Physics

Faculty:Magee Chair; Capece, Graham, Lanz, MacDonald, McGee, Nesh, Nguyen, Ochoa, Richards, Wickramasinghe

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The objectives of the department are to develop the student's comprehension of the basic principles of physics, to develop analytical and problem-solving skills, to instill a sense of inquiry, to develop an appreciation of the role of physics in our attempt to understand the universe, and to develop an understanding of its power to deal with problems related to technology and the environment. The curriculum is designed to prepare students for graduate study in physics and related fields as well as to provide students with a foundation for work in education or the private sector.

Three degree paths are offered within the major: Physics-Liberal Arts, the Seven-Year BS/MD Program, and Physics-Secondary Education. The physics requirements of all degree paths are the same. The department also offers major specializations within the Physics-Liberal Arts program: Pre-graduate physics, Astrophysics, Biomedical Physics, Computational Physics, Materials Science, and Geophysics. Self-designed specializations are also possible. The department encourages all students to engage deeply in the major through research opportunities within the department and to broaden their liberal education by exploring opportunities for college core concentrations, minors, and study abroad experiences.

Physics: Liberal Arts

The requirements of the physics major consist of the following courses:

1. **Core Courses**: A fixed core of physics courses, regardless of degree path or specialization. Core courses may not be double counted in any other category.
   PHY 203/Physics I for Physicists or 201/General Physics I
   PHY 204/Physics II for Physicists or 202/General Physics II
   PHY 299/Research Fundamentals
   PHY 306/Mathematical Physics I
   PHY 321/Modern Physics
   PHY 356/Thermal Physics
   PHY 401/Classical Mechanics
   PHY 421/Electromagnetic Theory I
   Note that PHY 203 and PHY 204 are required courses for Physics Majors unless exceptions are approved by the Department Chair.
2. **4 Physics Option Course Units**: 200-level or higher physics (PHY prefix) courses
   Specifications:
   - At least one course must have a lab component; this can be chosen from PHY 220, 311, 345, and 411.
   - A maximum of one course unit may come from a combination of PHY 393, 493, 290, or 291. Note that this does not satisfy the lab component requirement.
   - These 4 course units may not double-count in any other category.
3. **2 Correlates:** MAT 127/Calculus A and MAT 128/Calculus B (or AP credit).

4. **5 Additional STEM Units**: These courses can be used to partially fulfill one of the Physics Specializations and/or for breadth.

    Specifications:

    - These are selected from the Schools of Science or Engineering;
    - At least three must be 200-level or higher;
    - For Secondary Education students, two of these four courses may be from the School of Education.
    - See Program Policy on PHY 290, 291, 393, and 493 Courses for information on how these courses may partially satisfy this requirement. These five course units may not double-count in any other category.
5. **1 Orientation Course**: PHY 099 Orientation to Physics
6. **1 Capstone Course:** PHY 451 or SED 498 (for Secondary Education students)

Recommended First-Year Course Sequence

The following sequence of courses is recommended for most entering freshmen. Depending on high school coursework and AP credits, individual adjustments may be advised.

Freshman Year			
Fall courses	Fulfills Req.	Spring courses	Fulfills Req.
Freshman Seminar (0 credit)	Core 0	Physics II for Physicists	Core 2
Physics I for Physicists	Core 1	Calculus B	Correlate 2
Calculus A	Correlate 1	Language	Language 2
Language	Language 1	Additional STEM	Add. STEM 1
FSP	College-wide		

Program Policy on PHY 290, 291, 393, and 493 Courses

PHY 290 and 291 are Learning Assistant courses (0.25 CU) and PHY 393 and 493 are Independent Research courses (typically 0.25-1.0 CU). These courses can be combined in various course unit amounts to add up to a total of 2.0 CU that can be counted towards the major. When combining course unit totals from PHY 290, 291, 393, and 493, the following maximum contributions to the major may not be exceeded: a maximum of 0.5 CU from PHY 290/291, a maximum of 1.0 CU from PHY 393, and a maximum of 1.0 CU from PHY 493. Note that Phy 393/493 cannot be used to satisfy the lab component requirement.

