHYS 406.

Astronomy majors who have completed the prerequisites for ASTR 405, have a GPA of at least 3.50 in ASTR and PHYS courses taken at GMU, and have a GPA of at least 3.50 in all courses taken at GMU may apply for admission to the astronomy honors program. To graduate with honors in astronomy, a student must maintain a GPA of at least 3.50 in their ASTR/PHYS courses. Students accepted into the honors program must complete ASTR 405 and ASTR 406 with a GPA of at least 3.50 and a grade of A- or better in ASTR 406. Students in ASTR 405/ASTR 406 will complete a research project and write a thesis working under the supervision of a faculty member. At the end of ASTR 406, the student will write a substantial thesis paper and make a presentation of results to their honors committee.

Writing-Intensive Requirement

Mason requires all students to complete at least one course designated as "writing intensive" in their majors at the 300 level or above. Students majoring in Physics fulfill this requirement by successfully completing PHYS 407. Astronomy majors fulfill the requirement by completing ASTR 402.

Teacher Licensure

Students who wish to become teachers should consult the College of Education and Human Development section and attend an information session early in their undergraduate career. For more information, call 703-993-2078, e-mail gacline2@gmu.edu, or go to gse.gmu.edu.

Physics for Nonmajors

PHYS 243, PHYS 244, PHYS 245, and PHYS 246 are recommended for biology, geology, and premedical students, and mathematics students who seek a BA degree. PHYS 101, PHYS 102, PHYS 103, and PHYS 104 are intended for nonscience majors. PHYS 160, PHYS 161, PHYS 260, PHYS 261 or PHYS 265, PHYS 262, and PHYS 263 constitute a calculus-based sequence in general physics to be taken by physics and engineering majors, and chemistry, computer science, and mathematics students who are pursuing a BS degree. Students may receive credit for only one of the following three sequences: PHYS 243, 244, 245, 246; PHYS 103, 104; or PHYS 160, 161, 260, 261, 262, 263.

Graduate Programs

The School offers master's degrees in Applied and Engineering Physics, and in Computational Science. The School also administers the Energy and Sustainability concentration in the Interdisciplinary Studies, MAIS program. A graduate certificate is available in Computational Techniques and Applications.
The School offers doctoral degrees in Computational Sciences and Informatics, and in Physics. These graduate programs are strongly supported by the extensive research activities of the School faculty, including many collaborations with scientists and engineers at regional government laboratories.

**Bachelor of Science**

**Astronomy, BS**

**Banner Code: SC-BS-ASTR**

The BS in astronomy prepares students for graduate school, a career in research or teaching positions, or employment in industry, business, or education fields where analytical skills and a scientific background are advantageous. Students who are considering a double major should talk to the undergraduate coordinator. Note that at least 18 credits used to fulfill an astronomy BS cannot be used to fulfill another major or minor. Some course substitutions are allowed for double majors, subject to approval from the department.

Students must fulfill all requirements for bachelor's degrees including the Mason Core. In addition, students must complete a total of 52 credits in physics and astronomy and 14 credits in mathematics with a minimum GPA of 2.00. Through the course work below, astronomy majors satisfy the university-wide requirements in natural science and quantitative reasoning. Also, by taking ASTR 402, astronomy majors satisfy the university’s writing-intensive requirement.

This program of study is offered by the School of Physics, Astronomy, and Computational Sciences in the College of Science.

**Degree Requirements**

**Required astronomy courses (10 credits)**

- ASTR 210 - Introduction to Astrophysics Credits: 3
- ASTR 328 - Stars and Interstellar Medium Credits: 3
- ASTR 402 - Methods of Observational Astronomy Credits: 4

**Additional astronomy courses (6 credits)**

Take two of the following:

- ASTR 403 - Planetary Sciences Credits: 3
- ASTR 404 - Galaxies and Cosmology Credits: 3
- PHYS 428 - Relativity Credits: 3

**Required physics courses (21 credits)**

- PHYS 160 - University Physics I Credits: 3
- PHYS 161 - University Physics I Laboratory Credits: 1
- PHYS 260 - University Physics II Credits: 3
- PHYS 261 - University Physics II Laboratory Credits: 1
- PHYS 262 - University Physics III Credits: 3
- PHYS 263 - University Physics III Laboratory Credits: 1
- PHYS 303 - Classical Mechanics Credits: 3
- PHYS 305 - Electromagnetic Theory Credits: 3
• PHYS 308 - Modern Physics with Applications Credits: 3

Required math courses (14 credits)

• MATH 113 - Analytic Geometry and Calculus I Credits: 4
• MATH 114 - Analytic Geometry and Calculus II Credits: 4
• MATH 213 - Analytic Geometry and Calculus III Credits: 3
• MATH 214 - Elementary Differential Equations Credits: 3

15 credits from the following:

(at least 12 credits must be from upper-level courses)

• ASTR 301 - Astrobiology Credits: 3
• ASTR 408 - Senior Research Credits: 3
• PHYS 306 - Wave Motion and Electromagnetic Radiation Credits: 3
• PHYS 307 - Thermal Physics Credits: 3
• PHYS 402 - Introduction to Quantum Mechanics and Atomic Physics Credits: 3
• ASTR 403 , ASTR 404 or PHYS 428 if not taken as part of additional astronomy course requirement above, may be used here.
• Other ASTR or PHYS course with the permission of the department

Total: 66 credits

Sample Schedule for Astronomy BS

First Semester

• MATH 113 - Analytic Geometry and Calculus I Credits: 4
• ENGH 101 - Composition Credits: 3
• UNIV 100 - Introduction to Mason Credits: 1
• Mason Core requirement
• Mason Core requirement

Second Semester

• MATH 114 - Analytic Geometry and Calculus II Credits: 4
• PHYS 160 - University Physics I Credits: 3
• PHYS 161 - University Physics I Laboratory Credits: 1
• Mason Core requirement
• Mason Core requirement

Third Semester

• PHYS 260 - University Physics II Credits: 3
• PHYS 261 - University Physics II Laboratory Credits: 1
• MATH 213 - Analytic Geometry and Calculus III Credits: 3
• Mason Core requirement
• Mason Core requirement
• Elective course

Fourth Semester

• PHYS 262 - University Physics III Credits: 3
• PHYS 263 - University Physics III Laboratory Credits: 1
• MATH 214 - Elementary Differential Equations Credits: 3
• ASTR 210 - Introduction to Astrophysics Credits: 3
• Mason Core requirement
• Elective Course

Fifth Semester

• ASTR 328 - Stars and Interstellar Medium Credits: 3
• PHYS 303 - Classical Mechanics Credits: 3
• PHYS 305 - Electromagnetic Theory Credits: 3
• ENGH 302 - Advanced Composition Credits: 3
• Elective course

Sixth Semester

• ASTR 404 - Galaxies and Cosmology Credits: 3
• PHYS 306 - Wave Motion and Electromagnetic Radiation Credits: 3
• PHYS 308 - Modern Physics with Applications Credits: 3
• Elective course
• Elective course

Seventh Semester

• ASTR 402 - Methods of Observational Astronomy Credits: 4
• ASTR 403 - Planetary Sciences Credits: 3
• ASTR 408 - Senior Research Credits: 3
• PHYS 402 - Introduction to Quantum Mechanics and Atomic Physics Credits: 3
• Elective course

Eighth Semester

• PHYS 307 - Thermal Physics Credits: 3
• PHYS 428 - Relativity Credits: 3
• Synthesis requirement
• Elective course
• Elective course
Degree Total: Minimum 120 credits

Physics, BS

Banner Code: SC-BS-PHYS

The BS in physics prepares students for graduate school and careers in education, business, or industry. Students in the fields of mathematics, science, and engineering who are considering a double major in physics should discuss this option with the respective undergraduate coordinators. Note that at least 18 credits used to fulfill a physics BS cannot be used to fulfill another major or minor. Some course substitutions are allowed for double majors, but these should be discussed in advance.

