Physics

2016 - 2017

Degrees Offered

• Master of Science (Applied Physics)
• Doctor of Philosophy (Applied Physics)

Program Description

The Physics Department at CSM offers a full program of instruction and research leading to the M.S. or Ph.D. in Applied Physics and is part of interdisciplinary programs in Materials Science and in Nuclear Engineering, through which students can obtain both the M.S. and the Ph.D degrees. The research in these graduate programs is supported by external grants and contracts totaling $6.5M/year. Research in the Department is organized under three primary themes: subatomic physics, condensed matter physics, and applied optics. With 23 faculty, 83 graduate students, and 262 undergraduate physics majors, the Physics Department at CSM is a vibrant intellectual community providing high-quality education in state-of-the-art facilities.

Graduate students are given a solid background in the fundamentals of classical and modern physics at an advanced level and are encouraged early in their studies to learn about the research interests of the faculty so that a thesis topic can be identified.

Program Requirements

Students entering graduate programs in Applied Physics will select an initial program in consultation with the departmental graduate student advising committee until such time as a research field has been chosen and a thesis committee appointed.

Master of Science

Requirements: 20 semester hours of course work in an approved program, plus 16 semester hours of research credit, with a satisfactory thesis.

Doctorate of Philosophy

Requirements: 32 semester hours of course work in an approved program, plus 40 semester hours of research credit, with a satisfactory thesis. 12 semester hours of course work will be in a specialty topic area defined in consultation with the thesis advisor. Possible specialty topic areas within the Physics Department exist in Optical Science and Engineering, Condensed Matter Physics, Theoretical Physics, Renewable Energy Physics, and Nuclear/Particle Physics and Astrophysics.

To demonstrate adequate preparation for the Ph.D. degree in Applied Physics, each student must achieve a grade of 3.0 or better in each core course. Students not meeting this standard must pass oral examinations covering the relevant core courses or retake the courses with a grade of 3.0 or better within one year. This process is part of the requirement for admission to candidacy, which full time Ph.D. students must complete within two calendar years of admission, as described in the campus-wide graduate degree requirements (http://bulletin.mines.edu/graduate/programs) section of this bulletin. Other degree requirements, time limits, and procedural details can be found in the Physics Department Graduate Student Advising Brochure.

Physics Colloquium

All full-time physics graduate students must attend the Physics Colloquium, which is represented in the curriculum by the Graduate Seminar courses. Students must take one of these courses every semester that they are enrolled at CSM. Those students who are in the M.S. Program, sign up for PHGN501 (fall) and PHGN502 (spring). Students in the Ph.D. program sign up for PHGN601 (fall) and PHGN602 (spring). At the end of each semester students are assigned either a satisfactory or unsatisfactory progress grade, based on attendance, until the final semester of the student's degree program, when a letter grade is assigned based on all prior semesters' attendance grades. As a result, while these courses are taken each year, only 1 hour total of course credit is conferred for each of 501, 502, 601, or 602. Students who have official part-time status and who have already taken at least one semester of 501 and 502 for the M.S. degree, or 601 and 602 for the Ph.D. degree are not required to sign up for Graduate Seminar during subsequent semesters.

Prerequisites

The Graduate School of the Colorado School of Mines is open to graduates from four-year programs at accredited colleges or universities. Admission to the Physics Department M.S. and Ph.D. programs is competitive and is based on an evaluation of undergraduate performance, standardized test scores, and references. The undergraduate course of study of each applicant is evaluated according to the requirements of the Physics Department.

Required Curriculum

Master of Science, Applied Physics

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<th>Core Courses</th>
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<tbody>
<tr>
<td>PHGN511</td>
<td>MATHEMATICAL PHYSICS</td>
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<tr>
<td>PHGN520</td>
<td>QUANTUM MECHANICS I</td>
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<tr>
<td>Select one of the following:</td>
<td>3.0</td>
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<tr>
<td>PHGN505</td>
<td>CLASSICAL MECHANICS I</td>
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<tr>
<td>PHGN507</td>
<td>ELECTROMAGNETIC THEORY I</td>
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<tr>
<td>PHGN521</td>
<td>QUANTUM MECHANICS II</td>
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<td>PHGN530</td>
<td>STATISTICAL MECHANICS</td>
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<tr>
<td>PHGN501</td>
<td>GRADUATE SEMINAR</td>
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<tr>
<td>&amp; PHGN502</td>
<td>and GRADUATE SEMINAR *</td>
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<td>PHGN707</td>
<td>Master's Thesis</td>
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<td>16.0</td>
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<tr>
<td>Total Semester Hrs</td>
<td>36.0</td>
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* Graduate Seminar: Each full-time M.S. graduate student will register for Graduate Seminar each semester for a total of 2 semester hours of credit cumulative over the degree.