Program Entrance, Retention, and Exit Standards

Every major program at the College has set standards for allowing students to remain in that program, to transfer within the College from one program to another, and to graduate from a program. The following are the standards for the physics program. Minimum grades are noted in parentheses.

- Retention in the program is based on the following minimum performance standards in these “critical content courses”: PHY 203 or PHY 201 (C), PHY 204 or PHY 202 (C), PHY 321 (C).

- Transfer into the program from another program within the College is based upon the following performance standards in this "foundation course": PHY 201 or PHY 203 (C).
- Graduation requires a GPA of 2.0 for in-major courses and earning a minimum grade of C in the following courses: PHY 203 or PHY 201, PHY 204 or PHY 202, PHY 321.

Physics: Secondary Education

The Physics-Secondary Education program prepares students to become teachers of physics in the secondary public schools of New Jersey and many other states. It includes a college core component, a strong and broad foundation in the content area with an emphasis in physics, as well as professional experience both in the classroom and in the field. Upon completion of the basic program, students are prepared for certification in physics in New Jersey. An overview of the entire secondary-level teacher preparation sequence for students can be found in the section of this bulletin for the Department of Education Administration and Secondary Education.

Students planning to teach middle or high school physics should consult with their advisor in planning their academic program. These plans should take into account requirements for: the major, college core, professional courses, and state certification. To be retained in the program, a student must earn at least a 2.5 cumulative grade point average before enrolling in the junior year education sequence. The student must establish a minimum 2.75 GPA in order to be allowed to student teach. Candidates for a teacher-education certificate must have a 3.0 or higher cumulative grade point average to successfully complete their teacher education program after September 2016. They also must meet the state hygiene/physiology requirement, the state Harassment, Intimidation, and Bullying Prevention (HIB) training certificate requirement, and pass the appropriate Praxis examination. Teacher-education candidates will receive a "certificate of eligibility with advanced standing" which requires a candidate to be provisionally certified for his or her first year of teaching. After one year of successful teaching, the candidate is eligible for a permanent certificate.

The courses listed below are the required of all Physics-Secondary Education students, however, most of these courses can be counted toward major or college core requirements (as noted in parentheses). While it can be challenging to fulfill the secondary education program and one of the five pre-set major specializations, it can be done through careful advisement and course selection. One additional specialization is also available to secondary education students who wish to prepare for certification in Physics and Physical Science.

Required Courses

CHE 201/General Chemistry I (may count as a specialization option)
SED 224/Adolescent Learning & Development (also counts as social science C.C.)
PHY 299/Research Fundamentals
EFN 299/School & Communities (also counts as social science C.C.)
SPE 103/Secondary Content Literacy in Incl. Classes (may count as specialization option)
SED 399/Pedagogy in Secondary Schools*(1.5 units; counts as specialization option)
PHY 390/Methods of Teaching Science* (counts as a physics option course)
RAL 328/Reading in Secondary Education*(0.5 units; counts as specialization option)
PHY 490/Student Teaching (counts as 2 physics option courses)♦
SED 498/Collaborative Capstone for Inquiry (capstone and specialization option)♦

*These three courses are typically taken together during the spring of the junior year.

♦These two courses are typically taken together during the fall of the senior year.

Major Specializations

Through choices in items 2, 4 and 6 of the Physics: Liberal Arts requirement, students may complete a seven course "***specialization,***" which is decided by advisement and is intended to be visible on the student transcript. A self-designed specialization may also be chosen with advisement. While all physics students are encouraged to choose a specialization within the major, it is not a requirement for graduation.

The seven required courses for each specialization are listed below. Exceptions to these must be approved by the Specialization Coordinator.

Specialization A: Pre-graduate Physics – Specialization coordinator – Dr. Angela Capece

Students in this specialization will acquire an excellent theoretical and experimental background that prepares them for graduate study in physics or astrophysics. Graduates can also find career placements in industrial or national laboratories for research and development.

