Physics, Ph.D.

About the Program
The objective of the Ph.D. program in Physics is to provide both a broad understanding of foundational areas of Physics and intensive training and experience in an important area of current research. A primary requirement for the degree is an original and significant research contribution, which is presented in the Ph.D. dissertation.

Time Limit for Degree Completion: 7 years

Campus Location: Main

Full-Time/Part-Time Status: The degree program can be completed on a full- or part-time basis.

Job Prospects: The program is intended to produce well-trained physicists, who are qualified for careers as research scientists in government and industrial laboratories or as university faculty members.

Non-Matriculated Student Policy: Non-matriculated students are restricted to taking the following courses:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credit Hours</th>
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<tbody>
<tr>
<td>PHYS 5101</td>
<td>Analytical Mechanics I</td>
<td></td>
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<tr>
<td>PHYS 5301</td>
<td>Electromagnetic Theory</td>
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<tr>
<td>PHYS 5501</td>
<td>Mathematical Physics I</td>
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</tbody>
</table>

If the student applies to and is accepted into the program, the courses taken, up to 9 credits, may be applied toward the degree requirements.

Financing Opportunities: Financial aid is available in the form Teaching and Research Assistantships. The principal duties of a Teaching Assistant include laboratory instruction, grading of lab reports, and tutoring of students enrolled in introductory physics courses. Research Assistants are assigned to a faculty member, typically the thesis advisor, who is engaged in an externally funded research project and who determines the students' duties. Both Teaching and Research Assistantships provide tuition, a stipend for living expenses, and health insurance.

Admission Requirements and Deadlines

Application Deadline:

Fall: March 1; December 15 international
Spring: November 1; August 1 international

Applications are reviewed as they are received throughout the year. Late applications may be considered for admission.

APPLY ONLINE to this graduate program.

Letters of Reference:
Number Required: 2

From Whom: Letters of recommendation should be obtained from college/university faculty members or scientists familiar with the applicant's academic and scientific capabilities.

Coursework Required for Admission Consideration: Applicants should have successfully completed coursework typically required for a bachelor's degree in Physics.

Master's Degree in Discipline/Related Discipline: A master's degree is not required.

Bachelor's Degree in Discipline/Related Discipline: A baccalaureate degree in Physics is typically required. A certified transcript is required from each institution previously attended by the applicant.

Statement of Goals: One to two pages address the applicant's specific interest in Temple's program, research and career goals, and academic and research achievements.

Standardized Test Scores:
GRE: General Test required. Subject Test in Physics strongly recommended, but not required.
Physics, Ph.D.

For applicants whose native language is not English, the TOEFL, IELTS, or PTE Academic exam is required:

TOEFL: 79 iBT or 550 PBT minimum
IELTS: 6.5 minimum
PTE Academic: 53 minimum

**Transfer Credit:** Graduate credits from an accredited institution may be transferred into the program. The credits must be equivalent to coursework offered at Temple, and the grade must be a “B” or better in order to transfer. The Graduate Program Committee must approve all requests for transfer credit. The maximum number of credits a student may transfer is 6.

**Advanced Standing:** Students who enter the Ph.D. program in Physics with a master's degree in Physics or a closely related field may be considered for advanced standing. The Graduate Program Committee recommends the awarding of advanced standing on a case-by-case basis. The maximum number of advanced standing credits awarded is 33.

