Guidelines for Self-Study and External Evaluation of Undergraduate Physics Programs

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Endorsed by the Committee on Education
of the
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Guidelines for Self-Study and External Evaluation of Undergraduate Physics Programs is a joint project of AAPT's Committee on Physics and Committee on Professional Concerns.

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Contents

Introduction

This– document is intended to guide a physics department (or other administrative unit responsible for physics education) in initial, or mid-stream, evaluation of a program of undergraduate physics education. It is intended for use by programs leading to an undergraduate degree in physics in four-year colleges or universities. Under consideration are both the programs for the full physics major as well as physics courses for students who are not planning to major in physics. The document's content is cast in the form of a set of suggested questions for local consideration, the answers to which can elucidate the nature, strengths, and opportunities for improvement, of such programs.

These Guidelines form an update of a similar document published by the American Association of Physics Teachers in 1986. The new guidelines reflect the many changes which have taken place since then in the world that students meet after graduation—changes in the range and emphases of physics itself, changes in the flow pattern of students into college physics programs and into post-graduate employment or further study, and changes in the instructional patterns used in college physics courses.

The content of these Guidelines has been significantly influenced by the work of the project entitled "Strategic Programs for Innovations in Undergraduate Physics" (or, "SPIN-UP"). This project, sponsored by the ExxonMobil Foundation and the three physics societies (AAPT, APS, and AIP) organized site visits to 21 colleges with thriving physics programs, and conducted a survey of all physics departments that grant undergraduate degrees in physics. A copy of its report, dated 2003, is available from AAPT and is posted on its website. The work was also summarized in an article in *Physics Today* (Hilborn and Howes, 56 (September 2003) 38-44.

The goals of each physics department and the goals of the students it serves, as well as the resources available, vary widely. There is no "one size" undergraduate physics program that will fit all institutions, and a given program may not fit an institution at every stage of its existence. Nevertheless, results from the SPIN-UP study suggest that all successful programs have certain common elements. For example, successful departments take responsibility for their own successes and failures. They recognize the limitations of the environments in which they find themselves and respond creatively to the challenges they face. Or as a second example, successful undergraduate physics programs constantly evaluate their strengths and weaknesses and make plans for improvement. All successful undergraduate programs are based in a community of faculty and students where students know that faculty care about them and believe that faculty members are on their side.

Although most successful undergraduate physics programs stress flexibility in their programs so that students can combine physics with other majors, there is remarkable agreement among physics departments with regard to the appropriate core curriculum for the physics major. (See Appendix for a table of the percentage of departments that require specific courses in their physics degree program and a summary of the different subject matter areas required for a physics degree.)

How To Use These Guidelines

This document can be used as a guide for formal reviews, as well as for informal departmental self-assessments. We shall phrase the questions as for use in a self-study, but the information contained in the answers will be equally useful in guiding an external review. External reviewers can, of course, provide a detached look at a local situation that can often help answer difficult questions objectively and give guidance for enhancements. Visits to other physics departments are also an excellent way to gain perspective on one's own department. A compilation of other useful resources can be found at:
http://ww2.lafayette.edu/~burciagj/undergradEd/resources.html.

The guidelines are arranged around five questions, each question divided into chapters. Each chapter addresses a particular aspect of an undergraduate program.

1. **What are the characteristics and goals of students in our undergraduate program?**
2. **Does the department's physics curriculum help students fulfill their goals?**
3. **Do we have adequate resources to support the objectives of our undergraduate physics program?**
4. **What support outside of the classroom and laboratory does our program provide to help students achieve their goals?**
5. **Does the climate in our department effectively support and energize our students?**

The division of the guideline questions into these five categories is necessarily somewhat arbitrary. Some questions in one section may overlap questions in another—perhaps emphasizing that productive connections are essential to the effective functioning of an undergraduate program.

We believe that careful consideration of the questions raised in this document will guide a department towards determining what aspects of its program are working and what are in need of change. Successful departments constantly reevaluate their programs. We hope that this document will help departments analyze their own situation and take responsibility for their own improvement.

