

Report of External Evaluator

Central Washington University
Department of Physics

Kenneth S. Krane
Department of Physics
Oregon State University

April 19, 2010

Executive Summary: After reviewing the Department of Physics' comprehensive self-study document, I visited the campus on March 8-9, 2010 to meet with faculty, staff, students, and administrators. My initial impression is that of a small department with faculty who are extraordinarily dedicated and productive, and students who are taking full advantage of the various programs offered by the Department and who are consequently launched into successful physics-related employment or postgraduate education. The Department seems to have the instructional capacity to expand the size of its undergraduate program but may be limited by insufficient space and personnel resources.

1. Evaluation Criteria

In contrast to the chemists, who have a formal accreditation process for undergraduate programs, the U.S. physics community has no similar procedure for evaluating undergraduate physics programs. There is no formal template by which the adequacy or completeness of a department's undergraduate curricula can be judged, nor is there a checklist of resources that must be present in order to maintain a viable program to prepare students for careers in physics. Nevertheless, despite the lack of formal standards, the U.S. physics community has evolved a set of benchmarks based on practices that are now common throughout virtually all of the 775 U.S. colleges and universities that offer a baccalaureate physics degree. It therefore makes sense to evaluate a department in comparison with other physics departments with similar goals that operate within similar institutional contexts.

Lacking national standardization criteria, the physics community has instead developed guidelines that may serve as a template for either self-study or external evaluation. The American Association of Physics Teachers, a national professional society devoted to the teaching and learning of physics, has published a set of such guidelines that are available on the AAPT web site.¹ Rather than offering evaluation criteria, these guidelines present a set of questions that should be addressed:

1. What are the characteristics and goals of students in our undergraduate program?

¹ http://www.aapt.org/Resources/upload/Guide_undergrad.pdf

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?

Within each of these five main categories, the document offers additional questions that can serve as a means of judging individual programs or of inspiring programs to advance their activities. No specific answers to the queries are presented; instead, it is the asking of the questions that is the primary usefulness of this document. And because it presents no answers that are specific to physics departments, the framework can be applied to any discipline. The document (which focuses mainly on the undergraduate major) can thus be very useful not only to physics departments, but also to administrators throughout the university.

A second set of guidelines does provide a template for assessing undergraduate programs. The National Task Force on Undergraduate Physics, a joint project of several professional societies funded by the ExxonMobil Foundation and the National Science Foundation, has engaged in a study to ascertain whether there are any common characteristics of undergraduate physics programs that can be regarded as "thriving." This project, known in the U.S. physics community as SPIN-UP (Strategic Programs for Innovations in Undergraduate Physics), produced a widely-circulated report that has had a great impact in helping physics departments expand their programs and increase their undergraduate enrollments.² The SPIN-UP report offers specific ideas for modeling successful physics programs, but the characteristics of these model departments (advising, student-faculty interactions, etc.) once again transcend the physics discipline and could represent model programs in *any* discipline.

My evaluation, then, is based in part on the use of the AAPT guidelines and the SPIN-UP criteria for successful undergraduate physics programs.

2. Characteristics of CWU Undergraduate Physics Students

In terms of the number of undergraduate majors, physics departments are often one of the smaller departments on campus. To achieve even those small numbers, physics departments must cobble together a variety of degree programs that serve as pathways to a diversity of careers. In this respect, the CWU physics department is no different than departments throughout the U.S., whether at small colleges or large universities.

In my meeting with a group of CWU physics undergrads, I was struck by the great variety of paths by which the students had come into the CWU physics program and equally by the diversity of career plans. Some students had begun the CWU physics

² <http://www.aapt.org/Programs/projects/ntfup/index.cfm>

program as freshmen, while others had entered after a year or two at a two-year college. One student already has a humanities B.A. and is working toward a second degree in physics. One student is in the B.A. track with plans to become a high-school teacher, another is headed toward a career in medical physics, and still another plans to take the B.S. in physics with an astronomy minor and then pursue graduate studies in astronomy. Several students are engaged in the 3-2 program in engineering and planning to complete their undergraduate work at an engineering school. Each student seemed to have a clear focus and a realistic sense of the requirements for his or her degree path. This reflects admirably the quality of the advising that is available to CWU physics undergrads.

During my meeting with the students, I worked very hard to try to get them to offer some criticisms of the physics program or the faculty, but I was not able to wring any negative comments out of them. The students seem extraordinarily satisfied with the quality of the program and with the assistance provided by the faculty. One of the SPIN-UP hallmarks of a successful department is one that does not “dumb down” the physics curriculum, but rather one that sets high standards and then assists students in meeting those standards. That seems to me to be a fair characterization of the CWU physics department. The only negative comment that the students could come up with is that Professor Jackson is such an animated lecturer that students can’t sleep in his classes.

I also spent some time trying to probe the students’ preparation for the rigors of the undergraduate physics curriculum. None seemed to have come into the physics program with unrealistic views of their own preparation. While they may have arrived with different backgrounds (and especially with differing levels of math skills), all seemed to have successfully negotiated the physics curriculum and to have overcome any deficiencies in their previous work. Students who had transferred from two-year colleges seemed well integrated, both academically and socially. I didn’t sense any significant mismatches between career aspirations and departmental curricula. The department’s Student Learning Outcomes Assessment Plan seems to suggest that students are on track to satisfy their curricular requirements and are gaining acceptable levels of physics content knowledge as a result of the instruction offered by the department.