Students must fulfill all requirements for bachelor's degrees including the Mason Core. In addition, students must complete a total of 45 credits in the major and 20 in mathematics, with a minimum GPA of 2.00, distributed as follows. Through the course work below, physics majors satisfy the university-wide requirements in natural science and quantitative reasoning, and the intensive writing requirement by taking PHYS 407.

This undergraduate program offers students the option of applying to the accelerated master's program in physics or curriculum and instruction (SECP concentration). See each listing for specific requirements.

This program of study is offered by the School of Physics, Astronomy, and Computational Sciences in the College of Science.

Alternative Introductory Sequence

Normally, students who intend to major in physics should take the physics introductory sequence (PHYS 160, 161, 260, 261, 262, and 263). Students who decide to major in physics after completing PHYS 243, 244, 245, and 246 may do so but only with written permission of the School. Those students are required to take 4 additional credits in approved physics courses.

Degree Requirements

Physics Core Courses (27 credits)

Note: Students double majoring in engineering and physics may substitute ECE 305 for PHYS 305 and ECE 333/ECE 334 for PHYS 407.

- PHYS 160 - University Physics I Credits: 3
- PHYS 161 - University Physics I Laboratory Credits: 1
- PHYS 260 - University Physics II Credits: 3
- PHYS 261 - University Physics II Laboratory Credits: 1
- PHYS 262 - University Physics III Credits: 3
- PHYS 263 - University Physics III Laboratory Credits: 1
- PHYS 303 - Classical Mechanics Credits: 3
- PHYS 305 - Electromagnetic Theory Credits: 3
- PHYS 308 - Modern Physics with Applications Credits: 3
- PHYS 402 - Introduction to Quantum Mechanics and Atomic Physics Credits: 3
- PHYS 407 - Senior Laboratory in Modern Physics Credits: 3

Physics Electives (6 credits)
Students take 6 credits selected from the following:

- PHYS 251 - Introduction to Computer Techniques in Physics Credits: 3
- PHYS 306 - Wave Motion and Electromagnetic Radiation Credits: 3
- PHYS 307 - Thermal Physics Credits: 3
- PHYS 405 or PHYS 406 - Honors Thesis in Physics Credits: 3
- PHYS 408 - Senior Research Credits: 2-3 or PHYS 409 - Physics Internship Credits: 3
- PHYS 416 - Special Topics in Modern Physics Credits: 1
- ASTR 328 - Stars and Interstellar Medium Credits: 3 or PHYS 428 - Relativity Credits: 3

Mathematics (20 credits)

- MATH 113 - Analytic Geometry and Calculus I Credits: 4
- MATH 114 - Analytic Geometry and Calculus II Credits: 4
- MATH 203 - Linear Algebra Credits: 3
- MATH 213 - Analytic Geometry and Calculus III Credits: 3
- MATH 214 - Elementary Differential Equations Credits: 3
- and one of the following:
  - MATH 313 - Introduction to Applied Mathematics Credits: 3
  - MATH 413 - Modern Applied Mathematics I Credits: 3
  - PHYS 301 - Analytical Methods of Physics Credits: 3

Additional Science Courses (12 credits)

Students may satisfy this requirement by choosing from courses show below as well as those listed in the Areas of Emphasis.

No more than 5 credits may be chosen from:

- PHYS 121 - Uses of Physics Credits: 1
- PHYS 122 - Inside Relativity Credits: 1
- PHYS 123 - Inside the Quantum World Credits: 1
- PHYS 124 - Experimental Explorations in Physics Credits: 2
- ASTR 210 - Introduction to Astrophysics Credits: 3
  Choose at least 7 credits from the following courses:
  - CS 112 - Introduction to Computer Programming Credits: 4
  - Additional approved upper-level physics, astronomy, chemistry, electrical engineering, or mathematics courses (for examples, see the areas of emphasis below)

Emphasis Option

In meeting all or part of the requirement for 12 credits of Additional Science Courses (above), students have the option of electing an emphasis. Students who wish to complete an emphasis should plan a program of study in consultation with their advisor.

Areas of emphasis and suggested courses for each are listed below.

Emphasis in Applied Solid State Physics

This emphasis is for students who wish to pursue a career in the semiconductor industry. To complete this emphasis, students should take 12 credits selected from the following courses:
- PHYS 512 - Solid State Physics and Applications Credits: 3
- ECE 430 - Principles of Semiconductor Devices Credits: 3
- ECE 431 - Digital Circuit Design Credits: 3
and one from the following:
- PHYS 405 - Honors Thesis in Physics Credits: 3
- PHYS 406 - Honors Thesis in Physics Credits: 3
- PHYS 408 - Senior Research Credits: 2-3
- PHYS 409 - Physics Internship Credits: 3

Total: 12 credits

**Emphasis in Astrophysics**

This emphasis is for students who are planning to attend graduate school in astrophysics or pursue a career in industry. To complete this emphasis, students should take 12 credits selected from the following courses:

- PHYS 428 - Relativity Credits: 3
- ASTR 328 - Stars and Interstellar Medium Credits: 3
- ASTR 404 - Galaxies and Cosmology Credits: 3
- ASTR 535 - Space Instrumentation and Exploration Credits: 3
- MATH 446 - Numerical Analysis I Credits: 3
  Students may choose only one from the following:
- PHYS 405 - Honors Thesis in Physics Credits: 3
- PHYS 406 - Honors Thesis in Physics Credits: 3
- PHYS 408 - Senior Research Credits: 2-3
- PHYS 409 - Physics Internship Credits: 3

Total: 12 credits

**Emphasis in Computational Physics**

This emphasis is for students who wish to pursue a career that applies computers to the solution of physical problems and data analysis. To complete this emphasis, students should take 12 credits selected from the following courses:

- PHYS 510 - Computational Physics I Credits: 3
- MATH 446 - Numerical Analysis I Credits: 3
- MATH 447 - Numerical Analysis II Credits: 3
  and one from the following:
- PHYS 405 - Honors Thesis in Physics Credits: 3
- PHYS 406 - Honors Thesis in Physics Credits: 3
- PHYS 408 - Senior Research Credits: 2-3
- PHYS 409 - Physics Internship Credits: 3

Total: 12 credits

**Emphasis in Electronics**

This emphasis is for students who wish to pursue a career in industry, applying a strong background in electronics to physical problems. To complete this emphasis, students should take 12 credits selected from the following courses:
- ECE 301 - Digital Electronics Credits: 3
- ECE 333 - Linear Electronics I Credits: 3
- ECE 430 - Principles of Semiconductor Devices Credits: 3
- ECE 431 - Digital Circuit Design Credits: 3
- ECE 433 - Linear Electronics II Credits: 3

Students may choose only one from the following:
- PHYS 405 - Honors Thesis in Physics Credits: 3
- PHYS 406 - Honors Thesis in Physics Credits: 3
- PHYS 408 - Senior Research Credits: 2-3
- PHYS 409 - Physics Internship Credits: 3

Total: 12 credits

**Emphasis on Graduate School Preparation**

Although any of the options listed here provide the successful student with a fully adequate background to enter graduate school, this emphasis is for students whose career goals definitely include graduate work in physics. To complete this emphasis, students should take 12 credits selected from the following courses:

- PHYS 410 - Computational Physics I Credits: 3
- PHYS 412 - Solid State Physics and Applications Credits: 3
- PHYS 440 - Nuclear and Particle Physics Credits: 3
- PHYS 405 - Honors Thesis in Physics Credits: 3
- PHYS 406 - Honors Thesis in Physics Credits: 3
- PHYS 408 - Senior Research Credits: 2-3
- PHYS 409 - Physics Internship Credits: 3

Total: 12 credits

**Emphasis in Medical Physics**

Physics majors generally have an excellent acceptance record in applying to medical, dental, or veterinary schools. Although there is no formal set of courses within physics that is uniquely suitable, students should meet with a physics advisor and a health sciences advisor for information about the university’s Medical Sciences Advisory Committee. For more information, call 703-993-1050.