**Program Requirements**

**General Program Requirements:**
*Number of Credits Required Beyond the Baccalaureate: 42*

**Required Courses:**

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<tr>
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<tr>
<td>PHYS 5002</td>
<td>Physics Research and Ethics</td>
<td>1</td>
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<tr>
<td>PHYS 5101</td>
<td>Analytical Mechanics I</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 5301</td>
<td>Electromagnetic Theory</td>
<td>6</td>
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<tr>
<td>PHYS 5302</td>
<td>and Electromagnetic Theory</td>
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<tr>
<td>PHYS 5501 &amp; PHYS 5502</td>
<td>Mathematical Physics I and Mathematical Physics II</td>
<td>6</td>
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<tr>
<td>PHYS 5701 &amp; PHYS 5702</td>
<td>Quantum Mechanics I and Quantum Mechanics II</td>
<td>6</td>
</tr>
<tr>
<td>PHYS 8001</td>
<td>Practicum Teaching of Physics</td>
<td>1</td>
</tr>
<tr>
<td>PHYS 8102</td>
<td>Statistical Mechanics</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 8701</td>
<td>Advanced Quantum Mechanics</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 8702</td>
<td>Solid State Physics</td>
<td>3</td>
</tr>
<tr>
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<td>Introduction to Elementary Particles Physics</td>
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<td>6</td>
</tr>
<tr>
<td>or PHYS 9999</td>
<td>Dissertation Research</td>
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Total Credit Hours 42

¹ Students typically take PHYS 9994 in the third academic term of full-time study.
² The combined number of credits for PHYS 9998 and PHYS 9999 must be at least 6, with a minimum of 2 of those credits required to be in PHYS 9999.

**Culminating Events:**

**Preliminary Examination:**
For elevation to candidacy for the Ph.D. degree, the student must pass a written and oral preliminary examination covering undergraduate and master's level physics. Students are required to take the examination by the end of their second year of full-time graduate study. The written part of the exam is typically taken during the week right before the start of the fourth academic term. The oral part usually follows during the first week of the fourth term. The exam is offered twice a year. In the event of failure, the exam may be retaken once. If the student fails a second time, s/he is dropped from the graduate program.

**Dissertation:**
A topic for the Ph.D. dissertation is selected in consultation with a faculty member who agrees to serve as the dissertation supervisor. For elevation to candidacy, the student must submit a dissertation proposal that meets the approval of the Graduate Program Committee and the Graduate School. The completed dissertation is submitted to the department before the final examination, in which the dissertation is presented and defended by the candidate in an oral examination.
Contacts

Department Web Address:
https://phys.cst.temple.edu

Department Information:
Dept. of Physics
406 SERC
1925 N. 12th Street
Philadelphia, PA 19122-1801
physics@temple.edu
215-204-7634

Submission Address for Application Materials:
https://apply.temple.edu/CST/

Department Contacts:
Admissions Chair:
Xifan Wu
xifan.wu@temple.edu
215-204-7627

Graduate Chair:
Andreas Metz
andreas.metz@temple.edu
215-204-7668

Chair:
James Napolitano
napolj@temple.edu
215-204-7827

Courses

PHYS 5001. Introduction to Quantum Computing. 3 Credit Hours.
This course will give an elementary introduction to some basics of quantum information and quantum computing that are accessible to not only physicists but also people with a variety of backgrounds. It will introduce the students to the latest scientific and technological advancement, and prepare for further study and/or initiating research if one wishes to pursue in this field.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

PHYS 5002. Physics Research and Ethics. 1 Credit Hour.
This course will introduce new graduate students to the diverse faculty research programs in physics at Temple, and help them to make an informed choice of research advisor and topic. It will also make sure that all students are aware of the ethical code for physicists. The course will meet for one hour per week. In the first 3 to 5 weeks, the instructor will lecture on the ethical and etiquette responsibilities of students, teachers, and researchers in physics. In each of the next 10 to 12 weeks, a faculty volunteer will explain his or her research program and opportunities for student participation in it. A faculty member may also nominate a graduate student to speak to the class. Former graduate students who hold physics research positions could also be invited to speak. Students will have ample opportunity to ask questions. They will be required to turn in one-page summaries of the lectures for grading by the lecturers; this should measure the students’ understanding and improve their writing skills. A possible text for the ethics lectures would be the National Academy of Sciences booklet "On Being a Scientist".

