Stevens Institute of Technology 2006-2007 Catalog

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, 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, Ph.D. (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

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

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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, or 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.
HUM	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.
HUM	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.
HUM	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.
HUM	Humanities	3	0	3
MA 227	Multivariate Calculus	3	0	3
	Elective[1] or Thermodynamics[3]	3	0	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.
HUM	Humanities	3	0	3
MA 232	Linear Algebra[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.
HUM	Humanities	3	0	3
PEP 542	Electromagnetism [1]	3	0	3
PEP 528	Math Methods of Sci. & Eng. II [1]	3	0	3
MA 222	Probability and Statistics	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.
HUM	Humanities	3	0	3
PEP 553	Intro. to Quantum Mechanics[1] (or Elective)	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 I [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 later semesters to ensure a complete undergraduate curriculum:

PEP 503 Introduction to Solid State Physics (3-0-3)
PEP 507 Introduction to Microelectrionics and Photonics (3-0-3)
PEP 509 Intermediate Waves and Optics (3-0-3)
PEP 520 Computational Physics (3-0-3)
PEP 541 The Physics of Gas Discharges (3-0-3)
PEP 555 Statistical Physics and Kinetic Theory (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.

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Requirements for a Minor in Physics

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 Introduction to Quantum Mechanics

B.S. Degree in Engineering Physics (EP)

The Department of Physics and Engineering Physics also offers an Undergraduate Engineering Physics (EP) Program, which leads to a B.S. 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 then the final two years separately for each concentration.

EP Undergraduate Curriculum

Freshman Year

Term I

		Hrs. Per Wk.		
		Class	Lab	Sem. Cred.
HUM	Humanities	3	0	3
MA 115	Calculus I	3	0	3
CH 107	General Chem. I	3	0	3
CH 117	General Chem. Lab I	0	3	1
E 115	Intro. to Programming	1	1.5	2
PEP 111	Mechanics 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	**13**	**11.5**	**19**

Term II

		Hrs. Per Wk.		
		Class	Lab	Sem. Cred.
HUM	Humanities	3	0	3
MA 116	Calculus II	3	0	3
CH 116	General Chem. II	3	0	3
CH 118	General Chem. Lab II	0	3	1
PEP 112	Electricity & Magnetism	3	0	3
E 122	Eng. Design II	0	3	2
PE 200	Physical Education II	0	2	1
	TOTAL	**12**	**8**	**16**

Sophomore Year

Term III

		Hrs. Per Wk.		
		Class	Lab	Sem. Cred.
HUM	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
PEP 297	SKIL I	1	3	2
E 245	Circuits & Systems	2	3	3
PE 200	Physical Education III	0	2	1
	TOTAL	**13**	**8**	**17**

Term IV

		Hrs. Per Wk.		
		Class	Lab	Sem. Cred.
HUM	Humanities	3	0	3
MA 227	Multivariable Calculus	3	0	3
PEP 242	Modern Physics	3	0	3
PEP 222	Physics Lab II	0	3	1
PEP 298	SKIL II	1	3	2
E 234	Thermodynamics	3	0	3
PE 200	Physical Education IV	0	2	1
	TOTAL	**13**	**8**	**16**

Junior Year

Term V

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

TE	Concentration Elective	3	0	3
E 243	Probability & Statistics	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	**16**	**8**	**19**

Term VI

		Hrs. Per Wk.		
		Class	Lab	Sem. Cred.
HUM	Humanities	3	0	3
	Free Elective	3	0	3
TE	Concentration Elective	3	0	3
PEP 542	Electromagnetism	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.
HUM	Humanities	3	0	3
TE	Concentration Elective	3	0	3
TE	Concentration Elective	3	0	3
PEP 553	Intro. to Quantum Mechanics	3	0	3
PEP 497	SKIL V	1	6	3
	TOTAL	**13**	**6**	**15**