Because schools in the health sciences vary both in their philosophies and specific requirements, it is wise for students to become aware of such information well in advance of applying for admission. Although specific requirements vary, most programs do require applicants to complete at least one year of biology. Other requirements generally include organic chemistry.

- CHEM 313 - Organic Chemistry Credits: 3
- CHEM 314 - Organic Chemistry II Credits: 3
- CHEM 315 - Organic Chemistry Lab I Credits: 2
- CHEM 318 - Organic Chemistry Lab II Credits: 2
- PHYS 408 - Senior Research Credits: 2-3

Total: 12 credits

**Emphasis in Physics Education**
This emphasis is intended for students wishing to pursue a career teaching secondary school physics. The goal of the program is to allow students to receive a license to teach physics in Virginia secondary schools within 120 credits.

It is recommended that students seeking a career in physics education take PHYS 306 and PHYS 307 to fulfill the additional physics requirement (see above) for the major. In addition to the standard requirements for the physics major, students should enroll in 3 credits of directed study in physics laboratory instruction under PHYS 390.

The following courses are required to qualify for the teaching license. Students who complete EDRD 419 and either EDCI 473 or EDCI 483 fulfill 6 of the 12 credits of the Additional Science Courses requirement (see above) and should consult the physics advisor on which courses fulfill the remainder of the requirement.

- PHYS 390 - Topics in Physics Credits: 1-4 (physics laboratory instruction) for 3 credits
- EDCI 473 - Teaching Science in the Secondary School Credits: 3
- EDCI 483 - Advanced Methods of Teaching Science in Secondary School Credits: 3
- EDRD 419 - Literacy in the Content Areas Credits: 3
- EDCI 490 - Student Teaching in Education Credits: 6
- EDUC 372 - Human Development, Learning, and Teaching Credits: 3
- EDUC 422 - Foundations of Secondary Education Credits: 3
- pass the Praxis Core and Praxis II exams

Total: 24 credits

Sample Schedule for Physics BS

(excluding Mason Core courses)

First Semester

- MATH 113 - Analytic Geometry and Calculus I Credits: 4
- PHYS 122 - Inside Relativity Credits: 1
- PHYS 123 - Inside the Quantum World Credits: 1

Second Semester

- MATH 114 - Analytic Geometry and Calculus II Credits: 4
- PHYS 160 - University Physics I Credits: 3
- PHYS 161 - University Physics I Laboratory Credits: 1
- CS 112 - Introduction to Computer Programming Credits: 4

Third Semester

- PHYS 251 - Introduction to Computer Techniques in Physics Credits: 3
- PHYS 260 - University Physics II Credits: 3
- PHYS 261 - University Physics II Laboratory Credits: 1
- MATH 213 - Analytic Geometry and Calculus III Credits: 3

Fourth Semester
• PHYS 262 - University Physics III Credits: 3
• PHYS 263 - University Physics III Laboratory Credits: 1
• MATH 203 - Linear Algebra Credits: 3
• MATH 214 - Elementary Differential Equations Credits: 3

Fifth Semester

• PHYS/MATH elective
• PHYS 303 - Classical Mechanics Credits: 3
• PHYS 305 - Electromagnetic Theory Credits: 3
• MATH 313 - Introduction to Applied Mathematics Credits: 3

Sixth Semester

• PHYS 306 - Wave Motion and Electromagnetic Radiation Credits: 3
  or
• PHYS 307 - Thermal Physics Credits: 3
• PHYS 308 - Modern Physics with Applications Credits: 3

Seventh Semester

• PHYS 402 - Introduction to Quantum Mechanics and Atomic Physics Credits: 3
• PHYS 407 - Senior Laboratory in Modern Physics Credits: 3
• PHYS 410 - Computational Physics I Credits: 3
• PHYS 416 - Special Topics in Modern Physics Credits: 1

Eighth Semester

• PHYS 408 - Senior Research Credits: 2-3
• PHYS 412 - Solid State Physics and Applications Credits: 3
• PHYS 440 - Nuclear and Particle Physics Credits: 3

Bachelor/Accelerated Master's

Physics, BS/Applied and Engineering Physics, Accelerated MS

This program allows academically strong undergraduates with a commitment to research to obtain the Physics, BS and Applied and Engineering Physics, MS degrees by successfully completing 144 credits. Upon completion, students are exceptionally well-prepared for entry into a professional school or a PhD program in physics or a related discipline. Well-prepared students are encouraged to apply to this program after they complete 90 undergraduate credits. Admitted students take selected graduate courses during their senior year (when they have successfully completed prerequisites) and are able to use up to 6 graduate credits in partial satisfaction of requirements for the undergraduate degree. Upon completion and conferral of the bachelor's degree and with satisfactory performance (3.00) in the graduate courses, students are given advanced standing in the master's program and complete an additional 24 credits to receive the master's degree.

See the AP.6.7 Bachelor's/Accelerated Master's Degrees section of the catalog for policies related to this program.
This program of study is offered by the School of Physics, Astronomy, and Computational Sciences.

Students in an accelerated degree program must fulfill all university requirements for the bachelor's and master's degrees. For policies governing all degrees, see the Academic Policies section of the catalog.

**Application Requirements**

Applicants to all graduate programs at George Mason University must meet the admission standards and application requirements for graduate study as specified in the Admissions section of the catalog.

Successful applicants will have an overall undergraduate GPA of at least 3.50 and will have completed 45 credits in physics major coursework. A recommendation letter from a research supervisor is also required. Interested applicants should then submit a letter to the undergraduate physics coordinator requesting admission along with the aforementioned recommendation letter. Contact the physics undergraduate or graduate coordinator for further details.

**Accelerated Option Requirements**

At the beginning of the student's final undergraduate semester, students must submit a bachelor's/accelerated master's transition form (available from the Office of the University Registrar) to the College of Science's Office of Academic and Student Affairs. Students must begin their master's program in the semester immediately following conferral of the bachelor's degree.

Students must maintain an overall GPA of 3.00 or higher in graduate coursework.

**Reserve Graduate Credit**

While still in undergraduate status, a maximum of 6 additional graduate credits may be taken as reserve graduate credit and applied to the master's program. Reserve graduate credits do not apply to the undergraduate degree.

**Doctor of Philosophy**

**Computational Sciences and Informatics, PhD**

**Banner Code: SC-PHD-CSI**

Founded in 1992, the computational sciences and informatics (CSI) doctoral program addresses the role of computation in science, mathematics, and engineering, and is designed around a core of advanced computer technology courses. Computational science is defined as the systematic development and application of computing systems and computational solution techniques for modeling and simulation of scientific and engineering phenomena. Informatics is defined as the systematic development and application of computing systems and computational solution techniques for analyzing data obtained through experiments, modeling, database searches, and instrumentation. The resulting interdisciplinary approach often leads to understanding that, in many cases, traditional theory or experimentation alone cannot provide. The close relationship of the CSI doctoral program to the research and development activities in federal laboratories, scientific institutions, and high-technology firms affords students opportunities for continued or new employment. Scheduled courses and sequences accommodate part-time students, with most courses meeting once a week in the late afternoon or early evening. The research and teaching activities associated with the CSI program reflect the recognized role of computation as part of a triad with theory and experimentation, leading to a better understanding of nature.

This program of study is offered by the School of Physics, Astronomy, and Computational Sciences in the College of Science.

**Admission Requirements**
Applicants to all graduate programs at George Mason University must meet the admission standards and application requirements for graduate study as specified in the Admission section of this catalog. Students interested in applying for admission into the CSI PhD program should have a bachelor's degree in any natural science, mathematics, engineering, or computer science with a minimum GPA of 3.00 in their last 60 credits of study. All applicants to the PhD program should have a mathematics background up to and including differential equations. All applicants to the PhD program should also have knowledge of a computer programming language such as C, C++, FORTRAN, etc.

The GRE is required, unless the applicant holds a master's degree from a school in the United States. A TOEFL score of 570 (paper-based test) or 230 (computer-based test), or 88 points total and a minimum of 20 points in each section (Internet-based test), is required for international students. The ETS code for GMU is 5827.

