The Arthur E. Imperatore School of Sciences and Arts

Department of Physics and Engineering Physics

KURT H. BECKER, DIRECTOR

FACULTY*

Professors

Kurt H. Becker, Ph.D. (1981), Universität Saarbrücken, Germany
E. Byerly Brucker, Ph.D. (1959), Johns Hopkins University
Wayne E. Carr, Ph.D. (1967), University of Illinois
Hong-Liang Cui, Ph.D. (1987), Stevens Institute of Technology
Norman J. Horing, Ph.D. (1964), Harvard University
Erich E. Kunhardt (Dean of the Arthur E. Imperatore School of Sciences and Arts), Ph.D. (1976), Brooklyn Polytechnic Institute
Harold Salwen, Ph.D. (1956), Columbia University
Knut Stamnes, Ph.D. (1978), University of Colorado
Edward A. Whittaker, Ph.D. (1982), Columbia University

Assistant Professors

Rainer Martini, Ph.D. (1999) RWTH, Aachen, Germany
Christopher Search, PhD (2002), University of Michigan

RESEARCH FACULTY*

Research Professors

Abraham Belkind, Ph.D. (1967), State University, Tartu, Estonia

Research Associate Professors

Bingquan Chen, Ph.D. (1996), University of Bergen, Norway
Vladimir Tarnovsky, Ph.D. (1989), New York University

Research Assistant Professors

Hans Eide, Ph.D. (2000), University of Alaska
Lev Murokh, Ph.D. (1996), Lobachevsky State University, Nizhny Novgorod, Russia

*The list indicates the highest earned degree, year awarded and institution where earned.

UNDERGRADUATE PROGRAMS

Physics

The laws of physics govern the universe from the formation of stars and galaxies to the processes in the Earth's atmosphere that determine our climate, to the elementary particles and their interactions that hold together atomic nuclei. Physics also drives many rapidly-advancing technologies such as information technology, telecommunication, microelectronics and medical technology including MRI imaging and laser surgery.

The physics program at Stevens combines classroom instruction with hands-on research experience in one of several state-of-the-art research laboratories (Photonics Science and Technology, Optical Communication and Nanodevices, Quantum Electron Science and Technology, Electron-Driven Processes and Plasmas, Light and Life, Ultrafast Spectroscopy and Communication). Perhaps the most differentiating feature of the Stevens physics curriculum is SKIL (Science Knowledge Integration Ladder), a six-semester sequence of project-centered courses. This course sequence lets students work on projects that foster independent learning, innovative problem solving, collaboration and team work, and knowledge integration under the guidance of a faculty advisor. The SKIL sequence starts in the sophomore year with projects that integrate basic scientific knowledge and simple concepts. In the junior and senior years, the projects become more challenging and the level of independence increases.

Our B.S. degree in Applied Physics is accredited by the Middle States Accreditation Board. Our graduates have a wide range of career opportunities beyond the pursuit of a traditional graduate degree in physics, including employment in a variety of other disciplines such as chemistry, life science, engineering or environmental science. Those who choose to further their physics education are accepted into graduate program at some of the best schools.

Freshman Year

Term I

		Hrs. Per Wk.		
		Class	Lab	Sem. Cred.
Hu	Humanities	3	0	3
Ma 115	Math Analysis I	3	0	3
Ch 115	General Chemistry I	3	0	3
Ch 117	General Chemistry Lab I	0	3	1
CS 105	Intro to Scientific Computing	2	2	3
OR				
CS 115	Intro to Computer Science	3	2	4
PEP 111	Mechanics	3	0	3
PE 200	Physical Education I	0	2	1
	TOTAL	**14(15)**	**7**	**17(18)**

Term II

		Hrs. Per Wk.		
		Class	Lab	Sem. Cred
Hu	Humanities	3	0	3
Ma 116	Math Analysis II	3	0	3
Ch 116	General Chemistry II	3	0	3
Ch 118	General Chemistry Lab II	0	3	1
Ch 281	Biology and Biotechnology	3	0	3
PEP 112	Electricity and Magnetism	3	0	3
PE 200	Physical Education II	0	2	1
	TOTAL	**15**	**5**	**17**

Sophomore Year

Term III

		Hrs. Per Wk.		
		Class	Lab	Sem. Cred.
Hu	Humanities	3	0	3

Ma 221	Differential Equations	4	0	4
PEP 209	Modern Optics	3	0	3
PEP 221	Physics Lab I	0	3	1
	Thermodynamics [1,3] or Elective	3	0	3
PEP 297	SKIL I	1	3	2
PE 200	Physical Education III	0	2	1
	TOTAL	**14**	**8**	**17**

Term IV

		Hrs. Per Wk.		
		Class	Lab	Sem. Cred
Hu	Humanities	3	0	3
Ma 227	Multivariate Calculus	3	0	3
	Elective[1] or	3	0	3
Ch 321	Thermodynamics[3]			
PEP 222	Physics Lab II	0	3	1
PEP 242	Modern Physics	3	0	3
PEP 298	SKIL II	1	3	2
PE 200	Physical Education IV	0	2	1
	TOTAL	**13**	**8**	**16**

Junior Year

Term V

		Hrs. Per Wk.		
		Class	Lab	Sem. Cred.
Hu	Humanities	3	0	3
Ma 222	Probability & Statistics [1]	3	0	3
PEP 527	Math Methods I of Sci. & Eng. [1]	3	0	3
PEP 538	Intro to Mechanics [1]	3	0	3
PEP 397	SKIL III	1	6	3
PE 200	Physical Education V	0	2	1
	TOTAL	**13**	**8**	**16**

Term VI

		Hrs. Per Wk.		
		Class	Lab	Sem. Cred
Hu	Humanities	3	0	3
PEP 542	Electromagnetism [1]	3	0	3
PEP 528	Math Methods of Sci. & Eng. II [1]	3	0	3
	Elective	3	0	3

PEP 398	SKIL IV	1	6	3
PE 200	Physical Education VI	0	2	1
	TOTAL	**13**	**8**	**16**

Senior Year

Term VII				
		Hrs. Per Wk.		
		Class	Lab	Sem. Cred.
Hu	Humanities	3	0	3
PEP 553	Quantum Mechanics and Eng. Appl. I [1]	3	0	3
	Elective	3	0	3
	Elective	3	0	3
PEP 497	SKIL V [1, 2]	1	6	3
	TOTAL	**13**	**6**	**15**

Term VIII				
		Hrs. Per Wk.		
		Class	Lab	Sem. Cred
Hu	Humanities	3	0	3
PEP 554	Quantum Mechanics II [1]	3	0	3
	Elective	3	0	3
Mgt	Economics	3	0	3
PEP 498	SKIL VI [1, 2]	1	6	3
	TOTAL	**13**	**6**	**15**

[1] Technical Electives
[2] SKIL V and SKIL VI can be a year-long Senior Project resulting in a final report or a thesis.
[3] Thermodynamics may be Ch 321 or E 234.

Other physics courses, needed in order to complete a concentration, may be substituted with the consent of your advisor.

Qualified students may participate in faculty-supervised projects.

Possible overloads during the latter semesters to insure a complete undergraduate curriculum:
PEP 555 Statistical Physics and Kinetic Theory 3-0-3
PEP 512 Nuclear Physics and Nuclear Reactors 3-0-3
PEP 520 Computational Physics 3-0-3
PEP 541 The Physics of Gas Discharges 3-0-3
PEP 509 Intermediate Waves and Optics 3-0-3
PEP 507 Introduction to Microelectronics and Photonics 3-0-3
PEP 503 Introduction to Solid State Physics 3-0-3

Minor in Physics

You may qualify for a minor in physics by taking the required courses indicated below. Completion of a minor indicates a proficiency beyond that provided by the Stevens curriculum in the basic material of the selected area. If you are enrolled in a minor program, you must meet the Institute requirements. In addition, the grade in any course credited for a minor must be "C" or better.

Requirements for a Minor in Physics

PEP 101 Physics I for Engineering Students
or
PEP 111 Mechanics
PEP 112 Electricity and Magnetism
PEP 209 Modern Optics
PEP 242 Modern Physics
PEP 527 Mathematical Methods of Science and Engineering
PEP 538 Introduction to Mechanics
PEP 542 Electromagnetism
PEP 553 Quantum Mechanics with Engineering Applications

BS Degree in Engineering Physics (EP)

The Department of Physics and Engineering Physics also offers an Undergraduate Engineering Physics (EP) Program, which leads to a BS degree in Engineering Physics in four concentrations (see below). The program aims to attract students who are intrigued by the possibility of combining a mastery of basic physics concepts with exposure to state-of-the-art engineering technology in selected high-tech areas. The EP Program is a special program that was developed jointly by the Department of Physics and Engineering Physics and the School of Engineering. Students in the EP Program follow a special core curriculum that combines aspects of the SoE and ISSA core curricula. This combination of courses provides the students with the basic concepts of engineering together with a basic understanding of physical phenomena at a microscopic level and lets them explore the relation of the physics concepts to practical problems of engineering in one of four high-tech areas of concentration: Applied Optics, Microelectronics and Photonics, Atmospheric and Environmental Science, or Plasma and Surface Physics. These concentrations represent high-tech areas of significant current local and global technological and economic interest. The PEP department has both research strength and educational expertise in these areas where there is significant growth potential. For all concentrations, required and/or elective courses offered by other departments (EE, EN, MT) can be used to complement departmental course offerings, which provide the students in the program with the necessary diversity, breadth, and depth of educational offerings and research opportunities. The following curriculum shows the common two years and t hen the final two years separately for each concentration.

EP Undergraduate Curriculum

Freshman Year

Term I				
		Hrs. Per Wk.		
		Class	Lab	Sem. Cred.
Hu	Humanities	3	0	3
Ma 115	Math Analysis I	3	0	3
Ch 107	General Chem. IA	2	0	2
Ch 117	General Chem. Lab I	0	3	1
E 115	Intro to Programming	1	1.5	2
PEP 111/PEP 101	Physics I	3	0	3
E 120	Eng. Graphics	0	2	1
E 121	Eng. Design I	0	3	2
PE 200	Physical Education I	0	2	1
	TOTAL	**12**	**11.5**	**18**

Term II				
		Hrs. Per Wk.		