Department Restrictions: Must be enrolled in one of the following Departments: CST:Physics.
Field of Study Restrictions: Must be enrolled in one of the following Majors: Physics.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.
PHYS 5101. Analytical Mechanics I. 3 Credit Hours.
Variational principles, Lagrange's and Hamilton's equations; canonical transformations; small oscillations; dynamics of particles, rigid bodies, strings and membranes; hydrodynamics; chaos in deterministic systems.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

PHYS 5301. Electromagnetic Theory. 3 Credit Hours.
Boundary value problems of the electrostatic and magnetostatic fields; Maxwell's equations; plane waves at boundaries in dielectric and conducting media; potentials in the Lorentz gauge; Green's functions for wave and Helmholtz equations; multipole radiation; material dispersion; diffraction.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Phys 5302. Electromagnetic Theory. 3 Credit Hours.
Maxwell stress tensor; relativistic dynamics; Lagrangian formulation of electrodynamics; Noether's theorem; laser resonant cavities and optics of Gaussian beams; Eikonal and geometrical optics limit; synchrotron radiation.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites:
PHYS 5301|Minimum Grade of B-|May not be taken concurrently.

PHYS 5501. Mathematical Physics I. 3 Credit Hours.
Tensor analysis; group theory; complex variable theory; partial differential equations; Sturm-Liouville systems; integral transforms; integral equations and Green's function methods.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

PHYS 5502. Mathematical Physics II. 3 Credit Hours.
Preliminaries; numerical applicability, survey of algorithms, computer modeling, programming considerations; basic numerical methods; numerical linear algebra; numerical solution to ordinary and partial differential equations; molecular dynamics; Monte Carlo simulations; nonlinear methods.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

PHYS 5701. Quantum Mechanics I. 3 Credit Hours.
Fundamental principles of quantum mechanics; relation to classical mechanics; Schroedinger and operator formulations; path integrals; Aharonov-Bohm effect; examples of exact solutions; central forces and angular momentum; scattering theory; Bell's theorem.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites:
(PHYS 5101|Minimum Grade of B-|May not be taken concurrently
AND PHYS 5501|Minimum Grade of B-|May not be taken concurrently)

PHYS 5702. Quantum Mechanics II. 3 Credit Hours.
Matrix mechanics; theory of electron spin; Hilbert space formulation of quantum mechanics; transformation theory; theory of rotations; spin and statistics; stationary approximation methods with application to atomic systems; time-dependent perturbation theory; exponential decay.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites:
PHYS 5701|Minimum Grade of B-|May not be taken concurrently.
**PHYS 8001. Practicum Teaching of Physics. 1 Credit Hour.**
Required of all graduate teaching assistants in their first semester. Consists of supervised instruction in undergraduate laboratories and a weekly two-hour class.

*Level Registration Restrictions:* Must be enrolled in one of the following Levels: Graduate.

*Repeatability:* This course may not be repeated for additional credits.

**PHYS 8004. Problems in Experimental Physics. 1 to 6 Credit Hour.**
Special problems in the field of experimental physics. The course is designed to acquaint the student with the research techniques employed in experimental physics.

*Level Registration Restrictions:* Must be enrolled in one of the following Levels: Graduate.

*Repeatability:* This course may be repeated for additional credit.

**PHYS 8005. Problems in Theoretical Physics. 1 to 6 Credit Hour.**
Special problems in the field of theoretical physics. The course is designed to acquaint the student with the research techniques employed in theoretical physics.

*Level Registration Restrictions:* Must be enrolled in one of the following Levels: Graduate.

*Repeatability:* This course may be repeated for additional credit.

**PHYS 8020. Topical Seminar II. 3 Credit Hours.**
This course considers special topics in Physics, not considered in depth in our other courses.

*Level Registration Restrictions:* Must be enrolled in one of the following Levels: Graduate.

*Repeatability:* This course may be repeated for additional credit.

**PHYS 8030. Topical Seminar III. 3 Credit Hours.**
This course considers special topics in Physics, not considered in depth in our other courses.

*Level Registration Restrictions:* Must be enrolled in one of the following Levels: Graduate.