1. What Are the Characteristics and Goals of Students in Our Undergraduate Program?

Undergraduate physics programs prepare students for a broad array of careers in industry, academia, K-12 teaching, the military, and many other areas. Student aspirations and backgrounds with respect to these diverse careers will differ from institution to institution. Thus, local knowledge of the target student population is essential.

A. What is the level of preparation and the capabilities of students entering our physics program?

Knowledge of prior preparation in physics and mathematics is critical to effective instruction. To assess the breadth and firmness of that preparation, many institutions employ placement tests as well as formal prerequisites. Subsequent educational outcomes can be strongly affected by quality information about students' "initial knowledge state."

1. How do we obtain knowledge of our students' preparation?
2. What steps do we take to challenge students who are well prepared? What steps do we take to help students whose preparation is weak, particularly those whose math background is too weak to allow them to enter the physics course for majors as first semester freshmen?
3. Do many of our students transfer into our program from two-year colleges or from four-year institutions? What steps do we take to integrate these students into the department and bring them up-to-speed in physics and mathematics so that they can graduate in a timely manner?

B. What goals do our students seek by completing their work in physics?

Strong undergraduate physics programs are vitally interested in what their students intend to do with their educations. Knowledge of students' goals in relation to the physics program being offered will assist the department's instructors in understanding students' attitudes and aspirations. Is the department providing its students with the kind of education they need to accomplish their goals?

More than 50% of all physics majors in the United States do not continue on to graduate study; instead, they seek employment immediately after receiving their bachelor's degrees. Is the education being offered serving these students as effectively as those students who plan to undertake graduate study in physics? Does it serve those who wish to become K-12 teachers?

1. What do the students who graduate from our department do after they leave?
2. How do we know that our program is meeting the current and future needs of our students? How do we respond to our perceived strengths and weaknesses in the way the program conforms to the students' needs?
3. What mechanisms do we use for collecting feedback on current students' perceptions of our physics program? What mechanisms do we use for collecting feedback on graduated students' perceptions of the physics programs?
4. How are students involved in shaping the undergraduate physics program? Do they sit on departmental committees or are they consulted informally?

C. Are our department goals for student achievement consistent with the students' goals and expectations?

The answer is critical because a mismatch between students' goals and expectations and departmental goals and expectations can lead to discontent among faculty and students.

D. Are we serving every student who may benefit from a physics degree?

Most students currently enrolled in the undergraduate physics program view a physics degree as a means to a productive career. Majoring in physics is excellent training for careers ranging from medicine to law to business. Given the breadth of career choices, it is appropriate to ask: Are we effectively reaching out to every student at our institution who would enjoy and profit by substantial work in physics?

How have our students' profiles changed in the last five years:

1. What is the racial, gender, and cultural backgrounds of students in the department?
2. How do the backgrounds of our students compare with that of the general student population at our institution?

E. Are we effectively serving students from other departments who take required physics courses?

Most physics departments teach large numbers of students from other majors, for example, engineering or the biomedical sciences.

1. How do you work with students from these "client" departments?
2. What steps do you take to interact with faculty members from these departments to ensure that physics courses meet the needs of their majors?
3. Do you work with engineering departments on issues such as ABET accreditation?

A particularly important group of students are pre-service K-12 teachers.

1. How does our department work with faculty from Education to be sure that these students have a solid grasp of fundamental physical science as they begin teaching?
2. How do we prepare students to become high school physics teachers?

2. Does Our Physics Curriculum Help Students To Fulfill Their Goals?

A. What are the requirements for a physics major and minor in our department?

B. Consider the physics major and minor programs in our department.

On what bases have we selected the elements and emphases of our major and minor programs, e.g., required courses, electives, independent work?

Expectations for student accomplishment in physics departments across the country have often been set without regard for the nature of and expectations of the student body at their particular institution. Such an approach may be appropriate for some students—those planning to move on to graduate school in physics need a certain common core of knowledge to succeed there. But a large fraction of students at most institutions move in other post-baccalaureate directions. Departments should continually review the content of their curricula to ensure that all students are well-prepared to meet their own goals. Departments may wish to take steps to inform students about the ways that the study of physics will prepare them for diverse careers.