		Class	Lab	Sem. Cred
Hu	Humanities	3	0	3
Ma 116	Math Analysis II	3	0	3
Ch 116	General Chem. II	3	0	3
Ch 118	General Chem. Lab II	0	3	1
E 126	Mechanics of Solids	4	0	4
PEP 112/PEP 102	Physics II	3	0	3
E 122	Eng Design II	0	3	2
PE 200	Physical Education II	0	2	1
	TOTAL	**16**	**8**	**20**

Sophomore Year

Term III

		Hrs. Per Wk.		
		Class	Lab	Sem. Cred.
Hu	Humanities	3	0	3
Ma 221	Differential Equations	4	0	4
PEP 242	Modern Physics	3	0	3
PEP 221	Physics Lab I	0	3	1
E 234	Thermodynamics	3	0	3
PEP 297	SKIL I	1	3	2
E 245	Circuits & Systems	2	3	3
PE 200	Physical Education III	0	2	1
	TOTAL	**16**	**11**	**20**

Term IV

		Hrs. Per Wk.		
		Class	Lab	Sem. Cred
Hu	Humanities	3	0	3
Ma 227	Multivariate Calculus	3	0	3
PEP 209	Modern Optics ‡	3	0	3
PEP 222	Physics Lab II	0	3	1
PEP 298	SKIL II	1	3	2
E 243	Prob. & Statistics ‡	3	0	3
E 246	Electronics & Instrum.	3	0	3
PE 200	Physical Education IV	0	2	1
	TOTAL	**16**	**8**	**19**

EP Undergraduate Curriculum, Concentration "Applied Optics"

Junior Year

Term V				
		Hrs. Per Wk.		
		Class	Lab	Sem. Cred.
Hu	Humanities	3	0	3
	CTE	3	0	3
PEP 527	Math. Methods I	3	0	3
PEP 538	Intro. to Mechanics	3	0	3
PEP 397	SKIL III	1	6	3
PE 200	Physical Education V	0	2	1
	TOTAL	**13**	**8**	**16**

Term VI				
		Hrs. Per Wk.		
		Class	Lab	Sem. Cred
Hu	Humanities	3	0	3
PEP 542	Electromagnetism	3	0	3
PEP 368	Transport Theo. & Sim.	3	0	3
PEP 509	Intermediate Optics	3	0	3
PEP 398	SKIL IV	1	6	3
PE 200	Physical Education VI	0	2	1
	TOTAL	**13**	**8**	**16**

Senior Year

Term VII				
		Hrs. Per Wk.		
		Class	Lab	Sem. Cred.
Hu	Humanities	3	0	3
PEP 553	Quantum Mechanics I	3	0	3
PEP 510	Modern Optics Lab.	3	0	3
PEP 577	Laser Theory	3	0	3
PEP 497	SKIL V	1	6	3
	TOTAL	**13**	**6**	**15**

Term VIII				
		Hrs. Per Wk.		
		Class	Lab	Sem. Cred
Hu	Humanities	3	0	3

PEP 554	Quantum Mechanics II	3	0	3
PEP 578	Laser Application ‡	3	0	3
MGT	Economics	3	0	3
PEP 498	SKIL VI	1	6	3
	TOTAL	**13**	**6**	**15**

‡ Can be replaced by PEP 678 with the consent of the instructor.
Possible CTE/TEs: PEP 515, PEP 516, PEP 528, PEP 570, PEP 679 (with consent of the instructor), PEP 680 (with consent of the instructor), EE 626 (with consent of the instructor)

EP Undergraduate Curriculum, Concentration "Microelectronics and Photonics"

Junior Year

Term V				
		Hrs. Per Wk.		
		Class	Lab	Sem. Cred.
Hu	Humanities	3	0	3
PEP 507	Intro. Microel./Photon.	3	0	3
PEP 527	Math. Methods I	3	0	3
PEP 538	Intro. to Mechanics	3	0	3
PEP 397	SKIL III	1	6	3
PE 200	Physical Education V	0	2	1
	TOTAL	**13**	**8**	**16**

Term VI				
		Hrs. Per Wk.		
		Class	Lab	Sem. Cred
Hu	Humanities	3	0	3
PEP 542	Electromagnetism	3	0	3
PEP 368	Transport Theo. & Sim.	3	0	3
PEP 596	Microfab. Techniques	3	0	3
PEP 398	SKIL IV	1	6	3
PE 200	Physical Education VI	0	2	1
	TOTAL	**13**	**8**	**16**

Senior Year

Term VII				
		Hrs. Per Wk.		
		Class	Lab	Sem. Cred.
Hu	Humanities	3	0	3
PEP 553	Quantum Mechanics I	3	0	3
PEP 515	Photonics I	3	0	3

PEP 561	Solid State Electronics I	3	0	3
PEP 497	SKIL V	1	6	3
	TOTAL	**13**	**6**	**15**

Term VIII

		Hrs. Per Wk.		
		Class	Lab	Sem. Cred
Hu	Humanities	3	0	3
PEP 516	Photonics II ‡ or CTE	3	0	3
PEP 562	Solid State Electronics II ‡ or CTE	3	0	3
MGT	Economics	3	0	3
PEP 498	SKIL VI	1	6	3
	TOTAL	**13**	**6**	**15**

‡ Technical Electives.

Possible CTE/TEs: PEP 503, PEP 595, PEP 628 (with consent of the instructor), PEP 678 (with consent of the instructor)

EP Undergraduate Curriculum, Concentration "Atmospheric and Environmental Science"

Junior Year

Term V

		Hrs. Per Wk.		
		Class	Lab	Sem. Cred.
Hu	Humanities	3	0	3
	CTE / TE	3	0	3
PEP 527	Math. Methods I	3	0	3
PEP 538	Intro. to Mechanics	3	0	3
PEP 397	SKIL III	1	6	3
PE 200	Physical Education V	0	2	1
	TOTAL	**13**	**8**	**16**

Term VI

		Hrs. Per Wk.		
		Class	Lab	Sem. Cred
Hu	Humanities	3	0	3
PEP 542	Electromagnetism	3	0	3
PEP 368	Transport Theo. & Sim.	3	0	3
EN 550	Env. Chem. of Atmosp.	3	0	3
PEP 398	SKIL IV	1	6	3
PE 200	Physical Education VI	0	2	1

	TOTAL	13	8	16

Senior Year

Term VII				
		Hrs. Per Wk.		
		Class	Lab	Sem. Cred.
Hu	Humanities	3	0	3
PEP 553	Quantum Mechanics I	3	0	3
PEP 575	Atmos. Rad. /Climate	3	0	3
	CTE / TE	3	0	3
PEP 497	SKIL V	1	6	3
	TOTAL	**13**	**6**	**15**

Term VIII				
		Hrs. Per Wk.		
		Class	Lab	Sem. Cred
Hu	Humanities	3	0	3
PEP 554	Quantum Mechanics II	3	0	3
EN 506	Air Pollution Control	3	0	3
MT	Economics	3	0	3
PEP 498	SKIL VI	1	6	3
	TOTAL	**13**	**6**	**15**

Possible CTE/TEs: PEP 509, PEP 510, PEP 520, EN 505, EN 541, EN 545, EN 570

EP Undergraduate Curriculum, Concentration "Plasma and Surface Science"

Junior Year

Term V				
		Hrs. Per Wk.		
		Class	Lab	Sem. Cred.
Hu	Humanities	3	0	3
	CTE / TE.	3	0	3
PEP 527	Math. Methods I	3	0	3
PEP 538	Intro. to Mechanics	3	0	3
PEP 397	SKIL III	1	6	3
PE 200	Physical Education V	0	2	1
	TOTAL	**13**	**8**	**16**

Term VI

		Hrs. Per Wk.		
		Class	Lab	Sem. Cred
Hu	Humanities	3	0	3
PEP 542	Electromagnetism	3	0	3
PEP 368	Transport Theo. & Sim.	3	0	3
PEP 541	Physics of Gas Discharges	3	0	3
PEP 398	SKIL IV	1	6	3
PE 200	Physical Education VI	0	2	1
	TOTAL	**13**	**8**	**16**

Senior Year

Term VII

		Hrs. Per Wk.		
		Class	Lab	Sem. Cred.
Hu	Humanities	3	0	3
PEP 553	Quantum Mechanics I	3	0	3
PEP 525	Tech. Surface Analysis	3	0	3
	CTE / TE	3	0	3
PEP 497	SKIL V	1	6	3
	TOTAL	**13**	**6**	**15**

Term VIII

		Hrs. Per Wk.		
		Class	Lab	Sem. Cred
Hu	Humanities	3	0	3
PEP 554	Quantum Mechanics II	3	0	3
PEP 545	Plasma Processing	3	0	3
MT	Economics	3	0	3
PEP 498	SKIL VI	1	6	3
	TOTAL	**13**	**6**	**15**

Possible CTE/TEs: PEP 503, PEP 520, PEP 524, PEP 540, PEP 544, MT 544.

Interdisciplinary Program in Computational Science

For students interested in interdisciplinary science and engineering Stevens offers an undergraduate computational science program. Computational science is a new field in which techniques from mathematics and computer science are used to solve scientific and engineering problems. See the description of the Program in Computational Science in the Interdisciplinary Programs section.

GRADUATE PROGRAMS

The graduate program in physics is designed for the student who desires to master fundamental concepts and techniques, who is interested in studying applications in various areas of technology and science, and who wishes to keep abreast of the latest experimental and theoretical innovations in these areas. We offer a varied curriculum consisting of either highly specialized courses or broad training in diverse areas.

When you seek an advanced degree, you can gain both breadth and specialization. The required degree courses provide broad skills in basic physics; the elective choices give highly specialized training in a variety of different areas. The Department of Physics and Engineering Physics is large enough to offer rich and varied programs in pure and applied physics, yet it is small enough to sustain the sense of a coherent community in search of knowledge.