Term VIII

		Hrs. Per Wk.		
		Class	Lab	Sem. Cred.
HUM	Humanities	3	0	3
TE	Concentration Elective	3	0	3
TE	Concentration Elective	3	0	3
MGT	Economics	3	0	3
PEP 498	SKIL VI	1	6	3
	TOTAL	**13**	**6**	**15**

EP Undergraduate Curriculum, Concentration "Applied Optics"

Junior Year

Term V

		Hrs. Per Wk.		
		Class	Lab	Sem. Cred.
HUM	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.
HUM	Humanities	3	0	3
PEP 542	Electromagnetism	3	0	3
	Elective	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	Introduction to Quantum Mechanics	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 I (or Elective)	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, PEP 680, and 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.
HUM	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.
HUM	Humanities	3	0	3
PEP 542	Electromagnetism	3	0	3
	Elective	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.
HUM	Humanities	3	0	3
PEP 553	Intro. to Quantum Mechanics	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.
HUM	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, and 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.
HUM	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.
HUM	Humanities	3	0	3
PEP 542	Electromagnetism	3	0	3
	Elective	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.
HUM	Humanities	3	0	3
PEP 553	Intro. to Quantum Mechanics	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.
HUM	Humanities	3	0	3
PEP 554	Quantum Mechanics I (or Elective)	3	0	3
EN 506	Air Pollution Control	3	0	3
Mgt	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, and EN 570

EP Undergraduate Curriculum, Concentration "Plasma and Surface Science"

Junior Year

Term V

		Hrs. Per Wk.		
		Class	Lab	Sem. Cred.
HUM	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.
HUM	Humanities	3	0	3
PEP 542	Electromagnetism	3	0	3
	Elective	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.
HUM	Humanities	3	0	3
PEP 553	Intro. to Quantum Mechanics	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.
HUM	Humanities	3	0	3
PEP 554	Quantum Mechanics I (or Elective)	3	0	3
PEP 545	Plasma Processing	3	0	3
Mgt	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, and 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.

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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

B.S. 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 M.S. 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 I
One 600-level advanced quantum mechanics course (currently PEP 621, PEP 653, 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.

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Doctoral Program - Physics

Ph.D. students must pass a qualifying examination, which consists of two oral examinations. The first oral examination tests mastery of a set of core physics topics, while the second oral examination tests the student's ability to discuss physics problems and current research topics with an examining committee of three faculty members. The student has 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 Ph.D. student, 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's lacking this competency are encouraged to take PEP 520 Computational Physics or equivalent.

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

- 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 is 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 M.S. 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 may 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, Biomedical, 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 Academic Administration. The student will follow a study plan designed by his/her faculty advisor(s). The student will be granted official candidacy in the program upon successful completion of a qualifying exam that will be administered by the advisor(s) in consultation with the Dean of Academic Administration. All other policies 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 Academic Administration.

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 Introduction to Quantum Mechanics and Quantum Mechanics I
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 Intro. to Quantum Mechanics and Quantum Mechanics I

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.

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RESEARCH CENTERS AND LABORATORIES

Center for Controlled Quantum Systems

The Center for Controlled Quantum Systems (CCQS) is a cross-disciplinary research center involving collaborations between multiple research groups focusing on one of the last challenges in research: controlling (and thereby employing for future application) the quantum system. New waves of technologies are normally connected to breakthroughs in research which allowed for greater control of nature and opened up ways to harness the newfound potential. Today's limit of control is mostly based on the quantum mechanical nature, and while physicists have explored quantum mechanical phenomena of quantum systems like atoms, molecules, and the solid state for decades, only a few have tried to control the dynamics of these systems in real time.

One of the main directions of the center is based on optical techniques to control quantum systems. The advent of ultrafast lasers and laser cooling techniques in recent years has finally opened up the possibility of controlling quantum dynamics. This can be achieved using ultrafast femtosecond lasers to either probe the systems on time scales much shorter than the time scale for which quantum mechanical phase coherence is maintained, or by directly manipulating the environmental sources that destroy phase coherence. By contrast, laser cooling and trapping techniques can be used to create systems with temperatures so low and well isolated from their surrounding environment that phase coherence times can be increased by many orders of magnitude. The ability to precisely control the phase and amplitude of laser pulses provides a high degree of customization in their interaction with matter.