A particularly important issue for many departments is designing a major that is sufficiently flexible so that students can complete it in three academic years. This meets the needs of students who come in with weak math backgrounds and must wait a year before starting their study of physics and of those who wish to spend a year studying abroad as well as students with broad general interests in science or career goals that require a large number of courses. It also allows students who wait to take their first physics course until their sophomore year to switch their majors into physics.

The overall design of a major is a critical issue for nearly all departments. It can be difficult to obtain data that allow departments to measure their success. Much of the data will necessarily be qualitative, for example, interviews with graduating seniors and alumni. Various models of communicating with alumni have proved effective, such as a departmental alumni newsletter or having department members speak to local alumni clubs when they give colloquia at other universities. Another potential source of information on the preparation of physics graduates is the employers who hire them and can tell the department how well it has prepared its graduates. While gathering these data requires significant effort, thriving departments constantly check that the preparation of their graduates is appropriate.

C. Are the teaching methods we use successful in accomplishing the goals of the courses?

Research on the effectiveness of physics teaching strategies suggests that some techniques are more effective than others at increasing students' conceptual understanding with no measurable adverse effects on problem solving skills.

1. Has our department examined the effectiveness of its current teaching strategies?
2. Has our department tried or investigated the use of teaching strategies oriented toward active learning?

Many departments across the country are now using a common set of externally validated instruments (e.g., the Force Concept Inventory, the Mechanics Baseline Test, the Conceptual Survey of Electricity and Magnetism) to measure the effectiveness of introductory physics courses at improving students' conceptual knowledge. There are standardized assessment vehicles available for all levels of the undergraduate physics curriculum, some of which heavily emphasize problem-solving skills. There is no consensus that any of the instruments available for the upper-division curriculum produce valid measurements of students' knowledge and capabilities. Final exams and oral presentations, however, can provide relevant information if thoughtfully constructed.

3. Has the department considered alternatives? Do surveys of alumni indicate that the students learned what they need to be successful after they graduate?
4. How do we decide which faculty members teach particular courses? How do we assess their effectiveness?
5. Do we encourage faculty members to try new or innovative pedagogics in their courses and to carefully measure the success of these techniques? Do we provide opportunities for professional development and ongoing support for faculty who implement these new pedagogies?
6. Is the content of our courses and our laboratories current? How long has it been since our introductory laboratories received serious attention? Who takes responsibility for seeing that this work is done?

D. What role does research play in our curriculum?

There is a general consensus that undergraduate research both introduces students to the excitement of physics and prepares them for graduate research or for immediate entry into the job market. Many departments either require undergraduate research participation or strongly encourage it. The students can either work with a faculty member in the department or travel to another university or user facility for a summer research experience. Undergraduate research experiences frequently convince students to pursue a physics major. Anecdotal evidence strongly suggests that they are an attractive component of a strong physics major. Research experience is clearly valuable for students who are pursuing a career in science, but they also provide an understanding of how science is done that may prove particularly valuable to students who pursue careers outside of physics research, for example in clinical medicine, business or law.

E. How does our curriculum inform students about scientific ethics and teach them ethical behavior in their work?

In the increasingly competitive environment of scientific research, it is important that students be made aware of the ethical issues they may face. While few departments offer courses in ethics, they should address ethical behavior during regular departmental activities such as advanced labs, courses, and research experiences.

3. Do We Have Adequate Resources To Support Our Undergraduate Physics Program?

High quality undergraduate physics education demands adequate resources in terms of personnel, space, lab equipment, technical support, library resources, and support for interaction of faculty and students with the outside world. Without adequate resources even the most dedicated faculty cannot provide a thriving undergraduate physics program. In this section, we suggest items to be included in an inventory of departmental resources.

College administrators face many financial demands. Outside sources—state and/or federal agencies or foundations—can often provide extra resources and funds; therefore, departments should ask themselves whether they are alert to such possibilities.

Inventory of Resources

A. Who are the personnel in our physics program?

Faculty

An effective undergraduate program requires informed participation among faculty across the full spectrum of ranks, ages, and tenure. Faculty at graduate institutions not directly involved in undergraduate teaching might welcome undergraduate students in their research groups as well as participate in developing and improving the undergraduate curriculum. There are a number of issues affecting faculty that can significantly impact the quality of a department's programs.