Required courses:

MAT 326/Differential Equations
PHY 422/Electromagnetic Theory II
PHY 431/Quantum Mechanics
PHY 311/Analog and Digital Electronics
CSC 220/Computational Problem Solving or CSC 215/Computer Science I for Science and Engineering

and

Two additional courses in physics (typically PHY 411, PHY 413, PHY 425, PHY 426 by advisement), chemistry, or mathematics, at least two of which must be at the 300 or 400 level.

Specialization C: Computational Physics – Specialization coordinator – Dr. Nicholas Nesh

Students with an interest in both physics and computer science should consider this specialization. Students will acquire a college-level understanding of the laws governing the universe. They will also be trained in the art of analyzing and solving difficult problems. In the Junior and Senior years students are assigned projects that acquaint them with the techniques of computer modeling and using the computer to solve problems. Computers are necessary since some problems are impossible to solve completely using analytical mathematical techniques. In addition, students will take courses in computer science that will enable them to acquire a deeper understanding of how computer software works and how to use it more efficiently. The graduate of this program will be prepared for a career in technical and/or scientific software development. Some graduates, by proper choice of electives, enroll in graduate physics or graduate computer science programs.

Students who elect to specialize in Computational Physics are encouraged to take as many Computer Science courses as possible.

Required courses:

PHY 431/Quantum Mechanics
CSC 220/CS I – Computational Problem Solving
CSC 230/CS II – Data Structures
CSC 270/Discrete Structures

CSC 415/Software Engineering
and
Two additional courses in Physics, Chemistry, Computer Science, Mathematics or Engineering, by advisement

Specialization G: Geophysics – Specialization coordinator – Dr. Shannon Graham

Students with an interest in the physical earth sciences can complete a specialization in geophysics. Students following this specialization will be trained with eye toward a possible career or graduate study in one of the following areas: Seismology, Volcanology, Geochemistry, Bio-geoscience, Environmental Science, Meteorology, Climatology, Climate Change Science, Oceanography, Aeronomy, Planetary Sciences, Mineralogy, Petrology, Hydrology, and Geodesy. Students in this specialization will be exposed to multiple independent research opportunities in cutting-edge areas of geophysics research and invited to participate in national conferences. In addition to a core education in physics, students will be challenged to apply physical laws to the earth system.

Required courses:

PHY 120/Introduction to Geology
PHY 171/Introduction to Meteorology
CHE 201/ General Chemistry
PHY 220/Advanced Geology
PHY 345/Physics of Clouds and Climate
PHY 393/Independent Research I (in geophysics)
and
By advisement, one other Physics course (PHY 411, PHY 425, PHY 451) or any 200+ level course in the School of Science or Engineering.

Specialization H: Biomedical Physics – Specialization coordinator – Dr. Tuan Nguyen

This specialization offers an opportunity for students to enhance their education in biology, chemistry, and bioengineering, while using their physics skills and analytical problem solving abilities. Such students are often interested in careers in medicine, biology, biophysics, or medical physics. Other students may be interested in: the development of the next generation of equipment and software for the detection and cure of disease; research of materials that can be used in the human body; science and technology used in solving clinical problems. Premedical students with an interest in radiology, cardiology, neurology, or ophthalmology should find the course sequence especially valuable. This specialization satisfies the general medical school admission requirements when proper choices of options and electives are made. The courses in the Biomedical Physics specialization uphold the rigor of TCNJ physics major, while allowing adequate flexibility in choosing among the option courses. For example, students interested in nuclear medicine can take the Nuclear and Particle Physics course. Students interested in ophthalmology would be well served by choosing the Optics and Wave Motion course.