ADMISSIONS REQUIREMENTS

BS degree in physics or equivalent including the following coursework: calculus-based three- or four-semester introductory physics sequence, thermodynamics, electricity and magnetism, mechanics, quantum mechanics and mathematical methods.

Ph.D. applicants lacking the above courses are required to take the indicated courses for no graduate credit.

Graduate Record Examination including the Physics Subject Exam.

DEGREE REQUIREMENTS

Master of Science - Physics

The MS degree in physics will be awarded after completion of 30 credits of graduate coursework with the following requirements.

PEP 642 Mechanics
PEP 643/644 Electricity and Magnetism I and II
PEP 554 Quantum Mechanics II
One 600-level advanced quantum mechanics course
(currently PEP 621, PEP 655 or PEP 680)
PEP 528 Mathematical Methods of Science and Engineering II
PEP 555 Statistical Physics and Kinetic Theory
PEP 510 Modern Optics Lab (or another lab equivalent)
And, two additional elective courses, chosen in consultation with an academic advisor.

Doctoral Program - Physics

Ph.D. students must pass a qualifying examination. The examination will consist of a written part that tests mastery of a set of core physics topics, followed by an oral examination that tests the student's ability to discuss physical problems with an examining committee of three faculty members. The student will have two opportunities to pass the examination. The first attempt must be made within the first two years of study at Stevens.

Upon successful completion of the examination, the student becomes a qualified Ph.D. candidate. A Ph.D. advisory committee shall be formed for each candidate consisting of a major advisor on the physics department faculty, an additional physics department faculty member and a third Stevens faculty member from any department other than Physics. Additional committee members from Stevens or elsewhere may also be included.

Ph.D. candidates are required to have competency in using computer-based methods of calculation and analysis. Student lacking this competency are encouraged to take PEP 520 Computational Physics.

In addition to the courses required in the 30-credit MS degree, completion of the following coursework will be required for the Ph.D.:

PEP 529 Mathematical Methods of Science and Engineering III
PEP 667 Statistical Mechanics
One 600-level quantum mechanics application course
Three 700-level courses chosen in consultation with an academic advisor

The student will carry out an original research program under the supervision of the major advisor and advisory committee. The results of the research will be presented in a written dissertation. Upon approval of the advisory committee, the written dissertation will be defended by the student in an oral defense.

A total of 90 credits beyond the baccalaureate degree are required for the Ph.D. degree. Required coursework represents 48 credits. At least 30 of the remaining 42 credits must be for the Ph.D. research (PEP 960).

Applications are welcome from students who have already earned a master's degree elsewhere.

Applicants with the equivalent of the Stevens MS degree would be eligible to take the qualifying exam immediately and become candidates without additional course requirements. All remaining requirements including doctoral coursework, research and a total of 60 credits beyond the master's degree would be required for the doctoral degree.

Applicants with a non-physics master's degree would be required to complete sufficient coursework to meet the requirements for a physics degree in addition to the remaining doctoral requirements outlined above. The details of the makeup work would be determined with an academic advisor appointed by the Physics department.

Doctoral Program - Interdisciplinary

An interdisciplinary Ph.D. program is jointly offered by the Department of Physics and Engineering Physics and the Materials Program in the Department of Chemical, Biochemical and Materials Engineering. This program aims to address the increasingly cross-cutting nature of doctoral research in these two traditional disciplines, particularly in the area of solid state electronics and photonics and in the area of plasma and thin film technology. The interdisciplinary Ph.D. program aims to take advantage of the complementary educational offerings and research opportunities in these areas offered by both programs. Any student who wishes to enter this interdisciplinary program needs to obtain the consent of the two departments and the subsequent approval of the Dean of Graduate Studies. The student will follow a study plan designed by his/her faculty advisor. The student will be granted official candidacy in the program upon successful completion of a qualifying exam that will be administered according to the applicable guidelines of the Office of Graduate Studies. All policies of the Office of Graduate Studies that govern the credit and thesis requirements apply to students enrolled in this interdisciplinary program. Interested students should follow the normal graduate application procedures through the Dean of Graduate Studies.

Master of Engineering - Engineering Physics

The Master of Engineering - Engineering Physics degree program has two options. Students enrolled in either option develop a course of study in conjunction with their academic advisor.

The Engineering Physics option in Applied Optics seeks to extend and broaden training in those areas pertinent to the field of applied optics or optical engineering. A bachelor's degree in either science or engineering from an accredited institution is required.

Core Courses in Engineering Physics (Applied Optics)

PEP 509 Intermediate Waves and Optics
PEP 510 Modern Optics Lab
PEP 515-516 Photonics I, II
PEP 528 Mathematical Methods of Science and Engineering II
PEP 542 Electromagnetism
PEP 553-554 Quantum Mechanics and Engineering Applications I, II
PEP 577-578 Laser Theory and Design

The Engineering Physics option in Solid State Physics seeks to extend and broaden training in those areas pertinent to the field of solid state device engineering. A bachelor's degree in either science or engineering from an accredited institution is required.

Core Courses in Engineering Physics (Solid State Physics)

EE 619 Solid State Devices
PEP 503 Introduction to Solid State Physics
PEP 510 Modern Optics Lab
PEP 528 Mathematical Methods of Science and Engineering II
PEP 538 Introduction to Mechanics
PEP 542 Electromagnetism
PEP 553-554 Quantum Mechanics and Engineering Applications I, II
PEP 555 Statistical Physics Kinetic and Theory
PEP 691 Physics and Applications of Semiconductor Nanostructures

Courses with material already covered in undergraduate preparation must be replaced in consultation with an academic advisor.

The Physics and Engineering Physics program offers, jointly with Electrical and Computer Engineering (EE) and Materials Engineering, a unique interdisciplinary concentration in Microelectronics and Photonics Science and Technology. Intended to meet the needs of students and of industry in the areas of design, fabrication, integration and applications of microelectronic and photonic devices for communications and information systems, the program covers fundamentals as well as state-of-the-art industrial practices. Designed for maximum flexibility, the program accommodates the background and interests of students with either a Master's degree or Graduate Certificate.

Interdisciplinary Concentration Microelectronics and Photonics Science and Technology
(PEP 507, plus three additional courses from the Optics or Solid State concentration)

Core: PEP 507 Introduction to Microelectronics and Photonics*
Six electives are required from the courses offered below by Materials Engineering, Physics and Engineering Physics, and Electrical Engineering. Three of these courses must be from Physics and Engineering Physics and at least one must be from each of the other two departments. Ten courses are required for the degree.
*Cross-listed with EE 507 and Mt 507

Required Concentration Electives
PEP 503 Introduction to Solid State Physics
PEP 515 Photonics I
PEP 516 Photonics II
PEP 561 Solid State Electronics for Engineering I
MT 562 Solid State Electronics for Engineering II
MT 595 Reliability and Failure of Solid State Devices
MT 596 Micro-fabrication Techniques
EE 585 Physical Design of Wireless Systems
EE 626 Optical Communication Systems
CpE 690 Introduction to VLSI Design

Graduate Certificate Programs

The Department of Physics and Engineering Physics offers five Graduate Certificate programs to students meeting the regular admission requirements for the master's program. Each Graduate Certificate program is self-contained and highly focused, carrying 12 graduate credits. All of the courses may be used toward the master's degree as well as for the certificate.

Applied Optics
PEP 577 Laser Theory and Design
PEP 578 Laser Applications and Advanced Optics
and two out of the following four courses:
PEP 515-516 Photonics I, II
PEP 570 Guided-Wave Optics
PEP 679 Fourier Optics

Photonics
EE/MT/PEP 507 Introduction to Microelectronics and Photonics
EE/MT/PEP 515 Photonics I
EE/MT/PEP 516 Photonics II
EE/MT/PEP 626 Optical Communication Systems

Microelectronics
EE/MT/PEP 507 Introduction to Microelectronics and Photonics
EE/MT/PEP 561 Solid State Electronics I
EE/MT/PEP 562 Solid State Electronics II
CpE/MT/PEP 690 Introduction to VLSI Design

Microdevices and Microsystems
EE/MT/PEP 507 Introduction to Microelectronics and Photonics
EE/MT/PEP 595 Reliability and Failure of Solid State Devices
EE/MT/PEP 596 Micro-Fabrication Techniques
EE/MT/PEP 685 Physical Design of Wireless Systems
Any ONE elective in the three certificates above may be replaced with another within the Microelectronics and Photonics (MP) curriculum upon approval from the MP Program Director.

Plasma and Surface Physics
PEP 503 Introduction to Solid State Physics
PEP 524 Introduction to Surface Science
and two out of the following four courses:
PEP 525 Techniques of Surface Analysis
PEP 540 Physical Electronics
PEP 541 The Physic of Gas Discharges
PEP 545 Plasma Processing

Satellite Communications Engineering

(*Interdisciplinary with Electrical and Computer Engineering*)
EE 587 Microwave Engineering I or EE 787 Applied Antenna Theory
EE 611 Digital Communications Engineering
EE 620 Reliability Engineering
EE 674 Satellite Communications
EE 740 Selected Topics in Communication Theory
EE course descriptions can be found in the Electrical and Computer Engineering section of the catalog.

Atmospheric and Environmental Science and Engineering
(*Interdisciplinary with Civil, Ocean and Environmental Engineering*)
PEP 575 Fundamentals of Atmospheric Radiation and Climate
CE 591 Dynamic Meteorology
ME 532/EN 506 Air Pollution Principles and Control
EN 550 Environmental Chemistry of Atmospheric Processes
This graduate certificate program is offered as a campus-based program as well as a Web-based distance learning program.

RESEARCH LABORATORIES

Laboratory for the Study of Electron-Driven Processes - Prof. K. H. Becker

Electron collisions with atoms, molecules and free radicals; experimental and theoretical studies of excitation, dissociation and ionization processes; measurement of electron attachment and detachment cross sections and rates; collision induced emission spectroscopy; laser-induced fluorescence experiments; collision processes in low-temperature plasmas; atomic processes in atmospheric pressure plasmas; application of collisional and spectroscopic data to plasma diagnostic techniques; atomic, molecular, and plasma processes in environmental systems; internal collaborations with the Center for Environmental Systems (CES) and the John Vossen Laboratory for Thin Film and Vacuum Technology; external collaborations with the Universität Greifswald and the Institut für Niedertemperaturplasmaphysik (Institute for Low-Temperature Plasma Physics), Greifswald, Germany and the Universität Innsbruck, Austria.