The work in this center will contribute to and direct the development of new quantum mechanics-based technologies, such as quantum computers, new types of solid state and interferometric sensors, and light sources with customizable photon statistics and coherence properties. A unique characteristic of this center is the close collaboration between theoretical and experimental groups. This provides the opportunity for students to gain both theoretical and experimental research experience working on the same project.

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; and 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; and 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, and 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); and device analysis for quantum computations.

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

Controlling light with light – and application of this idea in multiple different exciting applications (such as communication, imaging, or sensors) is at the heart of the "Femtolab" (nickname of this laboratory). By employing ultrashort laser pulses, we can utilize and shape the ultrahigh-speed dynamics of quantum systems (like electrons in semiconductor structures – but also single atoms or molecules in a gas or on a surface) and use it to control or probe a separate second light beam. With the second light beam located in a different part of the electromagnetic spectrum (ranging from visible over the mid-infrared to the far-infrared terahertz region), we can bridge technological gaps and transfer control and precision directly in the spectral region of our choice - allowing for unprecedented control at this wavelength.

This scheme gives rise to new concepts for many applications, such as imaging cameras, chemical or biological sensors, and modulator for communication or beam-shaping application. These concepts can overcome today's technological problems and surpass their classical counterparts in major key issues. But it also allowfor easy access, exploration, and utilization of vastly unused parts of the electromagnetic spectrum.

A permanent goal of this laboratory is thereby not only the prediction and investigation of such control, but also the demonstration of their applications. Free-Space Optical Communication in the mid-infrared spectrum is one of these applications, which has been continuously researched due to its greater stability and security features. These applications thereby offer a lot of undergraduate and graduate students to participate (even part-time) in the research work, as they will not only gain insight in basic science, but also part of the future application of it.

Mesoscopic Quantum Optics Group – Professor C. Search

The theoretical research in this lab is broadly organized into three areas: (1) The interaction of the quantized electromagnetic field with matter and, in particular, the analysis of systems for which the characteristics of the electromagnetic field have no classical analogue. Examples include cavity quantum electrodynamics, squeezing, and antibunching (sub-Poissonian photon statistics). (2) Atomic Bose-Einstein condensates and matter wave optics, i.e. the study of systems in which atoms and molecules behave like waves of light rather than particles. Problems of interest are the formation of ultracold molecular dimers from a

Bose-Einstein condensate by photoassociation or Feshbach resonances, the interaction of matter waves with electromagnetic waves, role of quantum statistics (bosons vs. fermions) in the matter wave properties of atoms and molecules, and utilizing atom interferometers for inertial navigation and measuring gravitation field gradients. (3) Mesoscopic condensed matter physics including transport through quantum dots, generation of spin currents, creating entangled states in quantum dots, Rashba spin-orbit interaction, and solid state quantum computing.

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.

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UNDERGRADUATE COURSES

PEP 111 Mechanics
(3-0-3)

Vectors, kinetics, Newton’s laws, dynamics or particles, work and energy, friction, conserverative 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 RC 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 Department 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 semester. Typical text: Cutnell and Johnson or any other algebra-based general physics text complemented by supplemental handouts, as needed.

PEP 122 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 Department 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 three 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
(1-0-1)
Selected topics in modern physics and applications. By invitation only. Prerequisite: high school physics. Corequisites: MA 115, PEP 111. Pass/Fail.

PEP 201 Modern Physics for Engineering Students
(2-3-3)
Simple harmonic motion, oscillations, and waves; wave-particle dualism; the Schrödinger 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; and fusion and fission. Prerequisites: PEP 111, PEP 112, MA 115, and MA 116 or equivalent.

