The Applied Physics Master's Degree Program

Harry K. Charles Jr.

The Master's Degree Program in Applied Physics at The Johns Hopkins University Whiting School of Engineering is outlined in this article, with significant emphasis on recent issues and programmatic changes. Although still a small program within the Hopkins community, enrollment has grown and stabilized at historic highs. The new curriculum offers students greater flexibility while allowing them to specialize in three major focus areas: Geophysics and Space Science, Photonics, and Materials and Condensed Matter. The Applied Physics Program fills a unique niche in the local educational community as the only cross-discipline physics program being offered on a part-time basis.

INTRODUCTION

Applied physics is a cross-discipline profession bridging the gap between pure physics and engineering. Few universities offer advanced degrees in applied physics, and people become applied physicists by virtue of their work experiences rather than by academic degree. Because the field is interdisciplinary and relies on work experience in solving complex problems, most academic institutions shy away from offering such a curriculum. Fortunately, the real world provides critical challenges to individuals and organizations that require them to develop solutions by applying fundamental physical principles to complex technological problems. Thus, many institutions, including APL, have staffs composed of not only physicists and engineers but also applied physicists. The need, role, and value of such people are obvious and so are their cross-discipline educational requirements. Based on the requirement for cross-discipline training and the need to solve complex technological programs, the Applied Physics Program at APL was initiated more than 42 years ago.

ORIGINS AND HISTORY

Historically, courses in physics (applied physics) were offered from the very beginning of the Evening College at APL in the 1964–1965 academic year. The Master of Science Program in Applied Physics was not introduced until the fall of 1967. The program as originally conceived consisted of five full-year (two-term) courses: modern physics, electromagnetics, theoretical mechanics, thermodynamics and optics, and mathematics. One term of advanced calculus and differential equations and one term of vector analysis and related mathematical methods were also offered. The next year (the 1968–1969 academic year), the Applied Physics Program was modified to allow students more flexibility (electives, projects) in

exploring the various specialties in applied physics. That program consisted of two one-semester courses in mathematical methods, four courses on the fundamentals of applied physics, a special applied physics topics course, a project, and one two-semester elective course. Most of the traditional physics topics were buried in the four courses on the fundamentals of applied physics, which covered thermodynamics and optics, electromagnetic waves, particle and rigid body dynamics, continuum mechanics, acoustics, quantum mechanics, atomic and molecular physics, and solid state physics. The electives covered a broad range of topics from biomedical engineering to microwaves. Four courses and a project were offered every year. Some of those courses were jointly listed with the Master of Science in Space Technology Program, which was offered from 1967 until 1983.

The academic year 1983–1984 was one of significant change. The APL Evening College programs became part of the JHU Whiting School of Engineering. A committee was formed under Vincent L. Pisacane, a previous coordinator for the Applied Physics Program, to revise the program. The four courses on the fundamentals of applied physics were revised and renamed according to their content. The program now consisted of eight required courses, a special topics course, and a project. To oversee the Applied Physics Program, another committee was formed, composed of Pisacane (Chair), Allan W. Bjerkaas, and Moshe Rosen. Rosen was from the Materials Science and Engineering Department at JHU and provided an important liaison between the APL-based Applied Physics Program and the JHU Homewood Campus.

Two years later, during the 1985–1986 academic year, students were able to choose from an extended menu of 20 courses. They were required to take four core courses (mathematical methods, electromagnetics, quantum mechanics, and classical mechanics), four applied physics electives, and two additional courses from either applied physics or other areas of the Whiting School programs. Bjerkaas chaired the Program Committee during the 1985–1986 academic year. Kishin Moorjani took over from Bjerkaas in 1986 and expanded and strengthened the program over the next 18 years.[1] During that period the number of courses increased from 20 to more than 35. Since 2003, I have served as the Chair, and the current members of the Program Committee are Robert C. Cammarata (JHU), Richard F. Gasparovic, Keith Peacock, David L. Porter, Kenneth A. Potocki, John C. Sommerer, and Joseph J. Suter.