John Vossen Laboratory for Thin Film and Vacuum Technology - Prof. A. Belkind

Basic and applied research in the field of plasma generation at low and atmospheric pressure, plasma diagnostics, and plasma implementation with particular emphasis on plasma-assisted deposition, surface cleaning, and environmental processes; special efforts are being devoted to the development of novel pulsed power plasma sources. Collaborations exist with industry (power supply and vacuum deposition system manufacturers) and, internally, with the Laboratory for the Study of Electron-Driven Processes and the Center for Environmental Systems.

Solid State Electronics and Nanodevices - Prof. H. L. Cui

Theoretical research on quantum electron transport, resonant tunneling devices and optical devices; modeling and simulation of semiconductor devices and acoustic wave devices and networks; large-scale, massively-parallel simulations of MM-wave spectroscopes and fiber optical communication devices.

Quantum Electron Physics and Technology - Prof. N. H. Horing

Quantum field theory of many-body systems; nonequilibrium and thermal Green's function methods in solid state and semiconductor physics and response properties; open quantum systems; nonequilibrium fluctuations; surface interactions; quantum plasma; high magnetic field phenomena; low dimensional systems; dynamic, nonlocal dielectric properties and collective modes in quantum wells, wires, dots, superlattices; nanostructure electrodynamics and optical properties; nonlinear quantum transport theory; magnetotransport, miniband transport, hot electrons and hot phonons in submicron devices; mesoscopic systems; spintronics; relaxation and decoherence in semiconductor nanostructures; nanoelectrical mechanical systems (NEMS); device analysis for quantum computations.

Light and Life Laboratory - Prof. K. Stamnes

Atmospheric/Space Research including satellite remote sensing of the environment. Measurements of broadband and spectral radiation including solar ultraviolet (UV) radiation. Inference of cloud and stratospheric ozone effects on UV exposure. Numerical modeling of geophysical phenomena and comparison with measurements. Study of radiation transport in turbid media such as the atmosphere-ocean system and biological tissue.

Photonics Science and Technology Lab - Prof. E. A. Whittaker

The theme of this laboratory is the development and application of laser based methods for remote sensing, chemical analysis and optical communications. Techniques used include frequency modulation spectroscopy, laser vibrometry and free space optical communications. The laboratory is equipped with a wide range of laser sources and detectors, high frequency electronic test equipment, computer controlled measurement systems and a Fourier transform infrared spectrometer.

Ultrafast Laser Spectroscopy and Communication Lab - Prof. R. Martini

The realization of ultrahigh-speed communication networks at and above Terahertz bandwidth is one of today's most challenging problems, as the limiting factors are given by fundamental physical properties and laws. To overcome the restrictions, new concepts and materials have to be invented and utilized. In this laboratory we investigate the high-speed response of new lasers and materials, as well as passive and active optical systems using ultrashort laser pulses (<100fs) to develop towards higher speed networks.

In addition to this, the ultrashort laser techniques in this laboratory enable us to apply many different measurement techniques accessing the world of the "ultrafast." Time-resolved Terahertz (THz) spectroscopy setup, for example, gives us the unique ability to measure optical as well as electrical properties in this ultrahigh-speed frequency region and use it also for new and fascinating applications in this new "frequency world."

UNDERGRADUATE COURSES

PEP 101 Physics I for Engineering Students
(3-0-3)
An introductory course for students enrolled in the engineering curriculum. Weekly lecture with demonstrations and a weekly recitation. Bi-weekly exams evaluate the student's progress in learning the central concepts of the course which include: Quantitative description of particle motion, vector manipulation and multiplication, Newton's Laws of Motion, forces, friction, uniform circular motion, work and energy, momentum, conservation laws and rotational kinematics. Corequisite: Ma 115.

PEP 102 Physics II for Engineering Students
(3-0-3)
Charge, Coulomb's law, electric field, Gauss' law, electric potential, capacitance, electric current, resistance, DC circuits, magnetic field, Ampere's law, Faraday's law of induction, inductance, induced magnetic field and displacement current. Prerequisite: Ma 115 and PEP 101.

PEP 111 Mechanics
(3-0-3)
Vectors, kinetics, Newton's laws, dynamics or particles, work and energy, friction, consverative forces, linear momentum, center-of-mass and relative motion, collisions, angular momentum, static equilibrium, rigid body rotation, Newton's law of gravity, simple harmonic motion, wave motion and sound. Corequisite: Ma 115.

PEP 112 Electricity and Magnetism
(3-0-3)
Coulomb's law, concepts of electric field and potential, Gauss' law, capacitance, current and resistance, DC and R-C transient circuits, magnetic fields, Ampere's law, Faraday's law of induction, inductance, A/C circuits, electromagnetic oscillations, Maxwell's equations and electromagnetic waves. Prerequisites: PEP 111, Ma 115.

PEP 121A General Physics I
(3-0-3)
This is the first course of a two-course, algebra-based conceptual general physics sequence for students in the Dept. of Humanities and Social Sciences. This course covers the basic principles and applications of mechanics and electricity and magnetism. The course consists of 3 lectures per week with certain lectures designated as recitations and/or demonstrations at the discretion of the instructor. Fall course. Typical text: Cutnell & Johnson or any other algebra-based general physics text complemented by supplemental handouts as needed.

PEP 122A General Physics II
(3-0-3)
This is the second course of a two-course, algebra-based conceptual general physics sequence for students in the Dept. of Humanities and Social Sciences. This course covers the basic principles and applications of oscillations and waves in mechanics, acoustics, electricity and magnetism, and optics and provides an introduction to Modern Physics. The course consists of 3 lectures per week with certain lectures designated as recitations and/or demonstrations at the discretion of the instructor. Spring course. Typical text: Cutnell and Johnson or any other algebra-based general physics text complemented by supplemental handouts as needed. Prerequisite: PEP 121A

PEP 187 Seminar in Physical Science I

Introduction to typical problems and applications in modern physics. Typical topics include: examples out of high-energy particle physics (relativistic physics, Bubble chamber photography, particle dynamics, work energy theorem), harmonic oscillatory motion (driven pendulum, atom models) and other areas. By invitation only. Prerequisite: high school physics. Corequisite: MA 115, PEP 111. Pass/Fail.

PEP 188 Seminar in Physical Science II
(1-0-1)
Introduction to typical problems and applications in modern physics. Typical topics include examples out of electro- and magnetostatic (capacitors, inductors, etc.), electromagnetism (Maxwell's Formula, waveguide propagation, microwave cavities, gauge theory), symmetry (concept and effects) and other areas. By invitation only. Prerequisite: PEP 111. Corequisite: Ma 116, PEP 112. Pass/Fail.

PEP 201 Physics III for Engineering Students
(2-0-2)
Simple harmonic motion, oscillations and waves; wave-particle dualism; the Schrädinger equation and its interpretation; wave functions; the Heisenberg uncertainty principle; quantum mechanical tunneling and application; quantum mechanics of a particle in a "box," the hydrogen atom; electronic spin; properties of many electron atoms; atomic spectra; principles of lasers and applications; electrons in solids; conductors and semi-conductors; the n-p junction and the transistor; properties of atomic nuclei; radioactivity; fusion and fission. Prerequisites: PEP 101, PEP 102, Ma 115 and Ma 116 or equivalent. Note: The course PEP 201A Physics III for Engineers listed in prior catalogs will be phased out by 5/04.

PEP 209 Modern Optics
(3-0-3)
Concepts of geometrical optics for reflecting and refracting surfaces, thin and thick lens formulations, optical instruments in modern practice, interference, polarization and diffraction effects, resolving power of lenses and instruments, X-ray diffraction, introduction to lasers and coherent optics, principles of holography, concepts of optical fibers, optical signal processing. Prerequisites: PEP 112. Fall semester.

PEP 211 Physics Laboratory for Engineers
(0-3-1)
An introduction to experimental physics. Students learn to use a variety of techniques and instrumentation, including computer controlled experimentation and analysis, error analysis and statistical treatment of data. Experiments include basic physical and electrical measurements, mechanical, acoustical, and electromagnetic oscillation and waves, and basic quantum physics phenomena. Co-requisite: PEP 201.

PEP 221-222 Physics Laboratory I-II for Scientists
(0-3-1) (0-3-1)
An introduction to experimental measurements and data analysis. Students will learn how to use a variety of measurement techniques, including computer interfaced experimentation, virtual instrumentation and computational analysis and presentation. First semester experiments include basic mechanical and electrical measurements, motion and friction, RC circuits, the physical pendulum, and electric field mapping. Second semester experiments include the second order electrical system, geometrical and physical optics, and traveling and standing waves.

PEP 242 Modern Physics
(3-0-3)
Simple harmonic motion, oscillations and pendulums; Fourier analysis; wave properties; wave-particle dualism; the Schrädinger equation and its interpretation; wave functions; the Heisenberg uncertainty principle; quantum mechanical tunneling and application; quantum mechanics of a particle in a "box," the hydrogen atom; electronic spin; properties of many electron atoms; atomic spectra; principles of lasers and applications; electrons in solids; conductors and semiconductors; the NP junction and the transistor; properties of atomic nuclei; radioactivity; fusion and fission. Prerequisite: PEP 112. Spring semester.

PEP 297 SKIL I
(1-3-2)
SKIL (Science Knowledge Integration Ladder) is a six-semester sequence of project-centered courses. This course introduces students to the concept of working on projects that foster independent learning, innovative problem solving, collaboration and teamwork, and knowledge of integration under the guidance of a faculty advisor. SKIL I familiarizes the student with the ideas and realization of project-based learning using simple concepts and basic scientific knowledge. Prerequisites: PEP 111 and PEP 112.