Required courses:

PHY 316/Biomedical Physics
PHY 336/Introduction to Biophysics
CHE 201/General Chemistry I
CHE 202/General Chemistry II
CHE 331/Organic Chemistry I
BIO 201/Foundations of Biological Inquiry

BIO 211/Biology of the Eukaryotic Cell

Students should also consider at least one of the following courses, depending on their interests and goals*:
BIO 231/Genetics (with lab)
BIO 332/Comparative Vertebrate Anatomy (with lab)
BME 251/Introduction to Biomedical Engineering
BME 311/Physiological Systems (BME 251 is a pre-requisite)
ENG 272/Advanced Engineering Math I
ELC 321/Signals and Systems (ENG 272 is a prerequisite)

**Students who are considering a career in medicine should note that medical school admissions typically require two semesters of biology with lab and two semesters of organic chemistry. It is commonly recommended that students select additional courses from this list with free electives.*

Specialization M: Materials Science – Specialization coordinator- Dr. Romulo Ochoa

The Materials Science (previously known as Chemistry and Physics of Condensed Matter) specialization is an interdisciplinary program open to Chemistry and Physics majors who have a strong interest in exploring the properties and applications of solid materials. Broadly defined, materials science refers to the mechanical, optical, thermal, and electrical properties of solid materials. This branch of Physics and Chemistry has direct applications to many technologies, such as nanomaterials, computer electronics, artificial biomaterials, and renewable energy. Students considering the Materials Science specialization should have a strong interest in both physics and chemistry. Physics students are free to pursue research projects in either the Physics Department or Chemistry Department. Students will be prepared to pursue a wide variety of careers or graduate study in physics, biophysics, or materials science. Students interested in the specialization should contact one of the following Physics faculty members: Drs. Capece, Magee, McGee, or Ochoa. Students may apply for the specialization at any time but are encouraged to do so in their sophomore year to facilitate planning and timely completion.

Required courses:

1 PHY 311/Analog and Digital Electronics
or PHY 451/Advanced Lab
or CHE 410/Instrumental Analysis

2 And at least three of the following courses, with at least one having a PHY prefix and at least one having a CHE prefix

PHY 345/Physics of Clouds and Climate
PHY 436/Condensed Matter
CHE 451/Inorganic Chemistry I
CHE 478/Special Topics in Condensed Matter (may be taken more than once)
PHY 478/Special Topics in Condensed Matter

Specialization S: Astrophysics – Specialization coordinator – Dr. Thulsi Wickramasinghe

This specialization is designed for those students who have an interest in astronomy and astrophysics, and who wish to pursue a career in these fields. Usually such students are planning to further their studies in graduate school in astrophysics or physics. There are also job

opportunities for baccalaureate level graduates at planetariums, science museums, NASA facilities, and national observatories.

Required courses:

PHY 162/Astronomy: Planets or PHY 163. Astronomy: Stars & The Universe
PHY 361/Galactic & Extragalactic Astronomy
PHY 413/General Relativity and Cosmology
PHY 466/Astrophysics

Three other Physics or Mathematics or Chemistry courses, by advisement, are also required. These would typically be chosen from: PHY 311/Electronics; PHY 411/Optics and Wave Motion; PHY 422/Electricity and Magnetism II; PHY 425/Plasma Physics; PHY 426/Particle and Nuclear Physics; PHY 431/Quantum Mechanics; PHY 436/Condensed Matter Physics

Specialization T2: Physical Science Secondary Education (for Secondary Education students only) – Specialization coordinators- Dr. Nathan Magee and Dr. AJ Richards

With several additional courses, secondary education students may also prepare for physical science certification, which can broaden school placement options. The following set of additional courses may be selected to prepare students for certification in Physical Science. A physical science certification is important for those wishing to broaden employment options, including those interested in teaching science in middle schools. With use of the one remaining SOS option, at least 1 advanced earth science course as a PHY option, and free electives, this dual certification preparation option can still be completed within the 32 total course units.

CHE 202/General Chemistry II
Two additional chemistry courses
Three of the following 8 courses:
PHY 120/Introduction to Geology
PHY 161/Introduction to Astronomy
PHY 171/Introduction to Meteorology
PHY 220/Advanced Geology
PHY 345/Physics of Clouds and Climate
PHY 361/Galactic and Extragalactic Astronomy
PHY 466/Astrophysics

Physics: 7-Yr BS/MD Program in Physics

The Seven-Year BS/MD Program in Physics allows incoming freshmen to earn both the BS and MD degrees in seven years. Students accepted into the Program study three years at The College of New Jersey and four at New Jersey Medical School (NJMS) of Rutgers University. The students receive a Bachelor of Science from TCNJ after finishing the first year of medical school and the MD degree after finishing four years at NJMS.