Teaching Loads. The level of formal teaching obligations ("teaching load") is always a concern. Experience shows that at undergraduate-based colleges, faculty members whose formal obligations exceed the "two classroom-based courses plus laboratory or scheduled tutoring time" standard don't have adequate time for essential activities outside the classroom—professional development, informal interactions with students, adaptation or creation of materials and strategies for instruction, assessments of effectiveness, research, or institutional and professional services. This criterion, however, does not apply to two-year colleges or any institution where faculty responsibilities are limited only to teaching.

For institutions with substantial graduate training, research programs, and concomitant obligations for guidance of graduate students, teaching loads are typically reduced to one "classroom-based course."

Professional Development and Sabbatical Opportunities. Faculty need opportunities to learn new strategies both in summer research and in education. Opportunities for professional development via a sabbatical or a similar program are essential. Departments might consider strategies such as semesters with an extra teaching load, which allow semester plus summer "mini-sabbaticals." It is important to provide all faculty members with opportunities to attend professional meetings and to conduct research. This issue is particularly important for young faculty, who need mentoring on how to teach, especially if they are thrust into large introductory physics sections. They also need guidance on producing research results and demonstrating scholarship.

Incentives for Making Major Changes in Courses. Effective teaching implies routinely updating content and introducing new teaching techniques. Major revisions of courses and laboratories—e.g., a switch from lectures to workshops for teaching introductory courses or a major overhaul of the advanced laboratory—require enormous investments of time and creative effort. But such changes are critical to building high-quality undergraduate programs, and it is important that faculty who implement such changes be rewarded for their efforts.

Promotion and Tenure Policy. Do promotion and tenure policies reflect the goals of the institution, not only in writing but also in the way they are implemented? Do all members of the department fully understand the policies? Are junior faculty informed of their success in progressing towards tenure and promotion?

Diversity. It is also important that the faculty represent various racial, gender, and cultural backgrounds. Does the department reflect regional and national gender, ethnic, and cultural patterns? Does it reflect the diversity in the physics profession? Do promotion and tenure policies regarding childbearing/childrearing leave or stopping the tenure clock indicate a sincere effort to ensure that faculty of all races, genders, and cultures succeed in our department?

Staff

Does our department employ non-faculty staff of sufficient size and competence to support our undergraduate program?

Local variations among institutions make it difficult to establish numerical standards on how the support staff of an undergraduate program should be composed. However, it is safe to say that any department with a program of viable size (i.e., four or more majors graduating each year) needs adequate non-faculty support in setting up, maintaining, and improving laboratory equipment, both at the introductory and upper levels; staffing a student-supportive departmental office; and maintaining an up-to-date and well maintained computer environment.

Graduate Teaching Assistants. In many large research departments, graduate student TAs play a critical role in teaching introductory level courses. Many examples can be found to contradict the common belief that instruction by graduate TAs is inherently inferior. The fact that TAs are more contemporary to beginning students and thus less intimidating than professors can often counterbalance their inexperience.

Do the institution and the department adequately prepare graduate TAs for teaching experience and provide support to create a good learning experience for both the students and the TAs?

Examples of ways to support the work of TAs are:

- Provide for a preliminary workshop of sufficient depth and duration to prepare the novice for his/her duties as a TA before classes begin.
- Provide for in-service interaction and evaluation. Weekly meetings among staff in a given course are invaluable.
- Provide recognition of TAs for outstanding performance.

A valuable resource on preparing high quality teaching assistants (and junior faculty for that matter) can be found in "Resource Letter EPGA-1: The education of physics graduate assistants," *American Journal of Physics* **68** (2000) 502-512.

Undergraduate Teaching Assistants. Many departments find that the use of undergraduate majors as teaching assistants, in appropriate roles, to be doubly beneficial—upper-level students are challenged in real-world ways and beginning students interact comfortably with upper-level peers. These undergraduate TAs require the same support and recognition from the department as do graduate TAs.