Students should submit a completed graduate application along with three letters of recommendation, an expanded goals statement, and application fee (payable to George Mason University) in addition to the items listed above.

Applications should be received by March 1 for fall semester and November 1 for spring semester. Applications requesting financial support must be received by February 1 for the fall semester. Please note that applications from local applicants may be accepted after these general deadlines.

Please send completed applications to the address below:

COS Graduate Applications Processing Center
George Mason University
4400 University Drive, MS 6A3
Fairfax, VA 22030

For additional information, phone 703-993-1998; fax 703-993-9300, or e-mail: blaisten@gmu.edu.

**Reduction of Credit**

For students entering the doctoral program with a master's degree in a related field from a regionally accredited institution, the number of required credits may be reduced up to 30 credits, subject to approval of the program faculty and the associate dean for student and academic affairs. See the College of Science graduate policies section for more information.

**Program of Study**

The list of research areas tells only part of the story because the greatest strength of the CSI doctoral program lies in its ability to foster and promote truly interdisciplinary research that crosses traditional domain boundaries. In the CSI doctoral program, each student is presented with an exciting opportunity to create a new area of interdisciplinary inquiry that would not fit into a traditional PhD program. Students in the CSI doctoral program use computationally intensive methods to solve current problems in these scientific areas.

**Degree Requirements**

The 72-credit doctoral program combines three intellectual elements:

- Core computational science topics
- Computational intensive courses in specific scientific areas
- Research leading to the dissertation

The doctoral program, designed to be completed in 4 to 5 years, includes the following requirements:

- 12 credits of core computational courses (scientific computing, databases, visualization)
• 33-35 credits of approved courses consistent with an area of emphasis, if applicable, and with the approval of the dissertation committee and the graduate coordinator, with at least 24 credits of CSI courses listed in the catalog.
• 1-3 credits in CSI colloquium/seminar
• 24 credits in dissertation research

Students must satisfy all requirements for doctoral degrees expressed in the Academic Policies section of this catalog.

Doctoral Course Work (48 credits)

Students are required to take 33 credits of science courses with at least 24 credits of CSI courses. Lists of courses that set the foundations for each research area are provided as guideline only.

General Core Courses (12 credits)

Select from the following:

• CSI 690 - Numerical Methods Credits: 3
• CSI 695 - Scientific Databases Credits: 3
• CSI 701 - Foundations of Computational Science Credits: 3
• CSI 702 - High-Performance Computing Credits: 3
• CSI 703 - Scientific and Statistical Visualization Credits: 3

Areas of Emphasis (12-15 credits)

Students are advised to choose one of the research areas listed below. Students may also pursue interdisciplinary research that combines the areas of emphasis listed below with each other and also with quantum information science, climate dynamics, bioinformatics, and computational neuroscience.

Computational Fluid Dynamics

• CSI 720 - Fluid Mechanics Credits: 3
• CSI 721 - Computational Fluid Dynamics I Credits: 3
• CSI 722 - Computational Fluid Dynamics II Credits: 3
• CSI 742 - The Mathematics of the Finite Element Method Credits: 3

plus one from:

• CSI 629 - Topics in Continuum Systems Credits: 3
• CSI 685 - Fundamentals of Materials Science Credits: 3
• CSI 780 - Computational Physics and Applications Credits: 3
• CSI 786 - Molecular Dynamics Modeling Credits: 3
• CSI 787 - Computational Materials Science Credits: 3
• CSI 789 - Topics in Computational Physics Credits: 3 (when topic is Mechanics of Solids)

Computational Materials and Physical Chemistry Sciences

• CSI 685 - Fundamentals of Materials Science Credits: 3
• CSI 780 - Computational Physics and Applications Credits: 3
• CSI 782 - Statistical Mechanics for Modeling and Simulation Credits: 3
or

- CSI 783 - Computational Quantum Mechanics Credits: 3
- CSI 787 - Computational Materials Science Credits: 3

plus one from:

- CSI 786 - Molecular Dynamics Modeling Credits: 3
- CSI 789 - Topics in Computational Physics Credits: 3 (when topic is Mechanics of Solids)
- CSI 885 - Atomistic Modeling of Materials Credits: 3

**Space Sciences and Computational Astrophysics**

- PHYS 685 - Classical Electrodynamics I Credits: 3
- CSI 661 - Stellar Astrophysics Credits: 3
  or
  - CSI 662 - Introduction to Space Weather Credits: 3
- CSI 781 - Plasma Science Credits: 3
  or
  - CSI 764 - Computational Astrophysics Credits: 3

plus two from:

- CSI 721 - Computational Fluid Dynamics I Credits: 3
- CSI 763 - Statistical Methods in Space Sciences Credits: 3
- CSI 780 - Computational Physics and Applications Credits: 3
- CSI 782 - Statistical Mechanics for Modeling and Simulation Credits: 3
- CSI 783 - Computational Quantum Mechanics Credits: 3

**Computational Mathematics**

- CSI 740 - Numerical Linear Algebra Credits: 3
- CSI 742 - The Mathematics of the Finite Element Method Credits: 3
- CSI 747 - Nonlinear Optimization and Applications Credits: 3
- CSI 771 - Computational Statistics Credits: 3
- CSI 786 - Molecular Dynamics Modeling Credits: 3

**Computational Physics**

- CSI 780 - Computational Physics and Applications Credits: 3
- CSI 782 - Statistical Mechanics for Modeling and Simulation Credits: 3
- CSI 783 - Computational Quantum Mechanics Credits: 3

plus two from:

- CSI 781 - Plasma Science Credits: 3
- CSI 786 - Molecular Dynamics Modeling Credits: 3
- CSI 787 - Computational Materials Science Credits: 3
• CSI 788 - Simulation of Large-Scale Physical Systems Credits: 3

Computational Statistics

• CSI 771 - Computational Statistics Credits: 3
• CSI 773 - Statistical Graphics and Data Exploration Credits: 3
  or
• CSI 876 - Measure and Linear Spaces Credits: 3
  or
• CSI 971 - Probability Theory Credits: 3
• CSI 972 - Mathematical Statistics I Credits: 3
• CSI 973 - Mathematical Statistics II Credits: 3

Computational Learning

• CSI 771 - Computational Statistics Credits: 3
• CSI 772 - Statistical Learning Credits: 3
• CSI 773 - Statistical Graphics and Data Exploration Credits: 3
• CSI 777 - Principles of Knowledge Mining Credits: 3
• CSI 873 - Computational Learning and Discovery Credits: 3

Colloquium/Seminar (1-3 credits)

The School of Physics, Astronomy, and Computational Sciences offers several weekly colloquia and seminar series to ensure that students are exposed to the latest developments at area research institutions. Doctoral students are encouraged to participate in national and international meetings where they can present their latest findings.

A maximum of 3 colloquium/seminar credits from CSI 898 and/or CSI 991 may be applied toward satisfying the 48-credit coursework requirement.

• CSI 898 - Research Colloquium in Computational Sciences and Informatics Credits: 1
• CSI 991 - Seminar in Scientific Computing Credits: 1

Electives (18-21)

If necessary, students take additional electives in consultation with program director to bring the total number of credits to 72.

Interdisciplinary Studies

Students may also pursue interdisciplinary research that combines the areas of emphasis listed above with each other and also with geoinformation sciences, remote sensing, computational chemistry, climate dynamics, and bioinformatics, several of which are autonomous PhD programs within COS.

Candidacy Examination

The student must successfully complete separate written, computational, and oral candidacy examinations prepared and administered by the dissertation committee.
Dissertation Proposal and Advancement to Candidacy

Students advance to doctoral candidacy by fulfilling the following requirements:

- The student must successfully complete candidacy examinations as stated above.
- The student prepares a dissertation proposal describing in detail the planned dissertation research. The proposal must be approved by the dissertation committee.
- Following successful completion of the research proposal and candidacy exams, the committee will recommend the student for advancement to doctoral candidacy.