PEP 298 SKIL II
(1-3-2)
Continuation and extension of SKIL I to complex projects. Prerequisite: PEP 297.

PEP 368 Transport: Theory and Simulation
(3-0-3)
Numerical solution of ordinary differential equations describing oscillation and/or decay. Formulation of diffusion and heat conduction equations (conservation laws, continuity equation, laws of Fick and Fourier). Numerical solution of heat equation by explicit method. Theory of simulation of sound waves. Prerequisite: PEP 242 or permission of instructor.

PEP 397 SKIL III
(1-6-3)
Continuation and extension of SKIL II to more complex projects. Projects may include research participation in well-defined research projects. Prerequisites: PEP 297 and PEP 298.

PEP 398 SKIL IV
(1-6-3)
Continuation and extension of SKIL III. Prerequisite: PEP 397.

PEP 443-444 Modern Physics Laboratory III
(0-3-2)(0-3-2)
You select from a variety of experiments illustrating the phenomena of modern physics. Typical experiments are: Rydberg constant and Balmer series, Zeeman effect, charge of the electron, excitation potential of mercury, Hall effect, absorption of photons by matter, half-life of radioactive decay, statistics of counting processes, mass of the neutron, gamma ray energies, diffraction grating, neutron activation of nuclides, x-ray diffraction, nuclear magnetic resonance, Langmuir probe. Prerequisite: PEP 222.

PEP 497 SKIL V
(1-6-3)
Continuation of SKIL IV. SKIL V and SKIL VI can be combined into a yearlong senior design project or a research project leading to a thesis. Prerequisites: PEP 397 and PEP 398 or permission of the instructor.

PEP 498 SKIL VI
(1-6-3)
Continuation of SKIL V. SKIL V and SKIL VI can be combined into a yearlong senior design project or a research project leading to a thesis. Prerequisite: PEP 497 or permission of the instructor.

GRADUATE COURSES

All Graduate courses are 3 credits except where noted.

PEP 500 Physics Review*
A review course in the fundamentals of physics, especially in mechanics and electromagnetism; dynamics of a particle; systems of particles and their conservation laws; motion of a rigid body; electrostatics, magnetic fields and currents; electromagnetic induction. Prerequisites: introductory mechanics and electromagnetism courses which employ calculus and vector analysis. Typical text: Halliday, Resnick and Walker, Fundamentals of Physics. No credit for Physics or Engineering Physics majors.

PEP 501 Fundamentals of Atomic Physics*
Electrolysis, Brownian motion; charge and mass of electrons and ions; Zeeman effect; photoelectric effect; reflection, refraction, diffraction, absorption and scattering of X-rays; Compton effect; diffraction of electrons; uncertainty principle; electron optics; Bohr theory of atom; atomic spectra and electron distribution; radioactivity; disintegration of nuclei; nuclear processes; nuclear energy and fission. No credit for Physics majors. Typical text: Weidner and lls, Elementary Modern Physics.

PEP 503 Introduction to Solid State Physics
Description of simple physical models which account for electrical conductivity and thermal properties of solids. Basic crystal lattice structures, X-ray diffraction and dispersion curves for phonons and electrons in reciprocal space. Energy bands, Fermi surfaces, metals, insulators, semiconductors, superconductivity and ferromagnetism. Fall semester. Typical text: Kittel, Introduction to Solid State Physics. Prerequisites: PEP 242, PEP 331 or equivalent. Cross-listed with EE 503 and MT 503.

PEP 506 Introduction to Astronomy and Cosmology
Theories of the universe, general relativity, big bang cosmology and the inflationary universe; elementary particle theory and nucleosynthesis in the early universe. Observational cosmology; galaxy formation and galactic structure; stellar evolution and formation of the elements. White dwarfs, neutron stars and black

holes, planetary systems and the existence of life in the universe.

PEP 507 Introduction to Microelectronics and Photonics
An overview of Microelectronics and Photonics Science and Technology. It provides the student who wishes to specialize in the application, physics or fabrication with the necessary knowledge of how the different aspects are interrelated. It is taught in three modules: design and applications, taught by EE faculty; operation of electronic and photonic devices, taught by Physics faculty; fabrication and reliability, taught by the Materials faculty. Cross-listed with EE 507 and MT 507.

PEP 509 Intermediate Waves and Optics
The general study of field phenomena; scalar and vector fields and waves; dispersion phase and group velocity; interference, diffraction and polarization; coherence and correlation; geometric and physical optics. Typical text: Hecht and Zajac, Optics. Spring semester. Prerequisite: PEP 331 or equivalent. Cross-listed with EE 509.

PEP 510 Modern Optics Lab
The course is designed to familiarize students with a range of optical instruments and their applications. Included will be measurement of aberrations in optical systems, thin-film properties, Fourier transform imaging systems, nonlinear optics and laser beam dynamics. Fall term. Prerequisite: PEP 410 or consent of the instructor. This course may sometimes be offered in the spring term if space is available.

PEP 512 Introduction to Nuclear Physics and Nuclear Reactors
Historical introduction; radioactivity; laws of statistics of radioactive decay; alpha decay; square well model; gamma decay; beta decay; beta energy spectrum; neutrinos; nuclear reactions; relativistic treatment; semiempirical mass formula; nuclear models; uranium and the transuranic elements; fission; nuclear reactors.

PEP 515-516 Photonics I, II
This course will cover topics encompassing the fundamental subject matter for the design of optical systems. Topics will include optical system analysis, optical instrument analysis, applications of thin-film coatings and opto-mechanical system design in the first term. The second term will cover the subjects of photometry and radiometry, spectrographic and spectrophotometric systems, infrared radiation measurement and instrumentation, lasers in optical systems and photon-electron conversion. Prerequisites for this course are either PEP 209 or PEP 509. Typical texts: *Military Handbook 141* (U.S. Govt. Printing Office); *S.P.I.E Reprint Series* (Selected Issues); W.J. Smith, *Modern Optical Engineering*. Cross-listed with EE 515-516 and MT 515-516.

PEP 520 Computational Physics
Both numerical techniques and the elements of continuum mechanics are covered. Numerical methods for integrating Newton's laws, the heat equation, Poisson's equation and the fluid flow are discussed. Topics also covered: discrete Fourier transform technique, stability theory and the diagonalization of matrices, and Monte Carlo methods. Course project offers students the opportunity to learn specialized techniques in areas of interest. Spring semester. Typical text: Potter, *Computational Physics*.

PEP 524 Introduction to Surface Science
A phenomenological and theoretical introduction to the field of surface science including experimental techniques and engineering applications. Topics will include: thermodynamics and structure of surfaces, surface diffusion, electronic properties and space-charge effects, physisorption and chemisorption. Spring semester. Alternate years.

PEP 525 Techniques of Surface Analysis
Lectures, demonstrations and laboratory experiments, selected from among the following topics, depending on student interest: vacuum technology; thin-film preparation; scanning electron microscopy; infrared spectroscopy, ellipsometry; electron spectroscopy; Auger, photoelectron, LEED; ion spectroscopies; SIMS, IBS, field emission; surface properties-area, roughness and surface tension. Alternate years. (See MT 525.)

PEP 527 Mathematical Methods of Science and Engineering I
Fourier series, Bessel functions and Legendre polynomials as involved in the solution of vibrating systems; tensors and vectors in the theory of elasticity; applications of vector analysis to electrodynamics; vector operations in curvilinear coordinates; numerical methods of interpolation and of integration of functions and differential equations.

PEP 528 Mathematical Methods of Science and Engineering II
Vector and tensor fields: transformation properties, algebraic and differential operators and identities, geometric interpretation of tensors, integral theorems. Dirac delta-function and Green's function technique

for solving linear inhomogeneous equations. N-dimensional complex space: rotations, unitary and hermitian operators, matrix-dyadic-Dirac notation, similarity transformations and diagonalization, Schmidt orthogonalization. Introduction to functions of a complex variable: analyticity, Cauchy's theorem, Taylor and Laurent expansions, analytic continuation, multiple-valued functions, residue theorem, contour integration, asymptotics. As techniques are developed, they are applied to examples in mechanics, electromagnetism and/or transport theory. First semester. Prerequisite: PEP 527.

PEP 529 Mathematical Methods of Science and Engineering III
Hilbert space: introduction, function vectors, expansion in complete sets, Schmidt orthogonalization, Weierstrass theorem and completeness, Legendre polynomials, spherical harmonics, Fourier series and integral, Laplace transform. Ordinary differential equations: series methods, Hermite equation, application to quantum oscillator, regular singular points and the method of Frobenius, Bessel equation, Sturm-Liouville systems, Green's function solution to inhomogeneous problems. Partial differential equations: heat equation, Poisson equation, transform and Green's function techniques for inhomogeneous initial value and boundary valve problems. Linear integral equations: Hilbert-Schmidt theory, Fredhohm theory, Volterra equation. Spring semester. Prerequisite: PEP 528.

PEP 538 Introduction to Mechanics
Particle motion in one dimension. Simple harmonic oscillators. Motion in two and three dimensions, kinematics, work and energy, conservative forces, central forces, scattering. Systems of particles, linear and angular momentum theorems, collisions, linear spring systems, normal modes. Lagrange's equations, applications to simple systems. Introduction to moment of inertia tensor and to Hamilton's equations.

PEP 540 Physical Electronics
Charged particle motions in electric and magnetic fields; electron and ion optics; charged particle velocity and mass spectrometry; electron and ion beam confinement; thermionic emission; the Pierce gun; field emission; secondary emission; photoelectric effect; sputtering; surface ionization; volume ionization, Townsend discharge. Typical text: Beck and Ahmed, *An Introduction to Physical Electronics*.

PEP 541 Physics of Gas Discharges
Charged particle motion in electric and magnetic fields; electron and ion emission; ion-surface interaction; electrical breakdown in gases; dark discharges and DC glow discharges; confined discharge; AC, RF and microwave discharges; arc discharges, sparks and corona discharges; non-thermal gas discharges at atmospheric pressure; discharge and low-temperature plasma generation. Typical texts: J.R. Roth, *Industrial Plasma Engineering: Principles, Vol.1*, and Y.P. Raizer, *Gas Discharge Physics*. Cross-listed with EE 541.