Doctor of Philosophy, Applied Physics

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Colorado School of Mines
Physics

PHGN521 QUANTUM MECHANICS II 3.0
PHGN530 STATISTICAL MECHANICS 3.0
PHGN601 ADVANCED GRADUATE SEMINAR & PHGN602 and ADVANCED GRADUATE SEMINAR 2.0
PH ELECT Special topic area electives 12.0
PHGN707 Doctoral Thesis 40.0
Total Semester Hrs 72.0

* Graduate Seminar: Each full-time Ph.D. graduate student will register
  for Graduate Seminar each semester for a total of 2 semester hours
  of cumulative credit over the degree.

Fields of Research

Applied Optics: lasers, ultrafast optics and x-ray generation,
spectroscopy, near-field and multiphoton microscopy, non-linear optics,
 quasi-optics and millimeter waves.

Ultrasonics: laser ultrasonics, resonant ultrasound spectroscopy, wave
  propagation in random media.

Subatomic: low energy nuclear physics, nuclear astrophysics, cosmic
  ray physics, nuclear theory, fusion plasma diagnostics.

Materials Physics: photovoltaics, nanostructures and quantum dots,
thin film semiconductors, transparent conductors, amorphous materials,
thermoelectric materials, plasmonics, first principles materials theory.

Condensed Matter: x-ray diffraction, Raman spectroscopy, self
  assembled systems, soft condensed matter, condensed matter theory,
  quantum chaos, quantum information and quantum many body theory.

Surface and Interfaces: x-ray photoelectron spectroscopy, Auger
  spectroscopy, scanning probe microscopies, second harmonic
  generation.

Professors

Lincoln D. Carr
Reuben T. Collins
Charles G. Durfee III
Uwe Greife
Frank V. Kowalski
Mark T. Lusk
Frederic Sarazin
John A. Scales
Jeff A. Squier, Department Head
P. Craig Taylor

Assistant Professors

Kyle G. Leach
Susanta K. Sarkar
Eric S. Toberer
Jeramy D. Zimmerman

Teaching Professors

Alex T. Flournoy
Patrick B. Kohl
H. Vincent Kuo
Todd G. Ruskell
Charles A. Stone
Matt Young

Teaching Associate Professor

Kristine E. Callan

Research Professors

Mark W. Coffey
Jonathan L. Mace
Zeev Shayer

Research Associate Professor

James E. Bernard

Research Assistant Professor

P. David Flammer

Professors Emeriti

F. Edward Cecil
Thomas E. Furtak
James A. McNeil
Don L. Williamson

Associate Professors Emeriti

William B. Law
Arthur Y. Sakakura

Courses

PHGN501. GRADUATE SEMINAR. 1.0 Semester Hr.
(i) M.S. students will attend the weekly Physics Colloquium. Students
  will be responsible for presentations during this weekly seminar. See
  additional course registration instructions under Program Requirements
  above. 1 hour seminar; 1 semester hour.
PHGN502. GRADUATE SEMINAR. 1.0 Semester Hr.
(I) M.S. students will attend the weekly Physics Colloquium. Students will be responsible for presentations during this weekly seminar. See additional course registration instructions under Program Requirements above. 1 hour seminar; 1 semester hour.

PHGN503. RESPONSIBLE CONDUCT OF RESEARCH. 1.0 Semester Hr.
(II) This course introduces students to the various components of responsible research practices. Subjects covered move from issues related to professional rights and obligations through those related to collaboration, communication and the management of grants, to issues dealing with intellectual property. The course culminates with students writing an ethics essay based on a series of topics proposed by the course instructor. 1 hour lecture; 1 semester hour.

PHGN504. RADIATION DETECTION AND MEASUREMENT. 3.0 Semester Hrs.
Physical principles and methodology of the instrumentation used in the detection and measurement of ionizing radiation. Prerequisite: none. 3 hours lecture; 3 semester hours.

PHGN505. CLASSICAL MECHANICS I. 3.0 Semester Hrs.
(I) Review of Lagrangian and Hamiltonian formulations in the dynamics of particles and rigid bodies; kinetic theory; coupled oscillations and continuum mechanics; fluid mechanics. Prerequisite: PHGN350 or equivalent. 3 hours lecture; 3 semester hours.

PHGN507. ELECTROMAGNETIC THEORY I. 3.0 Semester Hrs.
(II) To provide a strong background in electromagnetic theory. Electrostatics, magnetostatics, dynamical Maxwell equations, wave phenomena. Prerequisite: PHGN462 or equivalent and PHGN511. 3 hours lecture; 3 semester hours.