Doctoral Research (24 credits)

No more than 24 combined credits from CSI 998 and CSI 999 may be applied toward satisfying doctoral degree requirements, with a minimum of 6 credits of CSI 999.

- CSI 998 - Doctoral Dissertation Proposal Credits: 1-12
- CSI 999 - Doctoral Dissertation Credits: 1-12

Dissertation Research and Defense

After advancing to candidacy, the student will work on a doctoral dissertation while enrolled in CSI 999. The dissertation is a written piece of original mathematics that demonstrates a doctoral candidate's mastery of the subject matter. A student is expected to produce new and original research worthy of publication in a peer-reviewed journal. After the dissertation is completed, the committee will review the dissertation and examine the student in a public oral dissertation defense.

Total: 72 credits

Academic Common Market

The CSI PhD degree program has been approved for inclusion in the Academic Common Market (ACM), offered through the Southern Regional Education Board (SREB). The ACM allows certified residents of some states that do not offer this degree program to enroll as full-time students in the CSI PhD program while paying tuition at the Virginia in-state rate. Program inclusion in the ACM is subject to periodic review by each participating state and is not guaranteed. If state certified, students must meet all requirements for ACM participation and stay continuously enrolled. More information is available in this catalog at AP.1.4.9, online through the SREB web site, and on the University Registrar's web page under Non-Resident Programs.

Physics, PhD

Banner Code: SC-PHD-PHYS

All doctoral students accepted into the physics PhD program take a common core of four courses (see below). By working with the Dissertation Committee, a student may choose to specialize in an emphasis area such as astrophysics, biophysics, nonlinear physics, planetary sciences, material physics, space weather physics, or others according to his or her particular interests. By the end of their first year, all students should pair with a faculty advisor who will guide them toward doctoral candidacy.

This program of study is offered by the School of Physics, Astronomy, and Computational Sciences in the College of Science.

Admission Requirements
Those holding a baccalaureate degree in physics or astronomy from an accredited institution, who earned a GPA of 3.00 (out of 4.00) or higher in their last 60 credits, and received acceptable scores on the GRE-GEN are invited to apply for admission. Three letters of recommendation must be submitted, preferably from former professors. The GRE subject test in physics is highly recommended for all interested applicants who received their baccalaureate degrees within the past five years. A degree-seeking graduate applicant with a baccalaureate degree who has not met all admission requirements may be offered provisional admission if sufficient evidence is presented to suggest that the applicant has the ability to pursue graduate work. For more details concerning admission requirements to George Mason University please refer to the Graduate Admission Policies and Admission of International Students sections of this catalog.

Reduction of Credit

For students entering the doctoral program with a master's degree in a related field from a regionally accredited institution, the number of required credits may be reduced up to 30 credits, subject to approval of the program faculty and the associate dean for student and academic affairs. See the College of Science graduate policies section for more information.

Degree Requirements

Students must satisfy all requirements for doctoral degrees expressed in the Academic Policies section of this catalog.

All students in the Physics PhD program must earn a minimum of 72 graduate credits. Of these, 48 are required course work and preliminary research credits, and 24 are doctoral dissertation proposal and doctoral dissertation research credits. For students entering the doctoral program with a master's degree in physics or a related field, or relevant graduate course work, the 48 credit requirement may be reduced by a maximum of 30 credits.

Doctoral Course Work (48 credits)

Physics Core (12 credits)

Note: the doctoral candidacy (qualifying) examination is based on the topics covered in these four core courses.

- PHYS 684 - Quantum Mechanics I Credits: 3
- PHYS 685 - Classical Electrodynamics I Credits: 3
- PHYS 705 - Classical Mechanics Credits: 3
- PHYS 711 - Statistical Mechanics Credits: 3

Qualifying Examination

All students must successfully pass the four individual sections (quantum mechanics, electromagnetic theory, classical mechanics and statistical mechanics) of a qualifying examination. The four topics in the qualifying exam are covered in the four core courses (PHYS 684, PHYS 685, PHYS 705, and PHYS 711). All four sections of the qualifying exam will be offered twice a year typically in the week before the start of the fall and spring semesters. A student can choose to take a particular section or a combination of sections at one sitting. Grades of "pass" or "unsatisfactory" will be given individually for each of the four sections of the exam. If a student receives a grade of "unsatisfactory" in a given section of the exam, he/she is allowed to retake that section in the next cycle but a student must satisfactorily pass all sections of the exam by the end of the third year from the date of enrollment in the PhD program. Students entering the program with equivalent courses taken at another institution can satisfy the core requirement by taking the qualifying exam without taking the course.

At the beginning of each academic year, the program director will appoint members to the qualifying examination committee. This committee is responsible for creating, administering, and grading the qualifying exams offered that year. Additional information and previous qualifying exams can be found at http://complex.gmu.edu/phd/qualifier.html.
Dissertation Committee and Program of Study

Upon successful completion of the qualifying examinations, a Dissertation Committee should be formed by the student as soon as possible. This chair of this committee must be a graduate faculty member from the School of Physics, Astronomy and Computational Sciences. The committee must include at least two additional members from the graduate faculty, one of whom must be from outside SPACS. The composition of the committee must be approved by the program director. The Dissertation Committee is responsible for directing the student in their chosen field of research. The student should work closely with their committee to select specialty courses and electives that form a cohesive program of study. The student's program of study must be approved by the dean before advancement to candidacy.

Specialty Science Courses (6 credits)

Students must complete two out of the following four physics and astronomy electives

- PHYS 784 - Quantum Mechanics II Credits: 3
- PHYS 785 - Classical Electrodynamics II Credits: 3
- ASTR 680 - Physics of Interstellar Media Credits: 3
- ASTR 730 - Stellar Astrophysics Credits: 3

General Science Electives (27 credits)

27 credits of approved general electives and preliminary research credits

- PHYS 796 - Directed Reading and Research Credits: 1-12
- PHYS 798 - Research Project Credits: 3
- ASTR 796 - Directed Reading and Research Credits: 1-12
- ASTR 798 - Research Project Credits: 3

NOTE: PHYS 796/ASTR 796 may be repeated as needed. General electives may be any graduate level courses chosen from physics, astronomy and/or other related disciplines approved by the student's advisor or dissertation committee.

Seminar (3 credits)

- PHYS 703 - Seminar in Physics Credits: 1 (must be taken three times)

Advancement to Candidacy

Before a student may be advanced to doctoral candidacy, he/she needs to complete all required course work, pass the qualifying examination, have the program of study and dissertation proposal approved by the dean, and been recommended by the dissertation committee. Advancement to doctoral candidacy implies that the student has demonstrated adequate breadth and depth of knowledge in the field of study and is capable of conducting research on the boundaries of knowledge.

Dissertation Research (24 credits)

Note: no more than 24 combined credits from PHYS 998/ASTR 998 and PHYS 999/ASTR 999 may be applied toward satisfying the doctoral degree requirements, with no more than 12 credits of PHYS 998/ASTR 998.

- ASTR 998 - Doctoral Dissertation Proposal Credits: 1-12
- ASTR 999 - Doctoral Dissertation Credits: 1-12
- PHYS 998 - Doctoral Dissertation Proposal Credits: 1-12
Doctoral Dissertation

After advancing to doctoral candidacy, the student works with their Dissertation Committee to develop their preliminary research into a doctoral dissertation. The dissertation research should represent a significant contribution to its scientific field and should be deemed publishable in a refereed scientific journal. The dissertation must be defended in a public forum before the Dissertation Committee and other interested faculty.

Total: 72 credits

Graduate Certificate

Computational Techniques and Applications Graduate Certificate

Banner Code: SC-CERG-CTA

This certificate program focuses on mastering a variety of basic computational skills. The certificate is independent of the doctoral and master's programs and is designed primarily for professionals in technical fields who seek to upgrade their computer expertise. This program is also available as an option for prospective or currently enrolled doctoral or master's degree students.

The program consists of 15 credits of course work designed to provide an accelerated introduction to concepts in modern computation. Topics include operating systems, environments, languages, graphics, databases, and applications.

