

## Physics

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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 in the student, 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, Condensed Matter 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 liberal learning concentrations, minors, and study abroad experiences.

### Physics: Liberal Arts

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

1. **8 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 (required for students matriculating in 2015 or later)
  - PHY 306/Mathematical Physics I
  - PHY 321/Modern Physics
  - PHY 356/Thermal Physics
  - PHY 401/Classical Mechanics
  - PHY 421/Electromagnetic Theory I
2. **5 Physics Options:** 200-level or higher physics (PHY prefix) courses
 

*Specifications:*

  - Two courses must have a lab component; only one physics lab course is required for Physics – Secondary Education, and the Seven-Year BS/MD tracks, but two are recommended
  - Independent research may be one of these courses, but does not satisfy the requirement for a lab-based option course;
  - These 5 courses may not double-count in any other category, with the exception of the capstone course.
3. **2 Correlates:** MAT 127/Calculus A and MAT 128/Calculus B (or AP credit).
4. **5 Specialization Options:** Elective courses to be used toward specialization and breadth.
 

*Specifications:*

  - These may be any courses from the Schools of Science or Engineering;

- At least two must be 200-level or higher;
  - Two of these 5 courses may be from the School of Education for secondary education students;
  - One of these five courses may be independent research;
  - These 5 courses may not double-count in any other category, with the exception of the capstone course.
5. **1 Capstone:** PHY 493, PHY 451, or SED 498. This course normally is also counted toward categories 2 or 4 above.

### **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 qualifying minimum SAT score 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 493 or 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\*
- Liberal Learning I\*

*\* At least 2 of these must be AP credit, placement, or taken before the freshman year*

**Freshman Summer**

Liberal Learning 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 even-numbered years in Spring)
- PHY 336 – Biophysics (offered odd-numbered years in Spring)
- PHY 451 - Advanced Experimental Physics (can count as Capstone; offered every Spring)
- PHY 493 - Independent Research II (can count as Capstone)

**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

Liberal Learning IV

One of the following, either in sophomore or junior year:

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

**Junior Summer**

Liberal Learning 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)  
 Liberal Learning VI (Psychiatry)

### **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 liberal learning 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, liberal learning, 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 liberal learning 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 L.L.)
PHY	299/Research Fundamentals
EFN	299/School & Communities (also counts as social science L.L.)
SPE	323/Secondary Content Literacy in Incl. Classes* (may count as specialization option)
SED	399/Pedagogy in Secondary Schools*(may count as specialization option)
PHY	390/Methods of Teaching Science* (counts as a physics option course)
EFN	398/Historical & Political Contexts in Schools
PHY	490/Student Teaching (counts as 2 physics options)
SED	498/Collaborative Capstone for Inquiry (capstone and specialization option)

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

Other Recommended Courses: It is strongly advised that all prospective teachers also take General Chemistry II as a specialization option course.

## Major Specializations

Through choices in items 2, 4 and 5 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. The major requires a total of 10 option courses (items 2 and 4); 7 of these may be chosen so as to fulfill one of the pre-set major specializations described below. 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.

### Specialization A: Pre-graduate Physics

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.

It is strongly recommended that students take the following courses:

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

*and*

Three additional courses in physics, chemistry, or mathematics, at least two of which must be at the 300 or 400 level.

### Specialization C: Computational Physics

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. However, it is recommended that they take at least the following four courses:

CSC 220/CS I – Computational Problem Solving  
CSC 230/CS II – Data Structures  
CSC 270/Discrete Structures  
CSC 415/Software Engineering

*and*

Three additional courses in the School of Science, by advisement

### **Specialization G: Geophysics**

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.

It is recommended that students take the following courses:

PHY 120/Introduction to Geology  
 PHY 171/Introduction to Meteorology  
 CHE 201/Introduction to Chemistry  
 PHY 220/Advanced Geology  
 PHY 345/Physics of Clouds and Climate  
 PHY 393/Independent Research I (in geophysics)

and

One other 200+ level science or engineering course by advisement.

### **Specialization H: Biomedical Physics**

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.

It is recommended that students take all seven of the following courses:

PHY 316/Biomedical Physics  
 PHY 336/Introduction to Biophysics  
 CHE 201/General Chemistry I  
 CHE 202/General Chemistry II  
 BIO 201/Foundations of Biological Inquiry  
 BIO 211/Biology of the Eukaryotic Cell  
 BME 251/Introduction to Biomedical Engineering

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)  
 CHE 331/Organic Chemistry I  
 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: Chemistry and Physics of Condensed Matter**

The 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, condensed matter 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 Condensed Matter 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.

To complete the Condensed Matter specialization, students **must** complete the following courses, though taking as many as possible specialization courses from this list is encouraged:

- 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**

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.

It is recommended that students take the following courses:

- PHY 161/Introduction to Astronomy
- PHY 261/Advanced General Astronomy
- PHY 361/Galactic & Extragalactic Astronomy
- PHY 466/Astrophysics
- PHY 413/General Relativity & Cosmology

PHY 393/Independent Research I (in astronomy or astrophysics)  
and  
One other physics or mathematics course by advisement.

### **Specialization T2: Physical Science Secondary Education, (for Secondary Education students only)**

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 261/Advanced General Astronomy  
PHY 345/Physics of Clouds and Climate  
PHY 361/Galactic and Extragalactic Astronomy  
PHY 466/Astrophysics

### **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	Specialization Option	Specialization 1
FSP	Liberal Learning 1		

### **Liberal Learning**

The liberal learning requirements for students in the physics major conform to the College's liberal learning policies and recommendations.

For details, see <http://liberalllearning.tcnj.edu/>

Several important nuances of liberal learning apply to specifically to physics majors:

#### **1. Option A: Designated Interdisciplinary Concentration:**

The Environmental Studies Concentration can count several physics courses. See <http://liberalllearning.pages.tcnj.edu/courses-information/interdisciplinary-concentrations/environmental-studies/> for details.

**2. Option C: 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.

**3. Language Requirement:**

Physics majors are required to progress through 2nd level proficiency (102).

**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 physics programs. Minimum grades are noted in parentheses.

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

**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). 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.