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, and optical signal processing. Fall semester. Prerequisite: PEP 112.

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. Prerequisites: PEP 111, PEP 112 (may,be taken concurrently with PEP 221-222).

PEP 242 Modern Physics
(3-0-3)
Simple harmonic motion, oscillations, and pendulums; Fourier analysis; wave properties; wave-particle dualism; the Schrödinger 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 n-p junction and the transistor; properties of atomic nuclei; radioactivity; and fusion and fission. Spring Semester. Prerequisite: PEP 112.

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 336 Introduction to Astronomy
Theories of the universe, Big Bang cosmology, and the inflationary universe. Observational cosmology; galaxy formation and galactic structure; and stellar evolution and formation of the elements. White dwarfs, neutron stars and black holes, planetary systems, and the existence of life in the universe. Prerequisite: PEP 111.

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
(0-6-3)(0-6-3)
You may participate in ongoing faculty research activities or select from a variety of experiments illustrating the phenomena of modern physics, such as the Rydberg constant and Balmer series, the Zeeman effect, charge of the electron, the Hall effect, absorption of photons by matter, statistics of counting processes, x-ray diffraction, nuclear magnetic resonance, the Langmuir probe, Rutherford scattering, and blackbody radiation. 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.

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GRADUATE COURSES

All Graduate courses are 3 credits except where noted.

NANO 600 Nanoscale Science and Technology
This course deals with the fundamentals and applications of nanoscience and nanotechnology. Size-dependent phenomena, ways and means of designing and synthesizing nanostructures, and cutting-edging applications will be presented in an integrated and interdisciplinary manner.

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; and 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 542, 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; and elementary particle theory and nucleosynthesis in the early universe. Observational cosmology; galaxy formation and galactic structure; and 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 students who wish to specialize in their 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; and 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; and geometric and physical optics. Typical text: Hecht and Zajac, *Optics*. Spring semester. Prerequisite: PEP 542 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 the measurement of aberrations in optical systems, thin-film

properties, Fourier transform imaging systems, nonlinear optics, and laser beam dynamics. Fall semester. Prerequisite: PEP 509 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; and 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. Typical texts: *Military Handbook 141* (U.S. Government Printing Office); *S.P.I.E. Reprint Series* (Selected Issues); W.J. Smith, *Modern Optical Engineering*. Prerequisite for this course is either PEP 209 or PEP 509. 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 and ellipsometry; electron spectroscopy; Auger, photoelectron, and LEED; ion spectroscopies; SIMS, IBS, and field emission;

surface properties-area, roughness, and surface tension. Alternate years. (See MT 525.)

PEP 527 Mathematical Methods for Physics and Engineering I

Vector and tensor fields and transformation properties under rotation of axes, vector identities, gradient, divergence, curl, tensor contraction, geometric interpretation of symmetric and antisymmetric tensors, divergence-Gauss' theorem for tensor fields and Stokes' theorem, Helmholtz' theorem, and scalar and vector potentials. Applications to inertia tensor, particle mechanics, transport, electromagnetism (Maxwell's equations), and viscous fluid dynamics (the Navier-Stokes equation, Euler equation, and the Bernoulli equation). Introduction to the Dirac delta-function and Green's function technique for solving linear inhomogeneous equations. Orthogonal curvilinear coordinates (general, also spherical, and cylindrical). N-dimensional complex space and unitarity, matrix notation, inverse of matrix, Pauli spin matrices, relativity, and Lorentz transformation. Tensors and pseudotensors in n-dimensions. Similarity transformations and diagonalization of Hermitian and unitary matrices, eigenvectors, and eigenvalues of Hermitian and unitary matrices, and Schmidt orthogonalization. Applications to coupled oscillators, rigid body dynamics, etc. Linear independence and completeness. Functions of a complex variable, analyticity, Cauchy's theorem, Residue theorem, Taylor and Laurent expansions, classification of singularities, analytic continuation, Liouville's theorem, multiple-valued functions, contour integration, Jordan's lemma, applications, and asymptotics. Fall Semester. Prerequisites: 4 semesters undergraduate math courses.