Special course schedules may be designed depending upon the background and qualifications of the student. For example, some (or all) of the tools and techniques courses may be waived if the equivalent knowledge can be adequately demonstrate equivalent knowledge. The waived credits are to be replaced with applications courses approved by the director of the certificate program. The recommended course sequence is tools and then applications.

The graduate certificate in computational techniques and applications may be pursued only on a part-time basis.

This program of study is offered by the School of Physics, Astronomy, and Computational Sciences in the College of Science.

Admission Requirements

Applicants to all graduate programs at George Mason University must meet the admission standards and application requirements for graduate study as specified in the Admission section of this catalog. Applicants to the Computational Techniques and Applications Graduate Certificate should have an academic background in physical or biological sciences, engineering, mathematics, or computer science. They should have an undergraduate degree from a regionally accredited institution, with a GPA of at least 3.00 in their last 60 credits of study. In addition, applicants should have taken at least one course in differential equations and have facility in using a high-level computer programming language.

To apply, prospective students should forward a completed Mason graduate application, two copies of official transcripts from each college and graduate institution attended, and a current résumé to the COS Fairfax Campus Graduate Admissions Processing Center. TOEFL scores are required of all international applicants.

Certificate Requirements

Tools Courses (3-12 credits as needed)
The tools courses are practical, skill-based courses covering specific software packages commonly used by scientists and engineers to solve science-related problems. Depending on the student's background, 3-12 credit hours of tools courses are required. These courses are designed for professionals who are already familiar with other languages, packages and operating systems, but need a rapid introduction to specific software and mathematical methods used by scientists and engineers. One 3-credit tools course is required.

Choose one to four courses from the following:

- CSI 500 - Computational Science Tools Credits: 3
- CSI 501 - Introduction to Scientific Programming Credits: 3
- CSI 600 - Quantitative Foundations for Computational Sciences Credits: 3
- CSI 690 - Numerical Methods Credits: 3

Applications Courses (minimum 3 credits)

The applications courses provide content from a specific scientific domain and demonstrate the utilization of techniques within its context. These courses are electives and can be selected from any CSI emphasis area. One 3-credit applications course is required.

- Choose from any CSI course listed in the catalog excluding CSI 796, CSI 798, CSI 799, CSI 898, CSI 899, CSI 991, CSI 996, and the courses used to satisfy the tools category

Total: 15 credits

Master of Science

Applied and Engineering Physics, MS

Banner Code: SC-MS-PHAE

This degree contains elements of traditional physics programs and the application of physics to a diversity of critical societal problems. The program is divided into three areas of emphasis. The standard emphasis is intended for students who may wish to pursue further graduate study in physics leading to a PhD degree in preparation for a career in basic research. The applied physics emphasis is intended for those who wish to apply the techniques and subject areas of physics to multifaceted problems encountered in the workplace, particularly in physics, engineering, computational science, and other related areas. The engineering physics emphasis allows students to select a larger number of courses from electrical engineering or nanotechnology and other areas.

Many courses are offered during late afternoon or evening hours to allow students with full-time employment to attend easily. Students employed at area high-technology organizations may take up to 6 credits (out of 30) for work done on the job under the guidance of a faculty member. This employment-related research may be conducted under an optional 3-credit research project or an optional 6-credit master's thesis. Master's students who are not employed full time may apply for financial aid or a limited number of research assistantships.

An accelerated master's option is available to students in the bachelor's program. See Physics, BS/Applied and Engineering Physics, Accelerated MS for specific requirements.

This program of study is offered by the School of Physics, Astronomy, and Computational Sciences in the College of Science.

Admission Requirements
Individuals holding a baccalaureate degree in physics or a related field from an accredited institution and who earned a GPA of 3.00 (out of 4.00) in their last 60 credits are invited to apply for admission. If the baccalaureate degree is in a field other than physics, applicants should have taken several courses beyond the introductory physics courses, such as junior-level classical mechanics, electricity and magnetism, or electronics. Applicants may be required to make up one or two deficiencies, based on a graduate physics advisor's assessment, and be provisionally admitted into the program. Three letters of recommendation must be submitted, preferably from former professors. The general GRE and the GRE subject test in physics are recommended for applicants who received their baccalaureate degrees within the past five years.

Degree Requirements

Candidates for the degree must successfully complete 30 credits in the categories shown below:

6 credits of required core courses:

- PHYS 684 - Quantum Mechanics I Credits: 3
- PHYS 685 - Classical Electrodynamics I Credits: 3

Course substitution in select emphases

For the applied physics emphasis and the engineering physics emphasis, students may substitute:

- PHYS 502 - Introduction to Quantum Mechanics and Atomic Physics Credits: 3 (for PHYS 684)
- PHYS 513 - Applied Electromagnetic Theory Credits: 3 (for PHYS 685)

15 credits in one of three emphases:

Standard Emphasis

Students must take:

- PHYS 705 - Classical Mechanics Credits: 3
- PHYS 711 - Statistical Mechanics Credits: 3

Plus any 9 credits from this list

- PHYS 510 - Computational Physics I Credits: 3
- PHYS 512 - Solid State Physics and Applications Credits: 3
- PHYS 533 - Modern Instrumentation Credits: 3
- PHYS 540 - Nuclear and Particle Physics Credits: 3
- PHYS 575 - Atmospheric Physics I Credits: 3
- PHYS 611 - Electro-optics Credits: 3
- PHYS 612 - Physics of Modern Imaging Credits: 3
- PHYS 613 - Computational Physics II Credits: 3
- PHYS 614 - Thermodynamics and Kinetics of Materials Credits: 3
- PHYS 615 - Fundamentals of Materials Science Credits: 3
- PHYS 620 - Continuum Mechanics Credits: 3
- PHYS 630 - Introduction to Biophysics Credits: 3
- PHYS 660 - Space Weather Credits: 3
- PHYS 676 - Atmospheric Physics Credits: 3
- PHYS 684 - Quantum Mechanics I Credits: 3
- PHYS 685 - Classical Electrodynamics I Credits: 3
- PHYS 701 - Theoretical Physics Credits: 3
- PHYS 728 - Simulation of Large-Scale Physical Systems Credits: 3
- PHYS 736 - Computational Quantum Mechanics Credits: 3
- PHYS 760 - Space Plasma Physics Credits: 3
- PHYS 780 - Advanced Selected Topics in Physics Credits: 3
- PHYS 784 - Quantum Mechanics II Credits: 3
- PHYS 785 - Classical Electrodynamics II Credits: 3
- ASTR 532 - Phys Interplanetary Med Credits: 3
- ASTR 602 - Methods of Observational Astronomy Credits: 4
- ASTR 603 - Planetary Sciences Credits: 3
- ASTR 604 - Galaxies and Cosmology Credits: 3
- ASTR 628 - Relativity Credits: 3
- ASTR 660 - Plasma Physics for Space and Astrophysics Credits: 3
- ASTR 680 - Physics of Interstellar Media Credits: 3
- ASTR 730 - Stellar Astrophysics Credits: 3
- ASTR 761 - N-Body Methods and Part Sim Credits: 3
- ASTR 764 - Computational Astrophysics Credits: 3
- ASTR 765 - High-Energy and Accretion Astrophysics Credits: 3
- CSI 720 - Fluid Mechanics Credits: 3
- CSI 721 - Computational Fluid Dynamics I Credits: 3
- CSI 722 - Computational Fluid Dynamics II Credits: 3
- CSI 786 - Molecular Dynamics Modeling Credits: 3
- CSI 787 - Computational Materials Science Credits: 3

Total: 15 credits

Engineering physics emphasis

Students must take:

- PHYS 510 - Computational Physics I Credits: 3
- PHYS 533 - Modern Instrumentation Credits: 3
- 9 credits of ECE graduate courses

Total: 15 credits

Applied physics emphasis

Students must take:

- PHYS 510 - Computational Physics I Credits: 3
- PHYS 533 - Modern Instrumentation Credits: 3
plus any 9 credits from this list:

- ASTR 535 - Space Instrumentation and Exploration Credits: 3
- BINF 731 - Protein Structure Analysis Credits: 3
- BINF 741 - Introduction to Computer Simulations of Biomolecules Credits: 3
- CLIM 710 - Introduction to Physical Climate System Credits: 3
- CLIM 711 - Introduction to Atmospheric Dynamics Credits: 3
- CLIM 712 - Physical and Dynamical Oceanography Credits: 3
- CLIM 713 - Atmosphere-Ocean Interactions Credits: 3
- CLIM 714 - Land-Climate Interactions Credits: 3
- CLIM 715 - Numerical Methods for Climate Modeling Credits: 3
- CLIM 750 - Geophysical Fluid Dynamics Credits: 3
- CSI 742 - The Mathematics of the Finite Element Method Credits: 3
- CSI 763 - Statistical Methods in Space Sciences Credits: 3
- CSI 782 - Statistical Mechanics for Modeling and Simulation Credits: 3
- CSI 783 - Computational Quantum Mechanics Credits: 3
- ECE 521 - Modern Systems Theory Credits: 3
- ECE 528 - Introduction to Random Processes in Electrical and Computer Engineering Credits: 3
- ECE 548 - Sequential Machine Theory Credits: 3
- ECE 565 - Introduction to Optical Electronics Credits: 3
- ECE 584 - Semiconductor Device Fundamentals Credits: 3
- ECE 699 - Advanced Topics in Electrical and Computer Engineering Credits: 1-6
- PHYS 581 - Topics in Renewable Energy Credits: 3
- or any course listed in the Standard Emphasis

Total: 15 credits

9 credits of electives chosen from courses in:

- Physics, chemistry, mathematics, engineering, information technology, and computational sciences and informatics. No more than 6 credits may be chosen from areas outside ASTR, CSI, ECE, NANO, and PHYS.

Elective credits can include a project or thesis.

- ECE 798 - Research Project Credits: 1-3
- ECE 799 - Master's Thesis Credits: 1-6
- PHYS 798 - Research Project Credits: 3
- PHYS 799 - Master's Thesis Credits: 1-6

Notes:

Students may choose to do either ECE/PHYS 798 - Research Project Credits: 3 or ECE/PHYS 799 - Master's Thesis (6 credits), but not both. The research project may be conducted at a student's place of employment with the concurrence of a faculty advisor.

The thesis is a more substantial piece of work performed under the supervision of a faculty member and requires students to make an oral defense. ECE/PHYS 798 may be taken only once. No more than 6 credits of PHYS 799 may be applied to the degree.
In addition to the requirements stated above, students may also select a research focus in astrophysics, atmospheric physics, biological applications of physics, computational physics, condensed matter, instrumentation (engineering physics), or nonlinear dynamics. A focus requires that students complete 15 credits of approved courses.

Students in the master's degree program can earn a graduate certificate in computational techniques and applications from the School of Physics, Astronomy, and Computational Sciences by choosing an approved sequence of courses.

Total 30 credits

Sample course lists for various focus areas:

Astrophysics:

- PHYS 701 - Theoretical Physics Credits: 3
- PHYS 711 - Statistical Mechanics Credits: 3
- ASTR 680 - Physics of Interstellar Media Credits: 3

Atmospheric physics:

- PHYS 510 - Computational Physics I Credits: 3
- PHYS 676 - Atmospheric Physics Credits: 3
- CLIM 710 - Introduction to Physical Climate System Credits: 3
- CLIM 713 - Atmosphere-Ocean Interactions Credits: 3

Biophysics:

- PHYS 510 - Computational Physics I Credits: 3
- PHYS 630 - Introduction to Biophysics Credits: 3
- PHYS 711 - Statistical Mechanics Credits: 3
- BINF 731 - Protein Structure Analysis Credits: 3
- NEUR 751 - Applied Dynamics in Neuroscience Credits: 3

Computational physics:

- PHYS 510 - Computational Physics I Credits: 3
- PHYS 613 - Computational Physics II Credits: 3
- PHYS 780 - Advanced Selected Topics in Physics Credits: 3
- CSI 744 - Linear and Nonlinear Modeling in the Natural Sciences Credits: 3
- CSI 764 - Computational Astrophysics Credits: 3

Instrumentation/engineering physics:

- PHYS 510 - Computational Physics I Credits: 3
- PHYS 533 - Modern Instrumentation Credits: 3
- NANO 500 - Introduction to Nanomaterials and Interactions Credits: 3
- NANO 510 - Strategies for Nanocharacterization Credits: 3
ECE 699 - Advanced Topics in Electrical and Computer Engineering Credits: 1-6

Material physics:

- PHYS 784 - Quantum Mechanics II Credits: 3
- PHYS 785 - Classical Electrodynamics II Credits: 3
- PHYS 711 - Statistical Mechanics Credits: 3
- PHYS 512 - Solid State Physics and Applications Credits: 3
- PHYS 614 - Thermodynamics and Kinetics of Materials Credits: 3

Nonlinear dynamics:

- PHYS 510 - Computational Physics I Credits: 3
- PHYS 701 - Theoretical Physics Credits: 3
- PHYS 705 - Classical Mechanics Credits: 3
- MATH 673 - Dynamical Systems Credits: 3
- NEUR 751 - Applied Dynamics in Neuroscience Credits: 3

Physics:

- PHYS 784 - Quantum Mechanics II Credits: 3
- PHYS 785 - Classical Electrodynamics II Credits: 3
- PHYS 701 - Theoretical Physics Credits: 3
- PHYS 705 - Classical Mechanics Credits: 3
- PHYS 711 - Statistical Mechanics Credits: 3

Computational Science, MS

Banner Code: SC-MS-COMP

The master's program in computational science addresses the growing demand for trained computational scientists and engineers, and data scientists. It combines a solid foundation in information technology skills with computational courses in a variety of scientific and engineering areas where large-scale simulation, data analysis, and high performance computing play a central role.

Working with an advisor, a student may choose to pursue an area of emphasis. Typical areas of emphasis are:

- **Modeling & Simulation**: intended for students who wish to learn computational solution techniques for modeling and simulation of scientific and engineering phenomena.
- **Data Science**: intended for students who wish to learn computational methods for acquiring, extracting, and analyzing large-scale data obtained by observations, experiments, modeling, and database searches.
- **Transportation Safety**: intended for students who wish to gain skills in modeling and simulation analysis for automotive crashworthiness and occupant safety, as well as other impact related applications.

Students may also combine areas of emphasis to create their own customized curriculum under the guidance of a faculty advisor.

Most of the courses are offered in the late afternoon or early evening to accommodate students with full-time employment outside of the university.

This program of study is administrated by the School of Physics, Astronomy, and Computational Sciences in the College of Science.
Admission Requirements

Applicants to all graduate programs at George Mason University must meet the admission standards and application requirements for graduate study as specified in the Admission section of this catalog. Applicants to the master's degree in computational science should have academic backgrounds in physical or biological sciences, engineering, mathematics, or computer science. They should have an undergraduate degree from an accredited institution with a GPA of at least 3.00 in their last 60 credits of study. In addition, applicants should have taken at least one course in differential equations and have facility in using a high-level computer programming language.

To apply, prospective students should complete the online application, supply two copies of official transcripts from each university attended, a current résumé, and an expanded goals statement. Applicants should also provide three letters of recommendation and an official report of scores on the GRE-GEN. The GRE-SUB is recommended if it is given in the student's undergraduate major. The GRE requirement will be waived if the student holds a master's degree from a U.S. institution. TOEFL scores are required of all international applicants. For more information, see the Admission of International Students section in the Admission section.

Degree Requirements

Candidates must successfully complete 30 credits chosen in the categories shown below to create a curriculum plan for an area of emphasis or combined areas of emphasis in consultation with their academic advisor:

9 credits of required core courses, chosen from:

- CSI 690 - Numerical Methods Credits: 3
- CSI 695 - Scientific Databases Credits: 3
- CSI 701 - Foundations of Computational Science Credits: 3
- CSI 702 - High-Performance Computing Credits: 3
- CSI 703 - Scientific and Statistical Visualization Credits: 3

12 credits of computational electives

- 12 credits of CSI courses listed in the catalog not including CSI 796, CSI 798, CSI 799, CSI 898, CSI 899, CSI 991, and CSI 996.