CURRICULUM: RECENT DEVELOPMENTS

The current course offerings (38 courses) are listed in the boxed insert and grouped according to the area of specialization. Since applied physics encompasses a broad range of topics, the grouping by three specializations (Geophysics and Space Science, Photonics, and Materials and Condensed Matter) allows students to study a given area in depth. Two Special Projects courses—Applied Physics Project (615.800) and Directed Studies in Applied Physics (615.802)—also give the students an opportunity to pursue a particular subject in greater depth than is covered by the regular courses. The project in applied physics offers students who are engaged in analytical or experimental research programs at their work the chance to undertake a work-related project under the guidance of an expert faculty member. Given the broad nature of applied physics, the research projects are quite diverse but are usually focused on the latest topics in physics such as observation and prediction of phytoplankton blooms in the Indian Ocean via satellite, investigation of auroral electrodynamics using global emissions, and laser remote sensing system design.

The Applied Physics Program works closely with several other programs to allow students the greatest opportunity to follow a high-quality and relevant (to their needs and interests) plan of study. For example, the Applied Physics and Electrical Engineering Program Chairs meet regularly to coordinate offerings in Photonics. Courses are jointly listed, and the scheduling of course offerings is coordinated to minimize overlap and give Photonics students maximum flexibility in completing their Photonics Program requirements. A similar joint listing and schedule coordinating activity is under way with the Materials Science and Engineering programs for our Materials and Condensed Matter students.

Recently, the Applied Physics Program began an extensive revamping in light of technological advances and the changing needs of our students. The resultant program (see the complete listing of current courses below) has several advantages over previous programs. First, the curriculum for the most part is organized into the three technically broad but relevant and focused subject matter areas noted above. Second, the Modern Physics course (615.465) has been added to help students who have some weaknesses in their undergraduate backgrounds, much in the same way that the ubiquitous Mathematical Methods for Physics and Engineering bolsters students' graduate-level mathematics ability. Third, flexibility has been improved in required core course selection. The number of core courses has been expanded from four to nine, and students are now required to select four courses from the nine. At least three of the four core courses must be selected from the following: Mathematical Methods for Physics and Engineering, Electromagnetics, Statistical Mechanics and Thermodynamics, Classical Mechanics, Quantum Mechanics, and Modern Physics. Three additional courses have been added to the core as precursors for each of the major curriculum focus areas, i.e.,

COURSE OFFERINGS FOR THE MASTER'S DEGREE PROGRAM IN APPLIED PHYSICS

Course number	Course title	Instructor(s)
I. Required[a]		
615.441	Mathematical Methods for Physics and Engineering	P. J. Adelman
615.442	Electromagnetics	D. R. Thompson, A. H. Najmi
615.451	Statistical Mechanics and Thermodynamics	P. K. Kundu
615.453	Classical Mechanics	D. E. Freund
615.454	Quantum Mechanics	A. H. Najmi
615.465	Modern Physics	S. E. Hawkins III
615.471	Principles of Optics	K. Peacock
615.480	Materials Science	H. K. Charles Jr.
615.491	Physical System Modeling	Staff
II. Elective[b]		
	Geophysics and Space Science	
615.444	Space Systems I (also 615.744[c])	Staff
615.445	Space Systems II (also 615.745[c])	Staff
615.462	Introduction to Astrophysics	A. H. Najmi
615.748	Introduction to Relativity	A. H. Najmi
615.753	Plasma Physics	R. A. Greenwald
615.755	Space Physics	B. Anderson
615.769	Physics of Remote Sensing	R. F. Gasparovic
615.761	Introduction to Oceanography	D. L. Porter
615.772	Cosmology	A. H. Najmi
615.773	Ocean Physics	D. L. Porter, R. F. Gasparovic
615.775	Physics of Climate	N. S. Winstead, D. L. Porter
	Photonics	
615.472	Optical Remote Sensing	E. W. Rogala
615.751	Modern Optics	K. Peacock
615.777	Applied Optics	K. Peacock
615.778	Computer Optical Design	K. Peacock
615.780	Optical Detectors and Applications	E. H. Darlington
615.781	Quantum Information Processing	B. C. Jacobs
615.782	Optics and Matlab	E. W. Rogala
	Materials and Condensed Matter	
615.460	Sensors and Sensor Systems for Homeland Security	J. C. Lesho, M. A. Carlson
615.746	Nanoelectronics: Physics and Devices	M. Ancona
615.747	Sensors and Sensor Systems	A. Banerjee
615.757	Solid State Physics	M. Ancona
615.760	Physics of Semiconductor Devices	H. K. Charles Jr.
615.768	Superlattices and Heterostructure Physics	M. Ancona
	General	
615.762	Applied Computational Electromagnetics	R. S. Awadallah
615.765	Chaos and Its Applications	Staff
615.779	Computational Physics	M. Ancona
	Special Projects	
615.800	Applied Physics Project	H. K. Charles Jr.
615.802	Directed Studies in Applied Physics	H. K. Charles Jr.