PEP 528 Mathematical Methods for Physics and Engineering II

Introduction to Hilbert space, function vectors, completeness in the strong and weak senses, expansion in complete orthonormal sets of functions, and Schmidt orthgonalization. The Weierstrass theorem and completeness of eigenfunctions of a Hermitian operator. Dirac/dyadic notation. Legendre polynomials, spherical harmonics, Fourier series and integral, Laplace transform, and multipole expansion. Ordinary differential equations, and ordinary point and iteration series solution and power series method, Hermite equation, Schrödinger equation for harmonic oscillator. Regular singular point and the method of Frobenius, including the second solution, and Bessel equation. Sturm-Liouville systems and weighted complete orthonormal sets of eigenfunctions, and Green's function determination and solution of the inhomogeneous problem. Partial differential equations, heat equation, wave equation, Poisson equation, solution by transform techniques, and Green's function solution of inhomogeneous initial value and boundary value problems. Linear integral equations, iteration series solution, convergence, Kernels separable in several parts, Hilbert-Schmidt theory, Fredholm theory, and Volterra equation. Spring semester. Prerequisite: PEP 527.

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, and scattering. Systems of particles, linear and angular momentum theorems, collisions, linear spring systems, and normal modes. Lagrange's equations and 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; and 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; and 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; and 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 and thermonuclear reactions; the Lawson condition; magnetic confinement fusion; and laser fusion. Fall semester. Prerequisite: PEP 542. Typical text: F. Chen, *Plasma Physics*.

PEP 545 Plasma Processing
Basic plasma physics; some atomic processes; and plasma diagnostics. Plasma production; DC glow discharges and 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; and ion implantation. Sputtering systems; ion sources; electron sources; and 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, and turbulence; flow past an object-boundary layer, wake, separation, vortices, and drag; convection in horizontal layers-conduction, convection, and 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; and 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; the Balmer series; Zeeman splitting; spectroscopic isotope shifts; the photovoltaic effect; the Hall effect; gamma ray spectrometry; beta ray spectrometry; neutron activation of nuclides; statistics of counting processes; optical and X-ray diffraction; the Langmuir probe; and nuclear magnetic resonance. Fall semester, repeated second semester. By arrangement. Laboratory fee $5. Typical texts: Young, *Statistical Treatment of Experimental Data*; Melissinos, *Experiments in Modern Physics*. Prerequisite: PEP 222.

PEP 553 Introduction to Quantum Mechanics

This course is an introduction to Schrödinger wave mechanics for students in physics and engineering, with an emphasis on engineering applications. This is a required course for all physics undergraduates, as well as students in the Microelectronics and Photonics M.S./M.E. degree program and other professional M.S./M.E. degree programs. Topics discussed include one-dimensional infinite and finite quantum wells, barrier penetration and scattering in one dimension, linear harmonic oscillator, Kronig-Penney model, angular momentum, central force problems, including the hydrogen atom, and spin. Typical texts: *Introductory Quantum Mechanics* by R. L. Liboff and *Quantum Mechanics Fundamentals and Applications to Technology* by J. Singh. Prerequisites: MA 221 and PEP 242 or equivalent.

PEP 554 Quantum Mechanics I

This course is meant as the first in a two-course sequence on non-relativistic quantum mechanics for physics graduate students, with an emphasis on applications to atomic, molecular, and solid state physics. Undergraduate students may take this course as a Technical Elective. Topics covered include: review of Schrödinger wave mechanics; operator algebra, theory of representation, and matrix mechanics; symmetries in quantum mechanics; spin and formal theory of angular momentum, including addition of angular momentum; and approximation methods for stationary problems, including time independent perturbation theory, WKB approximation, and variational methods. Typical text: *Quantum Mechanics* by E. Merzbacher. Prerequisites: PEP 553, PEP 538, and PEP 527 or equivalent.