PEP 542 Electromagnetism
Electrostatics; Coulomb-Gauss law; Poisson-Laplace equations; boundary value problems; image techniques, dielectric media; magnetostatics; multipole expansion, electromagnetic energy, electromagnetic induction, Maxwell's equations, electromagnetic waves, waves in bounded regions, wave equations and retarded solutions, simple dipole antenna radiation theory, transformation law of electromagnetic fields. Spring semester. Typical text: Reitz, Milford and Christy, *Foundation of Electromagnetic Theory*.

PEP 544 Introduction to Plasma Physics and Controlled Fusion
Plasmas in nature and application of plasma physics; single particle motion; plasma fluid theory; waves in plasmas; diffusion and resistivity; equilibrium and stability; nonlinear effects, thermonuclear reactions; the Lawson condition; magnetic confinement fusion: laser fusion. Fall semester. Prerequisite: PEP 331. Typical text: F. Chen, *Plasma Physics*.

PEP 545 Plasma Processing
Basic plasma physics; some atomic processes; plasma diagnostics. Plasma production; D.C. glow discharges, RF glow discharges; magnetron discharges. Plasma-surface interaction; sputter deposition of thin films; reactive ion etching, ion milling and texturing, electron beam assisted chemical vapor deposition; ion implantation. Sputtering systems; ion sources; electron sources; ion beam handling. Typical texts: Chapman, *Glow Discharge Processes*; Brodie, Muray, *The Physics of Micro-fabrication*. Fall semester.

PEP 550 Fluid Mechanics
Description of principle flow phenomena: pipe and channel flows-laminar flow, transition, turbulence; flow past an object-boundary layer, wake, separation, vortices, drag; convection in horizontal layers-conduction, convection, transition from periodic to chaotic behavior. Equations of motion; dynamical scaling; simple viscous flows; inviscid flow; boundary layers, drag and lift; thermal flows; flow in rotating fluids; hydro-dynamic stability; transitions to turbulence. Typical text: Tritton, *Physical Fluid Dynamics*.

PEP 551 Advanced Physics Laboratory
An experimental presentation of the evidence for atomic and nuclear theories; typical experiments are: excitation potentials; electronic charge; specific charge of the electron; Balmer series; Zeeman splitting; spectroscopic isotope shifts; photovoltaic effect; Hall effect; gamma ray spectrometry; beta ray spectrometry; neutron activation of nuclides; statistics of counting processes; optical and X-ray diffraction; Langmuir probe; nuclear magnetic resonance. Prerequisite: PEP 233. Fall semester, repeated second semester. By arrangement. Laboratory fee $5. Typical texts: Young, *Statistical Treatment of Experimental Data*; Melissinos, *Experiments in Modern Physics*.

PEP 553 Quantum Mechanics and Engineering Applications
This course is meant to serve as an introduction to formal quantum mechanics as well as to apply the basic formalism to several generic and important applications. Introduces the concept of operators, eigenvalues, commutators, and the other fundamental techniques to work with the Schroedinger and Heisenberg representation of quantum theory. The techniques will be applied to practical examples, such as laser oscillations, magnetic resonance phenomena, and the charge transport in semiconductors. Typical texts: Liboff, *Introductory Quantum Mechanics.*

PEP 554 Quantum Mechanics II
Basic concepts of quantum mechanics, states, operators; time development of Schroedinger and Heisenberg pictures; representation theory; symmetries; perturbation theory; systems of identical particles, L-S and j-j coupling; fine and hyperfine structure; scattering theory; molecular structure. Spring semester. Typical texts: Gottfried, *Quantum Mechanics*; Schiff, *Quantum Mechanics*.

PEP 555 Statistical Physics and Kinetic Theory
Kinetic theory: ideal gases, distribution functions, Maxwell-Boltzmann distribution, Boltzmann equation, H-theorem and entropy, simple transport theory. Thermodynamics: review of first and second laws, thermodynamic potentials, Legendre transformation, phase transitions. Elementary statistical mechanics: introduction to microcanonical, canonical and grand canonical distributions, partition functions, simple applications including ideal Maxwell-Boltzmann, Einstein-Bose and Fermi-Dirac gases, paramagnetic systems, blackbody radiation. Typical text: Reif, *Statistical and Thermal Physics.*

PEP 561 Solid State Electronics for Engineering I
This course introduces fundamentals of semiconductors and basic building blocks of semiconductor devices that are necessary for understanding semiconductor device operations. It is for first-year graduate students and upper-class undergraduate students in electrical engineering, applied physics, engineering physics, optical engineering and materials engineering, who have no previous exposure to solid state physics and semiconductor devices. Topics covered will include description of crystal structures and bonding; introduction to statistical description of electron gas; free-electron theory of metals; motion of electrons in periodic lattices-energy bands; Fermi levels; semiconductors and insulators; electrons and holes in semiconductors; impurity effects; generation and recombination; mobility and other electrical properties of semiconductors; thermal and optical properties; p-n junctions; metal-semiconductor contacts. Cross-listed with EE 561 and MT 561.

PEP 562 Solid State Electronics for Engineering II
This course introduces operating principles and develops models of modern semiconductor devices that are useful in the analysis and design of integrated circuits. Topics covered include: charge carrier transport in semiconductors; diffusion and drift, injection and lifetime of carriers; p-n junction devices; bipolar junction transistors; metal-oxide-semiconductor field effect transistors; metal-semiconductor field effect transistors and high electron mobility transistors; microwave devices; light emitting diodes, semiconductor lasers and photodetectors; integrated devices. Cross-listed with EE 562 and MT 562

PEP 570 Guided-Wave Optics
Review of electromagnetic theory; derivation of Fresnels' equations; guided-wave propagation by metallic and dielectric waveguides including step-index optical fibers, graded-index fibers; optical transmission systems; nonlinear effects in optical fibers, solitons and fiber-optic gyroscope.

PEP 575 Fundamentals of Atmospheric Radiation and Climate
This course treats scattering, absorption and emission of electromagnetic radiation in planetary media. The radiative transfer equation is derived, approximate solutions are found. Important heuristic models (Lorentz atom, two-level atom, vibrating rotator) as well as fundamental concepts are discussed including reflectance, absorptance, emittance, radiative warming/cooling rates, actinic radiation, photolysis and biological dose rates. A unified treatment is provided of radiative transfer within the atmosphere and ocean, and extensive use of two-stream and approximate methods is emphasized. Applications to the climate problem focus on the role of greenhouse gases, aerosols and clouds in explaining the temperature structure of the atmosphere and the equilibrium temperature of the earth. The course is suitable for beginning graduate and upper-level undergraduate students. Prerequisites: undergraduate calculus, ordinary

differential equations (MA 221 or equivalent) and basic modern physics (PEP 202 or PEP 242 or equivalent).

PEP 577 Laser Theory and Design
An introductory course to the theory of lasers; treatment of spontaneous and stimulated emission, atomic rate equations, laser oscillation conditions, power output and optimum output coupling; CW and pulsed operation, Q switching, mode selection and frequency stabilization; excitation of lasers, inversion mechanisms and typical efficiencies; detailed examination of principal types of lasers, gaseous, solid state and liquid; chemical lasers, dye lasers, Raman lasers, high power lasers, TEA lasers, gas dynamic lasers. Design considerations for GaAlAs, argon ion, helium neon, carbon dioxide, neodymium YAG and pulsed ruby lasers. Fall semester. Typical text: Yariv, *Optical Electronics*.

PEP 578 Laser Applications and Advanced Optics
Integrated optics, nonlinear optics, Pockels effect, Kerr effect, harmonic generation, parametric devices, phase conjugate mirrors, phase matching. Coherent and incoherent detection, Fourier optics, image processing and holography, and Gaussian optics. Detection of light, signal to noise, PIN and APD diodes, optical communication. Scattering of light, Rayleigh, Mie, Brillouin, Raman and Doppler shift scattering. Spring semester.

PEP 580 Electronic Materials and Devices
Electronic, magnetic, optical and thermal properties of materials, the description of these properties based on solid state physics. Description and principles of operation of devices. Spring semester.

PEP 585 Physical Design of Wireless Systems
Physical design of wireless communication systems, emphasizing present and next generation architectures. Impact of non-linear components on performance; noise sources and effects; interference; optimization of receiver and transmitter architectures; individual components (LNAs, power amplifiers, mixers, filters, VCOs, phase-locked loops, frequency synthesizers, etc.); digital signal processing for adaptable architectures; analog-digital converters; new component technologies (SiGe, MEMS, etc.); specifications of component performance; reconfigurability and the role of digital signal processing in future generation architectures; direct conversion; RF packaging; minimization of power dissipation in receivers. Cross-listed with EE/MT 585.

PEP 595 Reliability and Failure of Solid State Devices
This course deals with the electrical, chemical, environmental and mechanical driving forces that compromise the integrity and lead to the failure of electronic materials and devices. Both chip and packaging level failures will be modeled physically and quantified statistically in terms of standard reliability mathematics. On the packaging level, thermal stresses, solder creep, fatigue and fracture, contact relaxation, corrosion and environmental degradation will be treated. Prerequisite: PEP 507. Cross-listed with MT/EE 595.

PEP 596 Microfabrication Techniques
Deals with aspects of the technology of processing procedures involved in the fabrication of microelectronic devices and microelectromechanical systems (MEMS). Students will become familiar with various fabrication techniques used for discrete devices as well as large-scale integrated thin-film circuits. Students will also learn that MEMS are sensors and actuators that are designed using different areas of engineering disciplines and they are constructed using a microlithographically-based manufacturing process in conjunction with both semiconductor and micromachining microfabrication technologies. Prerequisite: PEP 507. Cross-listed with MT/EE 596

PEP 601 Fundamentals of Data Transmitting
The course if the first part of the graduate certificate program “Wireless Secure Network Design” which includes also three other courses – PEP 602, 603 and 604. Program focuses on heterogeneous wireless systems used by first-responders – police, fire fighters, National Guard and other emergency forces – to protect the public during large scale crises, such as natural disasters and acts of terrorism. The program also includes analysis of homeland defense, financial and military operations using secure wireless systems. At the end of the program students will learn how to protect existing wireless systems and how to design highly secure systems for a future use. The course presents a comprehensive analysis of different parts of the electromagnetic spectrum, transmission and modulation technologies, hardware, new artificially engineered materials, and MEMS with accent on security and robustness of communications. Prerequisites: PEP 507 and PEP 685 or permission of instructor.