PHGN511. MATHEMATICAL PHYSICS. 3.0 Semester Hrs.
(I) Review of complex variable and finite and infinite-dimensional linear vector spaces. Sturm-Liouville problem, integral equations, computer algebra. Prerequisite: PHGN311 or equivalent. 3 hours lecture; 3 semester hours.

PHGN520. QUANTUM MECHANICS I. 3.0 Semester Hrs.
(II) Schroedinger equation, uncertainty, change of representation, one-dimensional problems, axioms for state vectors and operators, matrix mechanics, uncertainty relations, time-independent perturbation theory, time-dependent perturbations, harmonic oscillator, angular momentum; semiclassical methods, variational methods, two-level system, sudden and adiabatic changes, applications. Prerequisite: PHGN511 and PHGN320 or equivalent. 3 hours lecture; 3 semester hours.

PHGN521. QUANTUM MECHANICS II. 3.0 Semester Hrs.

PHGN530. STATISTICAL MECHANICS. 3.0 Semester Hrs.
(I) Review of thermodynamics; equilibrium and stability; statistical operator and ensembles ideal systems; phase transitions; non-equilibrium systems. Prerequisite: PHGN341 or equivalent and PHGN520. Co-requisite: PHGN521. 3 hours lecture; 3 semester hours.

PHGN535. INTERDISCIPLINARY SILICON PROCESSING LABORATORY. 3.0 Semester Hrs.
(II) Explores the application of science and engineering principles to the fabrication and testing of microelectronic devices with emphasis on specific unit operations and interrelation among processing steps. Teams work together to fabricate, test, and optimize simple devices. Prerequisite: none. 1 hour lecture, 4 hours lab; 3 semester hours.

PHGN542. SOLID STATE DEVICES AND PHOTOVOLTAIC APPLICATIONS. 3.0 Semester Hrs.
(II) An overview of the physical principles involved in the characterization, and operation of solid state devices. Topics will include: semiconductor physics, electronic transport, recombination and generation, intrinsic and extrinsic semiconductors, electrical contacts, p-n junction devices (e.g., LEDs, solar cells, lasers, particle detectors); other semiconductor devices (e.g., bipolar junction transistors and field effect transistors and capacitors). There will be emphasis on optical interactions and application to photovoltaic devices. Prerequisite: PHGN440 or equivalent. 3 hours lecture; 3 semester hours.

PHGN550. NANO SCALE PHYSICS AND TECHNOLOGY. 3.0 Semester Hrs.
An introduction to the basic physics concepts involved in nanoscale phenomena, processing methods resulting in engineered nanostructures, and the design and operation of novel structures and devices which take advantage of nanoscale effects. Students will become familiar with interdisciplinary aspects of nanotechnology, as well as with current nanoscience developments described in the literature. Prerequisites: PHGN320, PHGN341, co-requisite: PHGN462. 3 hours lecture; 3 semester hours.

PHGN566. MODERN OPTICAL ENGINEERING. 3.0 Semester Hrs.
Provides students with a comprehensive working knowledge of optical system design that is sufficient to address optical problems found in their respective disciplines. Topics include paraxial optics, imaging, aberration analysis, use of commercial ray tracing and optimization, diffraction, linear systems and optical transfer functions, detectors, and optical system examples. Prerequisite: PHGN511. 3 hours lecture; 3 semester hours.

PHGN570. FOURIER AND PHYSICAL OPTICS. 3.0 Semester Hrs.
This course addresses the propagation of light through optical systems. Diffraction theory is developed to show how 2D Fourier transforms and linear systems theory can be applied to imaging systems. Analytic and numerical Fourier and microscopes, spectrometers and holographic imaging. They are also applied to temporal propagation in ultrafast optics. Prerequisite: PHGN462. 3 hours lecture; 3 semester hours.

PHGN585. NONLINEAR OPTICS. 3.0 Semester Hrs.
An exploration of the nonlinear response of a medium (semiclassical and quantum descriptions) and nonlinear wave mixing and propagation. Analytic and numeric techniques to treat nonlinear dynamics are developed. Applications to devices and modern research areas are discussed, including harmonic and parametric wave modulation, phase conjugation, electro-optic modulation. Prerequisite: PHGN462 or equivalent, PHGN520. 3 hours lecture; 3 semester hours.
PHGN590. NUCLEAR REACTOR PHYSICS. 3.0 Semester Hrs.
Bridges the gap between courses in fundamental nuclear physics and the 
practice of electrical power production using nuclear reactors. Review of 
nuclear constituents, forces, structure, energetics, decay and reactions; 
interaction of radiation with matter, detection of radiation; nuclear cross 
sections, neutron induced reactions including scattering, absorption, 
and fission; neutron diffusion, multiplication, criticality; simple reactor 
geometries and compositions; nuclear reactor kinetics and control; 
modeling and simulation of reactors. Prerequisite: PHGN422.