[a]Four one-term courses, with at least three selected from the first six courses listed.
[b]Six one-term courses, with at least four from the Applied Physics Program.
[c]Requires a special project or report.

Principles of Optics (615.471) for Photonics, Materials Science (615.480) for Materials and Condensed Matter, and Physical System Modeling (615.491) for Geophysics and Space Science. Fourth, the number of 400-level courses has been increased relative to the number of 700-level courses (i.e., 14 versus 24). A more balanced program gives the students greater flexibility in course selection and thus encourages increased enrollments and less migration to other curricula for elective selection.

FACULTY AND STUDENTS

The Applied Physics Program is one of the small programs in the Engineering and Applied Science Programs for Professionals (EPP), with enrollment more than 3% of the total EPP enrollment (2003–2004 academic year). This was a significant increase (35%) over the previous academic year, and it represented a 10-year high. Current enrollment appears to be supporting this trend of increased enrollment. Although small, the program is vigorous and dynamically changing to meet student needs. All 21 Applied Physics faculty members hold Ph.D. degrees and are practicing applied scientists and engineers. In their respective fields, the faculty members of the Applied Physics Program are well known, and all are recognized as being able to develop solutions to complex technological problems by applying fundamental physical principles.

Most of the faculty (18 of 21) are members of the APL staff. Given the diversity of activities and programs at the

Laboratory, as well as the varied talent and experience base of the APL portion of the Applied Physics faculty, students receive a broad and enriching educational experience despite the predominance of APL instructors. It is, however, a goal of the Applied Physics Program to increase faculty diversity. With the introduction of new courses and the planned changeover of instructors in established courses, increased opportunities exist for improving the mix with additional non-APL instructors.

Table 1. Survey results from students graduating from the EPP (Applied Physics versus the entire program).

	Applied Physics		Entire EPP[a]	
Questions	Yes (%)	No (%)	Yes (%)	No (%)
Did your course help in your present employment?	100	0	89	11
Did/will your degree program help you get a new position or job?	67	33	58	42
Would you recommend the program to others?	100	0	94	6

[a]Includes Applied Physics responses.

Table 2. Responses to the question: How would you rate the overall educational experience in the EPP?

Program	Excellent (%)	Good (%)	Fair (%)	Poor (%)	No response (%)
Applied Physics	16.7	66.6	16.7	0	0
Entire EPP[a]	36.0	54.9	7.9	0.4	0.8

[a]Includes Applied Physics responses.

While the number of students in the Applied Physics Program has rebounded from previous lows, there is still the ever-present specter that even a small downturn in the economy or student interest can seriously impact the program because of its small size. Since the curriculum is a key element in student satisfaction, course offerings are examined, modified, and reviewed at regular intervals based on suggestions from the students, the faculty, and/or the Program Committee. Modifications to existing courses and the introduction of new courses are essential to making the program responsive to the current and projected needs of students. Careful review and monitoring of existing courses are required to ensure the quality of the course content and the efficacy of instruction. The Chair routinely monitors all student evaluations, not only for course and instructor quality, but also for program improvement suggestions. Table 1 shows responses to a recent survey of graduating students. Although the Applied Physics student sample is small (2.4%) when compared to the EPP as a whole, the results clearly show that the students recognize the value of the Applied Physics Program. Table 2 compares overall educational experience between the Applied Physics Program and the EPP as a whole. Here, Applied Physics falls somewhat short of the mark, reflecting the need for change. I believe the changes introduced in the 2005–2006 academic year and described in this article will significantly improve the overall educational experience for Applied Physics students.