PEP 602 Secure and Robust Communications
The course presents an overview of areas of first responders and military activities and using of different heterogeneous wireless systems during large scale crises, such as natural disasters, acts of terrorism, and also during homeland defense, financial and military operations. The course includes an analysis of different wireless network architectures from a security point of view. The course is the second part of the graduate

certificate program “Wireless Secure Network Design” which includes also three other courses – PEP 601, 603 and 604. Prerequisite: PEP 601.

PEP 603 Physical and Logical Security
The course presents an overview of different methods of authentication and authorization in secure wireless networks. The course focuses on different methods of physical data and link protection, probability of detection and interception, anti-jam and covert capabilities, active and passive protection methods and equipment. The course is the third part of the graduate certificate program “Wireless Secure Network Design” which includes also three other courses – PEP 601, 602 and 604. Prerequisite: PEP 601, PEP 602.

PEP 604 Secure Telecomm Wireless System Design
The course presents an overview of different methods used in secure heterogeneous wireless systems design. Large scale infrastructure and ad hoc networks test and simulation are one of the major parts of the course. The course also includes practical exercises and lab experiments. The course is the last part of the graduate certificate “Wireless Secure Network Design” which includes also three other courses – PEP 601, 602 and 603. Students who have successfully finished all four courses will receive a graduate certificate in wireless secure network design. Prerequisite: PEP 601, PEP 602, PEP 603.

PEP 607-608 Plasma Physics III*
Motion of charged particles in electromagnetic field; Boltzmann equation for plasma; properties of magnetoplasmas; fundamentals of magnetohydrodynamics. Applications to include: mirror geometry, high frequency confinement, plasma confinement and heating by means of magnetic fields; motion of plasmas along and across magnetic field lines; magnetohydrodynamic stability theory; plasma oscillations, microinstabilities waves in magnetoplasma; dispersion relations; Fokker-Planck equation for plasmas; plasma conductivity; runaway electron; relaxation times; radiation phenomena in magnetoplasmas; stability theories; finite Larmor radius stabilization; minimum-B stability; universal instabilities. Prerequisites: PEP 642, PEP 643 and PEP 555. Fall and spring semester. Typical text: Schmidt, *Physics of High Temperature Plasmas*.

PEP 610 Advanced Modern Optics Lab*
A continuation of PEP 510 for those students desiring a more thorough knowledge of optical systems. Included would be the use of an OTDR, ellipsometry, vacuum deposition of thin films and other instrumentation. Students are encouraged to pursue their individual interests using the available equipment. Prerequisite: PEP 510 or the consent of the instructor.

PEP 619 Solid State Devices
Operating principle, modeling and fabrication of solid state devices for modern optical and electronic system implementation; recent developments in solid state devices and integrated circuits; devices covered include bipolar and MOS diodes and transistors, MESFET, MOSFET transistors, tunnel, IMPATT and BARITT diodes, transferred electron devices, light emitting diodes, semiconductor injection and quantum-well lasers, PIN and avalanche photodetectors. Prerequisite: EE 503 or equivalent. Cross-listed with EE 619.

PEP 621 Quantum Chemistry
Theorems and postulates of quantum mechanics; operator relationships; solutions of the Schrädinger equation for model systems; variation and perturbation methods; pure spin states; Hartree-Fock self-consistent field theory; applications to many-electron atoms and molecules. Prerequisite: Ch 520 or PEP 554 or equivalent.

PEP 626 Optical Communication Systems
Components for and design of optical communication systems; propagation of optical signals in single mode and multimode optical fibers; optical sources and photodetectors; optical modulators and multiplexers; optical communication systems: coherent modulators, optical fiber amplifiers and repeaters; transcontinental and transoceanic optical telecommunication system design; optical fiber local area networks. Cross-listed with EE 626, MT 626 and NIS 626.

PEP 630 Nonlinear Dynamics
Definition of dynamical systems; phase space, equilibrium states and their classification; nonlinear oscillator without and with dissipation; Van der Pol generator; Poincare map; slow and fast motion; forced nonlinear oscillator: linear and nonlinear resonances; forced generator: synchronization; Poincare indices and bifurcations; solitons; shock waves; weak turbulence; regular patterns in dissipative media; chaos: fractal dimension, Lyapunov exponents. Prerequisite: PEP 529 or permission of the instructor. Typical textbooks: H.D.I. Abarbanel, M.I. Rabinovich and M.M. Sushchik, *Introduction to Nonlinear Dynamics for Physicists*; R.H. Abraham and C.D. Shaw, *Dynamics: The Geometry of Behavior*.

PEP 642 Mechanics

Lagrangian and Hamiltonian formulations of mechanics, rigid boy motion, elasticity, mechanics of continuous media, small vibration theory, special relativity, canonical transformations, perturbation theory. Typical text: Goldstein, *Classical Mechanics*.

PEP 643 Electricity and Magnetism I
Electrostatics, boundary value problems, Green's function techniques, methods of image, inversion and conformal mapping; multipole expansion. Magnetostatics, vector potential. Maxwell's equations and conservation laws. Electromagnetic wave propagation in media. Crystal optics. Prerequisite: PEP 528 and PEP 542. Fall semester. Typical texts: Jackson, *Classical Electrodynamics*; Laundau and Lifshitz, *Electrodynamics in Continuous Media*.

PEP 644 Electricity and Magnetism II
Interaction of electromagnetic waves with matter, dispersion, waveguides and resonant cavities, radiating systems, scattering and diffraction, covariant electromagnetic theory, motion of relativistic particles in electromagnetic fields, relativistic radiation theory, radiation damping and self-fields. Prerequisite: PEP 643. Spring semester. Typical texts: Jackson, *Classical Electrodynamics* and Laundau and Lifshitz, *The Classical Theory of Fields, Electrodynamics in Continuous Media*.

PEP 651 Advanced Physics Laboratory II*
Advanced laboratory work in modern physics arranged to suit your requirement. Prerequisite: PEP 551. Fall and spring semesters. Laboratory fee: $5. Typical text: see PEP 551.

PEP 655 Quantum Mechanics III
Introduction to relativistic quantum mechanics: Dirac theory of electrons and their interaction with electromagnetic field. Feynman diagrams for perturbation. Theory of bosons and fermions, number representations. Nonrelativistic many-body theory: electron gas, atomic and molecular systems. Landau theory of Fermi liquid. Superconductivity and superfluidity. Fall semester of alternate years. Typical texts: Schiff, *Quantum Mechanics*; Ziman, *Elements of Advanced Quantum Theory*; Koltun and Eisenberg, *Quantum Mechanics of Many Degrees of Freedom*.

PEP 661-662 Solid State Physics III
Crystal symmetry. Space-group-theory analysis of normal modes of lattice vibration, Phonon dispersion relations; Raman and infrared activity. Crystal field splitting of ion energy level, and transition selection rules. Bloch theorem and calculation of electronic energy bands through tight binding and pseudopotential methods for metals and semiconductors, Fermi surfaces. Transport theory, electrical conduction, thermal properties, cyclotron resonance, de Haas van Alfen and Hall effects. Dia-, para- and ferro-magnetism, magnon spinwaves. Fall and spring semester. Recommended: PEP 503 and PEP 553-554. Typical texts: Callaway, *Quantum Theory of Solid State*; Ashcroft and Mermin, *Solid State Physics*; Kittel, *Quantum Theory of Solids*.

PEP 667 Statistical Mechanics
Advanced transport theory, classical statistical mechanics, fluctuation theory, quantum statistical mechanics, ideal Bose and Fermi gases, imperfect gases, phase transitions, superfluids, Ising model critical phenomena, renormalization group. Typical text: Huang, *Statistical Mechanics*.

PEP 678 Physics of Optical Communication Systems
The physics behind modern optical communication systems and high data rate communication systems; information theory and light propagation in optical fiber wave guide channels; semiconductor laser sources and detectors; digital optical communication systems; quantum optical information theory; coherence and quantum correlations; optical solution-based communication; squeezed light and noise limitations; coherent optical communication systems; de-phasing and de-coherence; teleportation, cryptography and fractal optics. Prerequisites: PEP 542, PEP 554, PEP 503.

PEP 679 Fourier Optics
Abbe diffraction theory of image formation, spatial filtering, coherence lengths and areas. Holograms; speckle photography; impulse response function; CTF, OTF and MTF of lens system; coherent and incoherent optical signal processing. Spring semester. Typical text: Goodman, *Introduction to Fourier Optics*.

PEP 680 Quantum Optics
This course explores the quantum mechanical aspects of the theory of electromagnetic radiation and its interaction with matter. Topics covered include Einstein's theory of emission and absorption, Planck's law, quantum theory of light-matter interaction, classical fluctuation theory, quantized radiation field, photon quantum statistics, squeezing, nonlinear interactions. Offered in alternate years. Typical text: Loudon, *Quantum Theory of Light*. Prerequisites: PEP 331 or equivalent, PEP 553, PEP 509.

PEP 690 Introduction to VLSI Design
This course introduces students to the principles and design techniques of very large scale integrated circuits (VLSI). Topics include: MOs transistor characteristics, DC analysis, resistance, capacitance models, transient analysis, propagation delay, power dissipation, CMOS logic design, transistor sizing, layout methodologies, clocking schemes, case studies. Students will use VLSI CAD tools for layout and simulation. Selected class projects may be sent for fabrication. Cross-listed with CpE 690 and MT 690.