9 credits of electives typically chosen from:

Physics, chemistry, mathematics, statistics, engineering, information technology, and computational sciences and informatics. No more than 6 credits may be chosen from areas outside of CSI.

Elective credits may also include:

- CSI 796 - Directed Reading and Research Credits: 1-6
- CSI 798 - Research Project Credits: 3
- CSI 799 - Master's Thesis Credits: 1-6

Total: 30 credits

Non-Degree
Astronomy Minor

Banner Code: ASTR

The minor requires completion of 18 or 20 credits in physics and astronomy, with a minimum GPA of 2.00. Eight credits of course work must be unique to the minor. For policies governing all minors, see the Undergraduate Policies section of this catalog.

This program of study is offered by the School of Physics, Astronomy, and Computational Sciences in the College of Science.

Course Work

Core (12 or 14 credits)

Students will take one of the following sequences listed below.

Sequence One

- PHYS 243 - College Physics Credits: 3 and PHYS 245 - College Physics Credits: 3
  or
- PHYS 160 - University Physics I Credits: 3 and PHYS 260 - University Physics II Credits: 3
  plus
- ASTR 111 - Introductory Astronomy: The Solar System Credits: 3
- ASTR 112 - Introductory Astronomy Lab: The Solar System Credits: 1
- ASTR 113 - Introductory Astronomy: Stars, Galaxies, and the Universe Credits: 3
- ASTR 114 - Introductory Astronomy Lab: Stars, Galaxies, and the Universe Credits: 1

Sequence Two

- PHYS 160 - University Physics I Credits: 3
- PHYS 260 - University Physics II Credits: 3
- PHYS 262 - University Physics III Credits: 3
- ASTR 210 - Introduction to Astrophysics Credits: 3

Astronomy Electives (6 credits chosen from the following):

- ASTR 301 - Astrobiology Credits: 3
- ASTR 302 - Foundations of Cosmological Thought Credits: 3
- ASTR 328 - Stars and Interstellar Medium Credits: 3
- ASTR 402 - Methods of Observational Astronomy Credits: 4
- ASTR 403 - Planetary Sciences Credits: 3
- ASTR 404 - Galaxies and Cosmology Credits: 3
- PHYS 428 - Relativity Credits: 3

Total: 18 or 20 credits
Computational and Data Sciences Minor

**Banner Code:** CDS

The minor in Computational and Data Sciences (CDS) provides an attractive option for students majoring in mathematics, science, or engineering who wish to augment their major degree program with additional courses in scientific computing. The combination of computer science, numerical methods, science, and CDS synthesis courses will significantly enhance the practical knowledge and computational skills of the students when compared with the major field alone. By absorbing the material in this curriculum, students will acquire the knowledge, skills, and techniques commonly used across scientific disciplines, which will allow them to apply their Mason education in a practical way in industrial, government, and academic settings.

The minor in CDS consists of 15 credits of course work. At least 8 credits must be unique to this minor and may not be used to fulfill requirements of the student's major, concentration, or another minor or undergraduate certificate. Students must complete at least 6 credits in their minor at Mason and achieve a minimum GPA of 2.00 in courses applied to the minor. For policies governing all minors, see the Undergraduate Policies section of this catalog.

For additional information, please call 703-993-8402, fax 703-993-9300, or e-mail: kborne@gmu.edu

This program of study is offered by the School of Physics, Astronomy, and Computational Sciences in the College of Science.

**Course Work**

Students must take one of the following two courses:

- CDS 101 - Introduction to Computational and Data Sciences Credits: 3
- CDS 130 - Computing for Scientists Credits: 3

9 credits chosen from:

- Any CDS or CSI courses

3 credits chosen from:

- Any College of Science course at the 300 level or above. Other discipline-based courses may be permitted with permission of the undergraduate program director.

**Total:** 15 credits

**Note:**

Many of the courses listed above have additional prerequisites. Nonetheless, the CDS minor is within efficient reach of most students majoring in science, mathematics, engineering, or computer science, since these students will generally have the prerequisites for the classes listed above.

**Physics Minor**

**Banner Code:** PHYS
Course Work

The minor requires 18 credits with a minimum GPA of 2.00, 8 credits of which must be unique to the minor. For policies governing all minors, see the Undergraduate Policies section of this catalog.

- PHYS 160 - University Physics I Credits: 3
- PHYS 161 - University Physics I Laboratory Credits: 1
- PHYS 260 - University Physics II Credits: 3
- PHYS 261 - University Physics II Laboratory Credits: 1
- PHYS 262 - University Physics III Credits: 3
- PHYS 263 - University Physics III Laboratory Credits: 1

Any two courses from:

- PHYS 303 - Classical Mechanics Credits: 3
- PHYS 306 - Wave Motion and Electromagnetic Radiation Credits: 3
- PHYS 307 - Thermal Physics Credits: 3
- PHYS 308 - Modern Physics with Applications Credits: 3
- PHYS 402 - Introduction to Quantum Mechanics and Atomic Physics Credits: 3
- PHYS 428 - Relativity Credits: 3
- PHYS 305 - Electromagnetic Theory Credits: 3
- PHYS 513 - Applied Electromagnetic Theory Credits: 3

Total: 18 credits

Renewable Energy Interdisciplinary Minor

Banner Code: RNRG

This college-wide interdisciplinary minor administered by the School of Physics, Astronomy and Computational Sciences is designed for students considering a career in the field of renewable energy, or as preparation for graduate work in a wide range of academic disciplines. Renewable energy, as normally understood, includes a variety of methods of energy generation, such as solar, wind, hydro, tidal, and geothermal, as well as energy storage methods and energy conservation. Jobs related to renewable energy lie in a wide range of areas including engineering, business, marketing, finance, installation, software, legal affairs, and research. Projections suggest that employment opportunities in the renewable energy field will increase dramatically in the near future. The renewable energy minor is therefore ideally suited for students with majors in engineering, business, and basic science. The minor in renewable energy comprises 18-20 credits of course work. Eight credits of course work must be unique to the minor. For policies governing all minors, see the Undergraduate Policies section of this catalog.

This program of study is offered by the School of Physics, Astronomy, and Computational Sciences in the College of Science.

Course Work

Core Courses (10 credits)
Physics (1-3 credits)
Choose one from the following:
- PHYS 245 - College Physics Credits: 3
- PHYS 262 - University Physics III Credits: 3
- PHYS 266 - Introduction to Thermodynamics Credits: 1

Chemistry (4 credits)
Choose one from the following:
- CHEM 211 - General Chemistry Credits: 4
- CHEM 212 - General Chemistry Credits: 4
- CHEM 251 - General Chemistry for Engineers Credits: 4

Internship (3 credits)
Students may choose one of the following options:
- PHYS 409 - Physics Internship Credits: 3 focused on renewable energy
- or a 3-credit internship focusing on renewable energy in another natural science or engineering field

Total: 18-20 credits

School of Systems Biology
Phone: 703-993-8400
Web: ssb.gmu.edu

Faculty

Professors: Bailey (distinguished), Jafri, Kashanchi, Liotta, Petricoin, Popov, Seto, Soyfer (distinguished university professor), Vaisman (Associate Director), Willett (Acting Director), Wu

Associate professors: Baranova, Christensen, Cox, Fryxell, Grant, Kinser, Klimov

Assistant professors: Hakami, Kehn-Hall, Luchini, van Hoek

Adjunct faculty: Pitt, Solka

Affiliate faculty: Baxevanis, Bokhari, Camphausen, Carr, Cooper, Grefenstette, Ikonomi, Kim, Lipsky, Masso, Marr, Matson, Matthews, Monroe, Reck, Sobie, Van Tassell, Ward, Williams

Emeritus: Isbister, Royt