As mentioned, the Applied Physics curriculum has been modified recently to allow more student flexibility and to create greater student interest. A new program brochure reflecting these changes has been developed, and new ways for increasing program presence among students are being explored. Currently, the Applied Physics Program is, without a doubt, a one-campus program (APL campus). Small forays from time to time have been made at Montgomery County[1] and the Dorsey Center, but no organized approach to expanding the program to other campuses has been pursued. With the enhancement of the current APL-based program, the introduction of more 400-level courses, and the closer coordination and cooperation with other EPP curricula, it may be possible to facilitate systematic expansion to other campuses.

THE FUTURE

The future of the Applied Physics Program looks bright, not only because of the rebound in student numbers, but also because of the many curriculum changes for the 2005–2006 academic year. The faculty and the Program Committee are committed to making the program modern, relevant, and of course, of the highest quality. Our faculty is first rate and is dedicated to ensuring that the program continues to meet the needs of the students while providing instructional excellence and adherence to professional physics standards. The increase in the number and subject areas of our 400-level courses will help attract students from outside the Applied Physics Program as well as give greater flexibility to our currently enrolled degree candidates.

The Applied Physics Program of the EPP has a unique niche in the Baltimore–Washington educational

community. It is the only such cross-discipline physics program being offered on a part-time basis. The natural extension to the program would be to offer the Ph.D. or Doctor of Science Degree in Applied Physics. Obtaining well-qualified, capable, and willing faculty for such a program poses little problem. Many students want the program and would enroll tomorrow if it were available. The time has come for the EPP to expand to the next level.

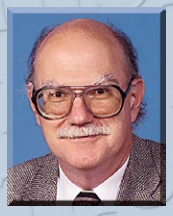
ACKNOWLEDGMENTS: I am grateful to all the past Chairs of the Applied Physics Program Committee for evolving and guiding the program for over 40 years. I am most appreciative of the support received from the administration of the EPP at both APL and the Dorsey Center. In Allan Bjerkaas and Jim Teesdale, JHU is fortunate to have two people whose knowledge of and commitment to the EPP is exceptional.

REFERENCE

[1]Moorjani, K., "The Master's Degree Program in Applied Physics," *Johns Hopkins APL Tech. Dig.* **10**(2), 140–142 (1989).

THE AUTHOR

Harry K. Charles Jr. received his B.S. in 1967 from Drexel University and his Ph.D. in 1972 from The Johns Hopkins University, both in electrical engineering. Dr. Charles joined APL in 1972 as a Post-Doctoral Research Associate. He is currently the Head of the Technical Services Department and a member of the Principal Professional Staff. Dr. Charles has worked for over 30 years in the microelectronics arena, has authored over 200 articles, holds 10 patents, and is an internationally recognized specialist in electronic devices, packaging, and reliability. His latest interests include advanced electronic interconnect; the development of flexible, low-profile packaging; biomedical instrumentation; and sensors based on both micro- and nano-scale technology. He is a Fellow and former President of IMAPS (the International Microelectronics and Packaging Society) and a Fellow of the IEEE. A consummate educator, Dr. Charles has taught in the EPP and its predecessor programs for over 25 years, as well as conducted numerous short courses and technical lectures around the United States and in several foreign countries. As an instructor in both applied physics and electrical engineering in the EPP, he has gained extensive knowledge of students' part-time educational needs. Dr. Charles has served as Chair of the Applied Physics Program since 2003. His e-mail address is harry.charles@jhuapl.edu.



Harry K. Charles Jr.