PEP 691 Physics and Applications of Semiconductor Nanostructures
This course is intended to introduce the concept of electronic energy band engineering for device applications. Topics to be covered are electronic energy bands, optical properties, electrical transport properties of multiple quantum wells, superlattices, quantum wires and quantum dots; mesoscopic systems, applications of such structures in various solid state devices, such as high electron mobility, resonant tunneling diodes and other negative differential conductance devices, double-heterojunction injection lasers, superlattice-based infrared detectors, electron-wave devices (wave guides, couplers, switching devices), and other novel concepts and ideas made possible by nano-fabrication technology. Prerequisite for the course is basic knowledge in quantum mechanics and solid state physics (at the levels of PEP 553, PEP 503). Fall semester. Typical text: M. Jaros, *Physics and Applications of Semiconductor Microstructures*; G. Bastard, *Wave Mechanics Applied to Semiconductor Heterostructures*.

PEP 700 Quantum Electron Physics and Technology Seminar
The seminars are focused on nanostructure-scale electron systems that are so small that their dynamic and statistical properties can only be properly described by quantum mechanics. This includes many submicron semiconductor devices based on heterostructures, quantum wells, superlattices, etc., and it interfaces solid state physics with surface physics and optics. Outstanding visiting scientists make presentations, as well as some faculty members and doctoral research students discussing their thesis work and related journal articles. Participation in these seminars is regarded as an important part of the research education of a physicist working in condensed matter physics and/or surface physics and optics. One-half credit per semester. PEP 700 and PEP 701 may be taken for up to three credits. Pass/Fail.

PEP 701 Topics in Physics and Engineering Physics*
This seminar is focused on current topics in physics and their applications in various areas. The format of the seminar is similar to PEP 700, but the scope of the seminar covers a broader range of topics including interdisciplinary areas and applications such as low-temperature plasma science and technology, atmospheric and environmental science and technology, and other topics. One-half credit per semester. PEP 700 and PEP 701 may be taken for up to three credits. Pass/Fail.

PEP 704 Group Theory for Physicists in Solid State and Molecular Physics
Group theory for physicists with applications to solid state and molecular physics. Relation between group theory and quantum (or classical) mechanics, between classes and observables, between representations and states. Point groups: full rotation group, crystallographic point groups, spin-associated double groups. Crystal field theory with and without spin; selection rules and character tables, use of product representation. Form of macroscopic crystal tensors molecular vibrational states and spectra. Translational properties of crystals. Energy band structure. Formal classification of space groups with examples. Time reversal and Onsager relations with examples. Lattice vibrations and phonons. Localized valence orbitals in chemistry. Hartree-Fock many-electron wave-functions. Phase transitions. Prerequisites: Course equivalent to PEP 553 in quantum mechanics and associated mathematics of operators and Hilbert spaces. Representative texts: M. Lax Symmetry, *Principles in Solid State and Molecular Physics*; Heine Group, *Theory in Quantum Mechanics*.

PEP 722 Molecular Spectroscopy
Theoretical foundations of spectroscopic methods and their application to the study of atomic and molecular structure and properties; theory of absorption and emission of radiation; line spectra of complex atoms; group theory; rotational, vibrational and electronic spectroscopy of diatomic and polyatomic molecules; infrared, Raman, uv-vis spectroscopy; laser spectroscopy and applications; photoelectron spectroscopy; multi-photon processes; also offered as Ch 622. Prerequisites: Ch 520 or PEP 554 and PEP 509 or equivalent.

PEP 739 Theory of Relativity*
Geometrical foundations of space-time theories, geometrical objects, affine geometry, metric geometry; structure of space-time theories, symmetry, conservation laws; Newtonian mechanics; special relativity; foundations of general relativity, Mach's principle, principle of equivalence, principle of general covariance, Einstein's equations; solution of Einstein's equations; experimental tests of general relativity; conservation laws in general relativity, gravitational radiation, motion of singularities; cosmology. Fall semester. Course may be taken for up to six credits.

PEP 740 The Physics of Nanostructures

Progress in the technology of nanostructure growth; space and time scales; quantum confined systems; quantum wells, coupled wells and superlattices; quantum wires and quantum dots; electronic states; magnetic field effects; electron-phonon interaction; quantum transport in nanostructures: Kubo formalism, Butikker-Landau formalism; spectroscopy of quantum dots; Coulomb blockade, coupled dots and artificial molecules; weal localization; universal conductance fluctuations; phase-breaking time; theory of open quantum systems: fluctuation-dissipation theorem; applications to quantum transport in nanostructures. Prerequisites: PEP 553-554 and PEP 661-662.

PEP 750 Quantum Field Theory*
This course is open to students who have had PEP 764 or its equivalent. It concerns itself with modern field theory; such topics as Yang-Mills fields, the renormalization group and functional integration. It will concern itself with applications to both elementary particles and condensed matter physics; i.e. the theory of critical exponents. Typical text: C. Quigg, *Gauge Theories of Strong, Weak and Electromagnetic Interactions*.

PEP 751 Elementary Particles*
This course is open to students who have had PEP 764 or its equivalent. It is an introduction to the theory of elementary particles. It stresses symmetries of both the strong and weak interactions. It presents a detailed study of SU(3) and the quark model as well as the Cabbibo theory of the weak interactions. Typical text: F. Close, *An Introduction to Quarks and Partons*.

PEP 757 Quantum Field Theory Methods in Statistical and Many-Body Physics
Dirac notation; Transformation theory; Second quantization; Particle creation and annihilation operators; Schrädinger, Heisenberg and Interaction Pictures; Linear response; S-matrix; Density matrix; Superoperators and non-Markovian kinetic equations; Schwinger Action Principle and variational calculus; Quantum Hamilton equations; Field equations with particle sources, potential and phonon sources; Retarded Green's functions; Localized state in continuum and chemisorption; Dyson equation; T-matrix; Impurity scattering; Self-consistent Born approximation; Density-of-states; Greens function matching; Ensemble averages and statistical thermodynamics, Bose and Fermi distributions, Bose condensation; Thermodynamic Green's functions; Lehmann spectral representation; periodicity/antiperiodicity in imaginary time and Matsubara Fourier series/frequencies; Analytic continuation to real time; Multiparticle Green's functions and equations of motion with particle-particle interactions; Hartree and Hartree-Fock approximations; Collisional lifetime effects; Sum-of-ladder-diagrams integral equation; Nonequilibrium Green's functions; Electromagnetic current-current correlation response; Exact variational relations for multiparticle Green's functions; Cumulants; Linked cluster theorem; Random phase approximation; Perturbation theory for Green's functions, self-energy and vertex functions by variational differential formulation; Shielded potential perturbation theory; Imaginary time contour ordering, Langreth algebra and the GKB Ansatz. Prerequisites: PEP 242 or equivalent and a good mathematical background in linear algebra and multivariate calculus; PEP 554 will be a corequisite unless waived by instructor. Typical texts: Kadanoff and Baym, *Quantum Statistical Mechanics*, W. A. Benjamin and Horing, *Advanced Quantum Mechanics for Interacting and Mesoscopic Systems*. Fall term.

PEP 758 Coupled Quantum Field Theory Methods in Condensed Matter Physics*
Dielectric response of solid-state plasmas; Random Phase Approximation; Semiclassical and hydrodynamic models; Plasmons; Shielding; Electron-hole plasmon Landau damping; Exchange and correlation energy; Atom-surface Van der Waals attraction; Charged particle energy loss; Electrodynamic response functions; Dyadic Green's functions; Dynamic, nonlocal conductivity and dielectric tensors; Polaritons of compound nanostructures; Coupling of light with 3D, 2D and superlattice collective modes; Electron(e) Đ Hole(h) Đ Phonon(p) Hamiltonian for solids with e-e, h-h, e-p, h-p and e-h interactions explained; Coupled electron-hole-phonon Green's functions of all orders and derivation of the fully-interacting equations of motion for 1-electron and 1-hole Green's functions and for 2-electron and 2-hole Green's functions, as well as the electron-hole Green's function with analysis of exciton states and electron-hole scattering matrix; Electron-phonon coupling effects on electron propagation and polarons; Phonons of periodic lattice in the harmonic approximation, eigenvector expansion of phonon Green's functions for monatomic and ionic diatomic lattices, acoustic and optical phonons, polarizability of a diatomic lattice; Phonon Green's function with coupling to dynamic nonlocal electron screening, umklapp, coupled ion-electron oscillations, Bohm-Staver phonon dispersion relation; Generalized shield potential approximation; Electron and hole interaction operators; Superfluid field operators and the Gross-Pitaevski equations; Bogoliubov approximation, superfluid Green's functions and elementary excitations; Superconductivity-BCS Theory, anomalous Green's functions and Gorkov equations, gap, derivation of Ginzburg-Landau equations. Prerequisites: PEP 757. Typical text: Horing, *Advanced Quantum Mechanics for Interacting and Mesoscopic Systems*; Mahan, *Many-Particle Physics*, Plenum Press and recommended readings. Spring term.

PEP 764 Advanced Quantum Mechanics*
Second quantization of Bose and Fermi fields; interaction and Heisenberg pictures; S-matrix theory; quantum electrodynamics; diagrammatic techniques. Fall semester. Typical texts: Mandl, *Introduction to Quantum Field Theory*; Sakurai, *Advanced Quantum Mechanics*.

PEP 800 Special Topics in Physics
Topics include any one of the following: magnetohydrodynamics, quantum mechanics, general relativity, many-body problem, nuclear physics, quantum field theory, low temperature physics, diffraction theory, particle physics. Limit of six credits for the master's degree.

PEP 801 Special Topics in Physics
One to six credits. Limit of six credits for the degree of Doctor of Philosophy.

PEP 900 Thesis in Physics
For the degree of Master of Science. Five to ten credits with departmental approval.

PEP 901 Thesis in Engineering Physics
For the degree of Master of Engineering. Five to ten credits with departmental approval.

PEP 960 Research in Physics
Original experimental or theoretical research undertaken under the guidance of the faculty of the department which may serve as the basis for the dissertation required for the degree of Doctor of Philosophy. Hours and credits to be arranged. This course is open to students who have passed the doctoral qualifying examination; a student who has already taken the required doctoral courses may register for this in the term in which s/he intends to take the qualifying examination.

* By request