PHGN597. SUMMER PROGRAMS. 6.0 Semester Hrs.

PHGN598. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special 
interests of instructor(s) and student(s). Usually the course is offered only 
onece, but no more than twice for the same course content. Prerequisite: 
none. Variable credit: 0 to 6 credit hours. Repeatable for credit under 
different titles.

PHGN599. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a 
faculty member, also, when a student and instructor agree on a subject 
matter, content, and credit hours. Prerequisite: Independent Study form 
must be completed and submitted to the Registrar. Variable credit: 0.5 
to 6 credit hours. Repeatable for credit under different topics/experience 
and maximums vary by department. Contact the Department for credit 
limits toward the degree.

PHGN601. ADVANCED GRADUATE SEMINAR. 1.0 Semester Hr.
(I) Ph.D. students will attend the weekly Physics Colloquium. Students 
will be responsible for presentations during this weekly seminar. See 
additional course registration instructions under Program Requirements 
above. 1 hour seminar; 1 semester hour.

PHGN602. ADVANCED GRADUATE SEMINAR. 1.0 Semester Hr.
(II) Ph.D. students will attend the weekly Physics Colloquium. Students 
will be responsible for presentations during this weekly seminar. See 
additional course registration instructions under Program Requirements 
above. 1 hour seminar; 1 semester hour.

PHGN608. ELECTROMAGNETIC THEORY II. 3.0 Semester Hrs.
Spherical, cylindrical, and guided waves; relativistic 4-dimensional 
formulation of electromagnetic theory. Prerequisite: PHGN507. 3 hours 
lecture; 3 semester hours. Offered on demand.

PHGN612. MATHEMATICAL PHYSICS II. 3.0 Semester Hrs.
Continuation of PHGN511. Prerequisite: none. 3 hours lecture; 3 
semester hours. Offered on demand.

PHGN623. NUCLEAR STRUCTURE AND REACTIONS. 3.0 Semester 
Hrs.
The fundamental physics principles and quantum mechanical models 
and methods underlying nuclear structure, transitions, and scattering 
reactions. Prerequisite: PHGN521. 3 hours lecture; 3 semester hours. 
Offered on demand.

PHGN624. NUCLEAR ASTROPHYSICS. 3.0 Semester Hrs.
The physical principles and research methods used to understand 
nucleosynthesis and energy generation in the universe. Prerequisite: 
none. 3 hours lecture; 3 semester hours. Offered on demand.

PHGN641. ADVANCED CONDENSED MATTER PHYSICS. 3.0 
Semester Hrs.
Provides working graduate-level knowledge of applications of solid state 
physics and important models to crystalline and non-crystalline systems 
in two and three dimensions. Review of transport by Bloch electrons; 
computation, interpretation of band structures. Interacting electron gas 
and overview of density functional theory. Quantum theory of optical 
properties of condensed systems; Kramers-Kronig analysis, sum rules, 
spectroscopies. Response and correlation functions. Theoretical models 
for metal-insulator and localization transitions in 1, 2, 3 dimensions 
(e.g., Mott, Hubbard, Anderson, Peierls distortion). Boltzmann equation. 
Introduction to magnetism; spin waves. Phenomenology of soft 
condensed matter: order parameters, free energies. Conventional 
superconductivity. Prerequisites: PHGN440 or equivalent, PHGN520, 
PHGN530. 3 hours lecture; 3 semester hours.

PHGN698. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special 
interests of instructor(s) and student(s). Usually the course is offered only 
once, but no more than twice for the same course content. Prerequisite: 
none. Variable credit: 0 to 6 credit hours. Repeatable for credit under 
different titles.

PHGN699. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a 
faculty member, also, when a student and instructor agree on a subject 
matter, content, and credit hours. Prerequisite: Independent Study form 
must be completed and submitted to the Registrar. Variable credit: 0.5 
to 6 credit hours. Repeatable for credit under different topics/experience 
and maximums vary by department. Contact the Department for credit 
limits toward the degree.

PHGN707. GRADUATE THESIS / DISSERTATION RESEARCH 
CREDIT. 1-15 Semester Hr.
(I, II, S) Research credit hours required for completion of a Masters-level 
thesis or Doctoral dissertation. Research must be carried out under the 
direct supervision of the student's faculty advisor. Variable class and 
semester hours. Repeatable for credit.