B. What laboratories, lecture rooms, and other spaces do we have to support our undergraduate program?

A strong undergraduate physics program requires well-equipped classrooms and laboratories. Trends toward encouragement of more active learning by students in both large and small classes put extra demands upon versatility of use of classroom and laboratory. Recognition of the importance of encouraging students to take on independent projects, whether in research lab, computer room or library, places other demands on availability of suitable work space.

For hardware-intensive components of the program, thoughtful interplay between active student space and storage space is desirable. Faculty members have a responsibility to achieve efficiency comparable to their peer institutions in use of laboratory space.

What are the long range plans of our department with respect to physical facilities?

C. Are our undergraduate laboratories and classrooms properly equipped? Do we have an annual budget adequate for purchasing and maintaining necessary capital equipment?

Do we have sources of funding available to support faculty initiatives in revising existing classroom or laboratory courses or creating new ones? (Many strong institutions regularly have internal institution-wide programs to make such funding available on a competitive basis.)

The phrase "properly equipped" implicitly raises the question, "Equipped for what?" The best choice of laboratory experiences for undergraduate students is a perpetually moving target. While many physicists are inclined towards having students experience the often-revolutionary consequences of classic experiments, the inexorable "sum rule" of time available warns that preparing students for the activities of the 21st century world is, perhaps, the central need. The components of laboratory work—electrical and optical measurement and apparatus, methods of data collection and analysis—are perpetually changing. The challenge in the undergraduate program is to use the limited time available to give the broadest and deepest experience which students can carry away into their own post-college work. Some departments approach this challenge by tying the advanced laboratories to faculty research interests because this brings an extra measure of faculty enthusiasm to the laboratories. Excellent undergraduate laboratories require both resources for bringing laboratory equipment up to date, AND frequent review of laboratory course content and procedures. Another source of ideas for laboratories are employers of recent graduates.

D. Does the institutional structure properly support our undergraduate program?

At the Department level

Budgets within large physics departments—those that support a graduate program and major research facilities—serve multiple needs. The department's management structure should meet the needs of the undergraduate program. Many institutions designate a faculty member as "Associate Chair" or "Director of Undergraduate Studies," who is responsible for managing the undergraduate teaching and support program as well as promoting the program's needs and goals before the department and the institution.

At the College level

Beyond basic personnel, space, and basic equipment needs described in Sections A, B, and C, college administrators must recognize and support other departmental needs.

Information Services

To stay abreast of the latest developments in physics research and education, students and faculty need access to adequate library resources—either in print or electronic form. What is "adequate" can only be defined in relationship to what other colleges have been able to achieve.

Sustaining Improved Practices

A crucial need at an institution of any size, and a need often neglected, is that recognized improvements in the quality of the educational program be institutionalized. In other words, the improvement (whether it be in syllabus, laboratory, independent projects, or outreach) must not, for its continuing existence, depend upon the commitment of particular individuals. Both department and college administrations must be full partners in this institutionalization. However, it is important that the program remain flexible enough so that new faculty can sustain it.

E. Do we have adequate financial support for the resource needs outlined in sections A thru D?

Budgetary needs will vary widely among institutions of different size and scope; still, it is important to identify the specific funding sources for the following items.

- Competitive faculty salaries;
- Professional development (time and travel for professional meetings, sabbatical or similar opportunities);
- Release time when needed to update courses;
- Competitive salary and benefits for non-faculty staff;
- Support structure for graduate teaching assistants (e.g., pre-service workshop, in-service guidance);
- Annual allocation for purchase and maintenance of laboratory and computer equipment;
- Library resources such as monographs and journals (many available online at reduced cost);
- Support for undergraduate research (often available through federally funded Research Experience for Undergraduates programs—either at the home institution or as a satellite program at larger universities).

4. What Support Does Our Program Provide To Help Students Achieve Their Goals Outside the Classroom and Laboratory?

In this section, we discuss departmental climate and co-curricular support for students. Evidence from a number of studies indicates that a successful physics program is more than a series of courses. Thriving departments pay attention to all aspects of the lives of their majors. No single department follows all of the steps below, but many work at a variety of different institutions. The questions below are intended to elicit a description of the measures your department takes that go above and beyond providing a high quality curriculum.