PEP 555 Statistical Physics and Kinetic Theory
Kinetic theory: ideal gases, distribution functions, Maxwell-Boltzmann distribution, Boltzmann equation, H-theorem and entropy, and simple transport theory. Thermodynamics: review of first and second laws, thermodynamic potentials, Legendre transformation, and 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, and 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 lattice-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; and 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; and 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 and graded-index fibers; optical transmission systems; and 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 and 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 of radiative transfer within the atmosphere and ocean is provided, 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 201 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; and chemical lasers, dye lasers, Raman lasers, high power lasers, TEA lasers, and 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, and 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, and 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; and 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
This course is the first part of the graduate certificate program “Wireless Secure Network Design,” which also includes 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 585 or permission of instructor.

PEP 602 Secure and Robust Communications
This course presents an overview of areas of first responders', military activities, and use of different heterogeneous wireless systems during large scale crises, such as natural disasters, acts of terrorism, and 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 also includes three other courses: PEP 601, 603 and 604. Prerequisite: PEP 601.

PEP 603 Physical and Logical Security
This 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 also includes three other courses: PEP 601, 602, and 604. Prerequisites: PEP 601, PEP 602.

PEP 604 Secure Telecom Wireless System Design
This 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 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. Prerequisites: PEP 601, PEP 602, and PEP 603.

PEP 607-608 Plasma Physics I-II*
Motion of charged particles in electromagnetic field; Boltzmann equation for plasma; properties of magnetoplasmas; and 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 electrons; relaxation times; radiation phenomena in magnetoplasmas; stability theories; finite

Larmor radius stabilization; minimum-B stability; and universal instabilities. Typical text: Schmidt, *Physics of High Temperature Plasmas*. Fall and spring semesters. Prerequisites: PEP 642, PEP 643, and PEP 555.

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 Schrödinger equation for model systems; variational and perturbation methods; pure spin states; Hartree-Fock self-consistent field theory; and 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; and 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 and equilibrium states and their classification; nonlinear oscillator with and without dissipation; Van der Pol generator; Poincare map; slow and fast motion; forced nonlinear oscillator: linear and nonlinear resonances; forced generators: synchronization; Poincaré indices and bifurcations; solitons; shock waves; weak turbulence; regular patterns in dissipative media; and chaos: fractal dimension, and Lyapunov exponents. 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*. Prerequisite: PEP 528 or permission of the instructor.

PEP 642 Mechanics
Lagrangian and Hamiltonian formulations of mechanics, rigid body motion, elasticity, mechanics of continuous media, small vibration theory, special relativity, canonical transformations, and 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. Fall semester. Typical texts: Jackson, *Classical Electrodynamics*; Laundau and Lifshitz, *Electrodynamics in Continuous Media*. Prerequisites: PEP 528 and PEP 542.

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. Spring semester. Typical texts: Jackson, *Classical Electrodynamics* and Laundau and Lifshitz, *The Classical Theory of Fields, Electrodynamics in Continuous Media*. Prerequisite: PEP 643.

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

PEP 653 Quantum Mechanics II
This course is a continuation of PEP 554. Topics include: principles of quantum dynamics, time-dependent perturbation theory, scattering theory, the density matrix, quantization of the electromagnetic field, interaction of photons with atoms and non-relativistic particles, identical particles, and second quantization for many-body systems. Typical text: *Quantum Mechanics* by E. Merzbacher. Prerequisites: PEP 554 and PEP 542 or equivalent.

PEP 661-662 Solid State Physics III
Crystal symmetry. Space-group-theory analysis of normal modes of lattice vibration, phonon dispersion relations, and 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 and Fermi surfaces. Transport theory, electrical conduction, thermal properties, cyclotron resonance, de Haas van Alfen, and Hall effects. Dia-, para-, and ferro-magnetism and magnon spinwaves. Fall and spring semesters. Typical texts: Callaway,

Quantum Theory of Solid State; Ashcroft and Mermin, *Solid State Physics*; and Kittel, *Quantum Theory of Solids*. Recommended: PEP 503 and PEP 553-554.