*Repeatability:* This course may be repeated for additional credit.

**PHYS 8050. Physics Seminar. 0 Credit Hours.**
This course provides the graduate students with the state of the field knowledge about Physics. Students attend 10 to 12 Colloquium/Seminars per semester given by the experts, mostly drawn from national and international authorities in the field. The students are graded on the basis of their attendance in these seminars, and are encouraged to discuss their research with these visiting experts. Last year's colloquium included among other experts, a Nobel Laureate, Sir Anthony Leggett, 2003.

*Level Registration Restrictions:* Must be enrolled in one of the following Levels: Graduate.

*Repeatability:* This course may be repeated for additional credit.

**PHYS 8102. Statistical Mechanics. 3 Credit Hours.**
Review of thermodynamics; kinetic theory; statistical definition of entropy; microcanonical, canonical, and grand canonical ensembles; applications to gases, diatomic molecules, magnetic systems, phase transitions; quantum statistics; ideal boson and fermion systems; Bose-Einstein condensation; black body radiation; models of solids; properties of liquid helium.

*Level Registration Restrictions:* Must be enrolled in one of the following Levels: Graduate.

*Repeatability:* This course may not be repeated for additional credits.

**Pre-requisites:**
(\(\text{PHYS 5501}\) Minimum Grade of B-)\(\text{May not be taken concurrently}\)
\(\text{AND PHSY 5701}\) Minimum Grade of B-)\(\text{May not be taken concurrently}\)
PHYS 8701. Advanced Quantum Mechanics. 3 Credit Hours.
Properties of quantized radiation field; emission, absorption and scattering of photons by atoms; nonrelativistic Lamb shift; Dirac equation: nonrelativistic limit, Lorentz covariance, exact solutions; hole theory; Lagrangian field theory; field quantization; S-matrix; covariant perturbation theory; Feynman rules for QED with application to various processes.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites:
PHYS 5702|Minimum Grade of B-|May not be taken concurrently.

PHYS 8702. Solid State Physics. 3 Credit Hours.
Crystal and x-ray diffraction; lattice vibrations and thermal properties; energy bands and electronic properties; semiconductors; optical and dielectric properties; para-, ferro-, and antiferromagnetism; introduction to superconductivity and superfluidity.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites:
(PHYS 5701|Minimum Grade of B-|May not be taken concurrently)
AND (PHYS 5702|Minimum Grade of B-|May not be taken concurrently)

PHYS 8703. Introduction to Elementary Particles Physics. 3 Credit Hours.
The Standard Model (SM); gauge invariance, non-Abelian gauge theories, SM Lagrangian, electroweak theory and QCD, Higgs mechanism, confinement; experimental considerations: accelerators and detectors, elastic scattering and form factors, deep inelastic scattering and structure functions; advanced topics in the SM: grand unification, neutrino mass, big bang cosmology, dark matter.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites:
(PHYS 5701|Minimum Grade of B-|May not be taken concurrently)
AND (PHYS 5702|Minimum Grade of B-|May not be taken concurrently)

PHYS 8704. Many Electron Theory. 3 Credit Hours.
The course is at an intermediate level and is appropriate for students of experimental and theoretical condensed matter and AMO physics. The course familiarizes students with the theory of correlated electrons and states with broken electron symmetry, it also provides a framework for the description of experimental properties in materials with electron correlations. Topics include: Phenomenology of cohesion in molecules and solids, Many-electron wavefunctions, Functionals and their extrema, Wavefunction variational principles, Hellmann-Feynman theorem, One- and two-particle density matrices, and the electron density Wavefunction vs. density functional methods, Hohenberg-Kohn theorem, Functional derivatives, Uniform electron gas Kohn-Sham spin-density functional theory, Approximate functionals, Linear Response Theory and Stability, Collective Excitations, Superconducting Instability, Magnetic Instabilities, Charge Density Wave Instabilities in low-dimensional systems, Ferromagnetic, Spin and Orbital density wave phases, Instabilities of the Half-Filled Band, BCS Theory of Superconductivity, s, p and d wave pairing, the Integer and Fractional Quantum Hall States, Collective Excitations and Goldstone Modes.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