A. How do our students receive academic advice?

It is essential that students receive timely and accurate information about physics courses and university requirements. A lack of information can lead to poor placement and students who are either bored by repetitive material or discouraged by courses for which they lack adequate preparation. When courses are not offered every term, failure to enroll in a required course could delay a student's graduation date.

In some institutions freshmen are advised by a core of academic advisors then receive departmental advisors after declaring their majors. Some departments assign responsibility for advising students to one faculty member; at others nearly all faculty play some role in advising students. An effective advisory process is key to students' success as physics majors and to their making career choices. Thriving programs ensure that all students receive careful, individual attention.

B. How do students learn about career opportunities and graduate programs?

Because there is no job called "physicist" at the bachelors level, students (and their parents!) frequently wonder what physics majors can do when they graduate. Therefore it is important that both students and faculty be well informed about the possible careers open to people holding a degree in physics. AIP, APS, and AAPT have made major efforts to increase the physics community's awareness of possible career paths.

C. How does our department stay in contact with alumni?

Alumni are a valuable resource for connecting physics students with the real world. They can assist a department in locating internships and research opportunities, apprise faculty of employment opportunities, help review departmental goals and curricula, and provide valuable information regarding the skills and knowledge desired by employers. Although it is difficult to track alumni, the effort spent doing it frequently pays off handsomely.

D. How does our department maintain contact with companies that hire our graduates?

The grapevine is important in identifying job opportunities for graduates. Thriving physics departments make use of mechanisms such as advisory groups and other industry contacts to keep students informed and to raise the profile of their physics graduates with potential employers. Companies can also review curricula and advise departments on what they expect their new employees to know and do.

As physics changes potential employers change their expectations of physics majors. By maintaining contact with institutions where physics majors are employed, undergraduate programs can ensure that their majors are well prepared before entering the job market.

E. How does our department interact with graduate programs where our majors pursue studies?

Graduate programs in physics understand the importance of recruiting talented students. As physics changes, graduate programs change their expectations of incoming students. By maintaining contact with institutions where physics majors pursue graduate study, undergraduate physics programs can ensure that their majors are well prepared for graduate work in physics and other related disciplines.

F. What steps does our program take to involve undergraduate physics majors in research experiences at our own or other institutions?

The excitement of actually doing physics bonds physics students to the major and prepares them for a career or graduate work. Thriving departments generally offer students opportunities to work closely with a faculty mentor on a research project. They also take advantage of REU programs and internship opportunities to broaden their students' experiences.

The importance of providing undergraduates with research experiences requires that physics departments also support faculty research with on-campus labs and through sabbaticals and summer stipends. A faculty member who loses interest in stretching his or her knowledge is unlikely to be effective in training physics majors or in providing quality teaching to non-majors.

G. How does our undergraduate physics program support students who wish to be K-12 teachers?

Well-prepared K-12 teachers are critical to ensuring a future supply of students eager and able to study physics and other sciences. Enlightened self-interest indicates that all physics departments must be concerned about the education of future teachers and/or in supporting teachers already in the classroom. How is working with teachers considered in distributing departmental rewards such as promotions, tenure and release time?

H. How does the physics department interact with other departments whose students take physics courses?

All undergraduate physics programs support other science, engineering, and technology programs by teaching high quality introductory physics courses that comprise part of their major program requirements. In addition to providing excellent instruction, physics departments need to interact with client departments whose majors enroll in introductory physics courses to ensure that the courses meet the needs of those majors as perceived by their home departments. Because public perception of physics is important, particularly in debates over funding, it is imperative that introductory physics courses are well taught and adequately supported with meaningful laboratories.

5. Does the Climate in Our Department Effectively Support and Energize the Undergraduate Physics Student?

Thriving undergraduate physics programs are characterized by a community of faculty and undergraduate students. Undergraduates feel that they belong to the community and that the faculty are "on their side." While it is difficult to measure this sense of community, it is easily noted when it is present. It is also a pillar of a healthy undergraduate program. The community should support all undergraduates including women and underrepresented minorities. The questions below are intended to illuminate the steps that your department has taken to promote this community.