If a student applies, but is not admitted to the Program, the student will still be considered for admission to TCNJ in the major he/she indicated on the application. Detailed information on the admission process and retention criteria for the Seven-Year Program may be found at http://biology.pages.tcnj.edu/biology-programs/medical-careers/7-year-medical-program.

To be considered for the Seven-Year Program, a student needs:

- a high school senior status;
- a high school class rank within the top 5%;
- a minimum SAT score of 1480 on the combined reading and math sections, from a single test date; ACT scores are not accepted in lieu of SAT scores.

Qualified students will be required to have two interviews as parts of the admission process. A favorable interview with a Medical Career Advisor at TCNJ will be followed by an in-person interview at NJMS in Newark.

To remain in the Program, the student needs:

- a minimum overall and semester GPA of 3.5;
- a B or better in each of the required science courses: General Physics I/II, (or Physics I and II for Physicists), General Chemistry I/II, Organic Chemistry I/II, Themes in Biology, and Genetics;
- a C or better in all other courses;
- to take the Medical College Admissions Test (MCAT) no later than the Spring Semester of the third (and final) year at TCNJ; no minimum MCAT score is required.

The Coursework

The course load is the same as that for other TCNJ students and for physics majors. Students admitted into the program will be able to enhance their education in biology, chemistry, and/or bioengineering while using their physics skills and analytical problem solving abilities. Besides majoring in physics, students may obtain a minor in chemistry by taking as an elective one more chemistry course numbered 300 or higher, beyond those required (CHE 202, 331, and 332 at TCNJ and Biochemistry at NJMS). The additional chemistry course must not be CHE 316, 317, 318, 340, 393, 399, 490, or 493.

General course requirements for the Physics major:

7 Core Physics Courses (may not be double counted in any other category):

PHY 203/Physics I for Physicists or 201/General Physics I
PHY 204/Physics II for Physicists or 202/General Physics II
PHY 306/Mathematical Physics
PHY 321/Modern Physics
PHY 356/Thermal Physics
PHY 401/Classical Mechanics
PHY 421/Electromagnetic Theory I

5 Physics Options: Must be 200-level or higher physics (PHY prefix) courses and satisfy the following:

- One course must have a lab component;
- Independent research may be one of these courses, but does not satisfy the requirement for a lab-based option course;
- The 5 courses may not double-count in any other category, with the exception of the capstone course.

2 Correlates: MAT 127/Calculus A and MAT 128/Calculus B (or AP credit).

5 Specialization Options:
- Any courses from the School of Science or Engineering; these will be Biology and Chemistry courses
- At least two must be 200-level or higher;
- One of these five courses may be independent research;
- The 5 courses may not double-count in any other category, with the exception of the capstone course.

1 Capstone: PHY 451**.** This course may also be counted toward Physics Option or Specialization Option courses.

Suggested 3 Year Course Sequence for the Seven-Year BS/MD Program in Physics

Freshman Year
PHY 099 - Orientation to Physics (0 - credit)
PHY 203 – Physics I for Physicists**
PHY 204 – Physics II for Physicists*
MAT 127 - Calculus A*
MAT 128 - Calculus B*
CHE 201 - Gen. Chem. I*
CHE 202 - Gen. Chem. II *
First Seminar
Language I*
Language II*
College Core I*
** At least 2 of these must be AP credit, placement, or taken before the freshman year*

Freshman Summer
College Core II and III
(May be taken during the Fall or Spring semester of the Freshman year, if a student has AP credits or places out of more than 2 Freshmen courses).