College Restrictions: Must be enrolled in one of the following Colleges: Science & Technology.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites:
PHYS 8702|Minimum Grade of B-|May not be taken concurrently.
PHYS 8705. Advanced Topics in Nuclear and Particle Physics. 3 Credit Hours.
The course is at an intermediate level and is appropriate for students of experimental and theoretical nuclear and particle physics. Topics include:
Accelerators, Detectors, Essential elements of data analysis and statistics, Selected advanced topics in QFT, Hard scattering processes and the parton structure of hadrons, Breaking of global and local symmetries (Higgs mechanism), Effective field theory, Neutrino physics, Physics beyond the SM, Nuclear matter under extreme conditions, Overview of nuclear structure and reactions.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
College Restrictions: Must be enrolled in one of the following Colleges: Science & Technology.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites:
PHYS 8703|Minimum Grade of B-|May not be taken concurrently.

PHYS 8985. Teach in Higher Ed: Phys. 2 Credit Hours.
Teaching in Higher Ed: Physics. This course focuses on learning theory and the best teaching practices, with the aim of preparing students for effective higher education teaching.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

PHYS 9991. Master's Research Projects. 1 to 6 Credit Hour.
Short-term, limited research project or laboratory project in the field. This course is not the capstone project course, nor can it be used for thesis based research. The course is for master's students only, including PSM, MA or MS. This class will not confer full-time program status unless nine credits are taken.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Degree Restrictions: Must be enrolled in one of the following Degrees: Master of Arts, Master of Science, Prof Science Masters.

Repeatability: This course may be repeated for additional credit.

PHYS 9994. Preliminary Examination Preparation. 1 to 6 Credit Hour.
This course is required for students who are preparing for the preliminary or candidacy examination. Students should enroll after coursework is completed or when preparing for the candidacy exam until the time that the preliminary or candidacy examination is completed. This course will confer full-time status at the minimum credit hour registration limit of one credit. All students must complete a minimum of one credit of this course. Students must complete a total of 6 credit hours of 9994, 9998 and 9999.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

PHYS 9995. Capstone Project. 1 to 6 Credit Hour.
Capstone project for master's students including students in PSM, MA or MS. This class will provide full-time status. Students in PSM programs need to register for at least one credit of this course to fulfill program requirements. Additional credits may be required for specific programs. This course will confer full-time status at the minimum credit hour registration limit of one credit.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Degree Restrictions: Must be enrolled in one of the following Degrees: Master of Arts, Master of Science, Prof Science Masters.

Repeatability: This course may be repeated for additional credit.

PHYS 9996. Master's Thesis Research. 1 to 6 Credit Hour.
Course for master's thesis research. Only intended for students in thesis bearing master's programs. A minimum of one credit is required. This course will confer full-time status at the minimum credit hour registration limit of one credit.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.
**PHYS 9998. Pre-Dissertation Research / Elevation to Candidacy. 1 to 6 Credit Hour.**

This course is intended for students who are performing research prior to candidacy. Students can register for this course after required courses are completed. This course will confer full-time status at the minimum credit hour registration limit of one credit. Students must be registered for this course during the semester that they are to be elevated to candidacy examination. Students must complete a total of 6 credit hours of 9994, 9998 and 9999.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may be repeated for additional credit.

**PHYS 9999. Dissertation Research. 1 to 6 Credit Hour.**

The course is for Ph.D. students who have been elevated to candidacy. During the course of their candidacy students must complete a minimum of two credits of dissertation research. This course will confer full-time status at the minimum credit hour registration limit of one credit. Students must complete a total of 6 credit hours of 9994, 9998 and 9999.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Student Attribute Restrictions:** Must be enrolled in one of the following Student Attributes: Dissertation Writing Student.

**Repeatability:** This course may be repeated for additional credit.