A. What steps does our program take to promote faculty-student interactions?

Steps include social activities such as picnics but also finding students desks in spaces near faculty and departmental offices or maintaining a seminar that involves both students and faculty members. A sign of success is the fact that faculty members know students in the department and are familiar with their backgrounds and abilities. Other signs of success are that faculty members keep regular office hours and frequently interact with students on an informal basis.

In many departments, upper division students are hired to act as lab assistants in introductory courses, to provide tutoring services to beginning students, or to perform other jobs such as problem grading. Such activities involve the students with the department and promote an important sense of community.

B. What steps does our program take to promote a sense of community?

Most thriving physics departments have an active SPS chapter or a physics club. The physics clubs frequently provide tutoring services and community outreach. Many offer student study areas where students congregate to work on physics or to connect with other students. Some departments assign upper-division mentors to new majors or develop courses that mix freshmen and upper-division students.

C. What steps does our department take to make sure that the departmental community includes all students, including women and underrepresented minorities?

How do faculty view their role in recruiting, acclimating, and retaining underrepresented groups? Are faculty aware of the activities of professional physics societies and other sectors of the university in recruiting and supporting these students? Are the students associated with organizations such as the National Society of Black Physicists, the National Society of Hispanic Physicists, the Association for Women in Science, and Women in Science and Engineering?

D. What role do undergraduate students play in departmental governance?

It is important that faculty teach to the level of the students they have rather than to the level of the students they wish they had. Thriving departments regularly seek their students' input then modify the program accordingly. In some cases physics majors sit on faculty committees. Many departments even seek the advice of their majors on new faculty hires.

E. What programs and services does the institution offer that support our physics majors?

In some institutions, physics departments provide tutoring and other services for undergraduates. However, many institutions have centralized tutoring services and services for students with disabilities. Centers for minority students may also be particularly supportive of students in physics majors. The interaction of physics departments with such services varies widely. When they work well together, they can provide great support to students.

Conclusion

You have done a great deal of work in compiling this self-study. We suggest that physics faculty members as a group review their work and identify areas in which your department is succeeding and areas where you could improve. No undergraduate physics program is ever perfect. Frequent revision seems to be necessary to meet the changing needs of our students and the changes in the society in which we operate and that we ultimately serve.

Lasting change in college and university physics departments requires the support of at least a majority of the faculty members in the department. By discussing data collected about your students, the resources available to you, and the structure of your undergraduate physics programs, you should be able to identify actions that you can take to improve the learning of the students you teach. At this point, it is often useful to bring in somebody from outside the department to examine both the report and the faculty members. The external visitor may be a team of physicists from industry or academia or a member of another department at the same institution. Physics faculty members are frequently so close to their own students and departments that they are immersed in day-to-day problems and miss larger problems and opportunities. In an ideal world, external reviewers of the department can serve precisely this function.

APPENDIX

Table A: Course Requirements and Undergraduate Degree Programs (Percentages)

Required Course	Bachelor of Science	Bachelor of Arts	Other Bachelor	**All Programs**
Introductory classical physics	99	99	97	**99**
Intermediate classical mechanics	97	88	87	**95**
Introductory modern physics	95	94	94	**95**
Intermediate electromagnetism	96	88	81	**94**
Advanced laboratory	90	74	90	**87**
Quantum mechanics	88	74	65	**84**
Thermal and/or statistical physics	82	57	81	**78**
Mathematical physics	45	38	36	**43**
Optics	46	24	52	**42**
Other physics courses	85	82	87	**84**
Number of survey respondents	387	92	31	**510**

Table B: Required courses as a percent of total physics credits required in a standard degree program

Required Course	Bachelor of Science	Bachelor of Arts	Other Bachelor
Introductory classical physics	22	24	26
Advanced laboratory	12	13	14
Intermediate electromagnetism	11	11	10
Introductory modern physics	10	12	11
Intermediate classical mechanics	10	11	10
Quantum mechanics	10	11	8
Mathematical physics	8	11	9
Thermal and/or statistical physics	8	10	9
Optics	8	10	9
Other physics courses	18	20	19
Number of survey respondents	380	91	30

Source: 2003 SPIN-UP Survey of physics programs offering an undergraduate degree in physics. Seventy percent of all programs surveyed responded. Data used by permission.

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