Sophomore Year
PHY 306 - Mathematical Physics
PHY 321 - Modern Physics
BIO 201 – Foundations of Biological Inquiry
CHE 331 - Organic Chem. I
CHE 332 - Organic Chem. II
Physics Option I

One of the following, either in sophomore or junior year:
- PHY 316 - Biomedical Physics (offered odd-numbered years in Spring)
- PHY 336 – Biophysics (offered even-numbered years in Spring)
- PHY 451 - Advanced Experimental Physics (as Capstone)
- PHY 493 - Independent Research II

Sophomore Summer
One of the following:

- PHY 493 - Independent Research II (can count as Capstone)
- PHY 399 - Physics Research Internship

Junior Year
PHY 401 - Classical Mechanics
PHY 356 - Thermal Physics
PHY 421 - Electromagnetic Theory I
BIO 231 - Genetics
Physics Option II
Physics Option III
College Core or Language III One of the following, either in sophomore or junior year:

- PHY 316 - Biomedical Physics (offered odd-numbered years in Spring)
- PHY 336 - Biophysics (offered even-numbered years in Spring)
- PHY 451 - Advanced Experimental Physics (as Capstone; offered at least every Spring)
- PHY 493 - Independent Research II

Junior Summer
College Core V
(May be taken during the Fall or Spring semester of the Junior year, if a student has AP credits or places out of more than 2 courses).

Senior Year (Completed while at NJMS)
Biochemistry (equivalent to CHE 430)
College Core VI (Psychiatry)

College Core
The college core requirements for students in the physics major conform to the College's college core policies and recommendations. For details, see http://liberallearning.tcnj.edu/

Some important nuances of college core apply to specifically to physics majors:

1. **Breadth Distribution:**
   - The Natural Sciences and Quantitative Reasoning Requirements are fully satisfied by major requirements.
   - For secondary education students, two of the Social Sciences and History requirements are satisfied by required education courses in the category of Behavioral, Social or Cultural Perspectives.

2. **Language Requirement:**
   Physics majors are required to progress through 3rd level proficiency (103). Physics-Secondary Education majors are required to progress through 2nd level proficiency (102)

Study Abroad
One of the opportunities available to students pursuing a degree in physics is to study abroad for a semester. Any student interested in studying abroad should meet with his/her faculty advisor early in his/her college career to plan a curriculum so that the student may complete his/her studies in four years. He/she may also need to meet with the Center for Global Engagement. The student must receive approval from the chairperson of the Physics Department in order for courses taken abroad to count toward requirements in the major.

Physics Minor
A minor in physics requires a total of five course units. The required courses are:

PHY 201/General Physics I or PHY 203/Physics I for Physicists
PHY 202/General Physics II or PHY 204/Physics II for Physicists
PHY 306/Mathematical Physics
PHY 321/Modern Physics
One advanced course elected at the 400 level with the prior approval of the physics department chair.

Minimum grade point average for retention and completion of the minor is the same as for the major.

Environmental Studies Minor
The minor in environmental studies has as its central organizing principle that to understand the human/environment relationship, students must understand how to examine this relationship from multiple disciplinary perspectives, within and outside the natural sciences. To this end, students are required to take five courses, with at least two from different Natural Science & Engineering disciplines (biology, chemistry, engineering, geology, physics) and at least two from different Social Science & Humanities disciplines (anthropology, economics, history, journalism, literature, philosophy, political science, sociology, women's & gender studies), with no more than two courses from any single discipline. Students may elect to complete either a third course in Natural Sciences & Engineering or in Social Sciences & Humanities, or may complete Independent Study, Independent Research, or Internships in Environmental Studies (ENV 391, ENV 393, or ENV 399). Disciplinary Topics courses and certain FSPs may also count towards the minor, with the approval of the Environmental Studies committee. At least three courses will be at the 300 or 400 level. In addition, students are required to complete a one unit co-requisite to demonstrate quantitative competency.

Course Repetition Policy
There is a limit on the number of times a student may take a course in Physics, whether they receive a normal letter (A-F) or a withdrawal (W) grade. Students can always take a course a second time if their first grade was unsatisfactory, though they should discuss this with their advisor. However, in order to register for a course for a third time a permission form must be signed by the department chair who will confer with the student's advisor and other professors with whom the student has studied before deciding on whether to grant such permission. Under no circumstances will a student be allowed to take a Physics course more than three times.