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, and 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; andteleportation, cryptography, and fractal optics. Prerequisites: PEP 542, PEP 554, and 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; and 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, and nonlinear interactions. Offered in alternate years. Typical text: Loudon, *Quantum Theory of Light*. Prerequisites: PEP 542 or equivalent, PEP 554 and 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, and 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. Fall semester. Typical text: M. Jaros, *Physics and Applications of Semiconductor Microstructures*; G. Bastard, *Wave Mechanics Applied to Semiconductor Heterostructures*. Prerequisite for the course is basic knowledge in quantum mechanics and solid state physics (at the levels of PEP 553, PEP 503).

PEP 700 Quantum Electron Physics and Technology Seminar
This seminar is 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 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 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, and between representations and states. Point groups: full rotation group, crystallographic point groups, and spin-associated double groups. Crystal field theory with and without spin, selection rules and character tables, and 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. Representative texts: M. Lax Symmetry, *Principles in Solid State and Molecular Physics*; Heine Group, *Theory in Quantum Mechanics*. Prerequisites: Course equivalent to PEP 554 in quantum mechanics and associated mathematics of operators and Hilbert spaces.

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, and uv-vis spectroscopy; laser spectroscopy and applications; photoelectron spectroscopy; and multi-photon processes. 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, and metric geometry; structure of space-time theories, symmetry, and conservation laws; Newtonian mechanics; special relativity; foundations of general relativity, Mach's principle, principle of equivalence, principle of general covariance, and Einstein's equations; solution of Einstein's equations; experimental tests of general relativity; conservation laws in general relativity, gravitational radiation, and motion of singularities; and 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; and quantum transport in nanostructures: Kubo formalism and 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; and 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 taken PEP 754 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 taken PEP 754 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 754 Advanced Quantum Mechanics

This course is an introduction to relativistic quantum mechanics and quantum field theory. Relativistic wave equations, including the Klein-Gordon equation and the Dirac equation. Commutation relation and canonical quantization of free fields. Spin and statistics of Bose and Fermi fields. Interacting quantum fields: interaction representation and S-matrix perturbation theory, Feynman diagrams, and renormalization theory with applications to quantum electrodynamics. Typical texts: *Advanced Quantum Mechanics* by J. J. Sakurai and *Quantum Field Theory* by F. Mandl and G. Shaw. Prerequisite: PEP 653.

PEP 757 Quantum Field Theory Methods in Statistical and Many-Body Physics

Dirac notation; Transformation theory; Second quantization; Particle creation, and annihilation operators; Schrödinger, 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; Green's function matching; ensemble averages and statistical thermodynamics, Bose, and Fermi distributions, and 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; and imaginary time contour ordering, Langreth algebra, and the GKB Ansatz. Typical texts: Kadanoff and Baym, *Quantum*

Statistical Mechanics, W. A. Benjamin and Horing, and *Advanced Quantum Mechanics for Interacting and Mesoscopic Systems*. Fall semester. 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.

PEP 758 Coupled Quantum Field Theory Methods in Condensed Matter Physics*

Dielectric response of solid state plasmas; random phase approximation; semiclassical and hydrodynamic models; elasmons; 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 3-D, 2-D, and superlattice collective modes; electron(e) - hole (h) - 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, and polarizability of a diatomic lattice; Phonon Green's function with coupling to dynamic nonlocal electron screening, umklapp, coupled ion-electron oscillations, and 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. Typical text: Horing, *Advanced Quantum Mechanics for Interacting and Mesoscopic Systems*; Mahan, *Many-Particle Physics,* Plenum Press; and recommended readings. Spring semester. Prerequisite: PEP 757.

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,and 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

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