Although the AAPT guidelines and the SPIN-UP report deal primarily with a department’s programs for its undergraduate majors, all physics departments play a broader role in the academic life of their institutions, particularly through service courses in introductory physics for students from diverse majors and through general education courses for all students. The CWU physics department offers two introductory one-year physics courses (111,112,113 and 181,182,183), the former without calculus and the latter with calculus, which serve students from a variety of science and technology majors. I met with a group of department chairs from various science disciplines (chemistry, biological sciences, mathematics, geological sciences, computer science, and science education) to try to gather their impressions of the physics service courses. All expressed great satisfaction with those courses and with the extent to which the courses are serving the needs of their students. During my previous evaluation visit in 2005, there was some discussion of difficulties arising when sections of the service courses were closed or when students found that two required courses, such as a math course and

a physics service course, were offered at the same time. There is no evidence that similar difficulties are still occurring, so these problems seem to have been successfully addressed.

The department offers several general education courses that serve students from any major. Courses in astronomy and in the physics of music have been offered for many years. New courses in physics by inquiry and in light and color have been recently added. This is not a terribly diverse curriculum of general education courses, but it is perfectly adequate for a small department. I suspect in comparing the number of general education courses per total faculty FTE, physics would probably be one of the more active supporters of the general education curriculum in COTS.

Recently the U.S. physics professional societies have begun to urge physics departments to play a greater role in the preparation of pre-service teachers. The new Physics by Inquiry class (106) is a good example of how a department should address that duty. This course will serve middle-school science teachers; it will present a broad survey of physics, and most importantly it will model successful inquiry-based teaching techniques. It is very important to this type of effort to have a faculty member like Professor Palmquist, who has strong credentials in physics as well as in science education.

3. The Curriculum for Physics Majors

According to the SPIN-UP survey, one of the hallmarks of a successful undergraduate physics program is the diversity of degree tracks available to students. CWU offers two tracks through the physics major: a B.S. degree, intended for students who will seek professional employment in a physics-related industry or graduate study in physics or engineering, and a B.A. degree, intended for students who wish a broader education and who may be considering careers in secondary teaching, law, medicine, or technical journalism. In addition, the Physics Department offers a dual physics-engineering degree program, in which the student spends the first 3 years studying physics at CWU and the final two years studying engineering at a participating university. Finally, the department offers minors in physics and astronomy, primarily for students in other science majors.

The CWU Physics Department is able to offer this diverse curriculum of degree programs despite its small size because of the overlap of the course offerings with the various degree programs. The curriculum for the B.S. consists of a “standard” set of courses that are equivalent in level and content to those at physics departments throughout the U.S. The course curriculum for the B.A. is a subset of those required for the B.S., and the curriculum for the physics minor is a still smaller subset. Thus no additional courses in the curriculum are needed to support the B.A. or the physics minor. The curriculum for the astronomy minor requires only one course (PHYS 301) that is not present in the curriculum to support the other degrees or the service or general education

curricula. In my view there is absolutely no “fat” to trim from the CWU physics curriculum.

It is remarkable to me that it is possible to support this curriculum with only 4.5 faculty members. Like many small departments, the CWU Physics Department offers the advanced physics courses (those normally taken in the junior and senior years) in alternate years. This seems to me to be an acceptable means to maintain a complete and rigorous physics curriculum with a small number of faculty. Although the courses of the “core” physics curriculum are virtually identical to what is offered at most of the physics departments in the U.S., the small size of the faculty limits the ability of CWU to offer additional courses that might broaden the students’ experience.

There is no national template such as an accreditation process that can be used to rate or rank undergraduate physics programs. Instead, it is my strong opinion that enrollment in the major is the primary criterion to use in comparing physics departments with national norms, because students will vote with their feet – low enrollments in the major are usually a signal that a department is having fundamental problems connecting with students, while high enrollments usually suggest that a department is on the right track. Table A.7 of the self-study shows a comparison of the physics degrees awarded by CWU over the past 10 years compared with those of 21 peer institutions. In evaluating the absolute numbers of physics B.S. degrees, it is necessary to do so relative to three institutional parameters: the total number of B.S. degrees, the number of physics faculty, and the enrollment in introductory physics. In this respect, CWU ranks somewhat below its peer institutions in number of physics degrees as a fraction of the total number of institutional B.S. degrees (0.18% vs. 0.33% for the average of the peer institutions) and somewhat above its peer institutions in number of degrees per faculty member (1.0 vs. 0.77) and also in degrees relative to enrollments in introductory physics (1.7% vs. 1.2%). These last two statistics are especially important, because in a small department the ability to advise and mentor majors can be limited by the available faculty time, and thus more faculty means more advising time is available. In addition, a large enrollment in introductory physics suggests a large number of students on campus who are seeking technical majors in the basic or applied sciences and who have a greater probability of choosing to major in physics compared with students in nontechnical majors. In this latter respect CWU is at a disadvantage in comparison with its peer institutions, but nevertheless manages to exceed the performance of the peer group. For example, in the survey my eye is drawn to the Boise State data, with 3 times as many faculty, three times the introductory physics enrollments, but only half as many physics degrees; based on these comparisons, CWU is 6 times as effective as BSU in producing physics majors.

One set of data missing from this comparison would be the number of physics degrees compared with the total number of science degrees awarded by the various institutions. It is almost always true that physics departments offer the smallest number of science degrees in their respective institutions. The small number of degrees at CWU is therefore of little concern to me. There are many U.S. physics departments that produce even smaller numbers of majors than CWU (11 of them are mentioned in Table A.7). Moreover, it appears that CWU is on the crest of a dramatic increase in the number

of physics students, with approximately 16 students in the sophomore-level courses and perhaps another 16 in the freshman year.

4. Resources Supporting the Undergraduate Program

Faculty. With a total of 4.5 faculty FTE, CWU is significantly smaller than any of the 21 peer institutions in the summary presented in Table A.7., which average 10 faculty. In the U.S. physics community, we typically find small liberal arts colleges with 3-6 faculty, regional undergraduate public institutions with 5-15 faculty, and graduate institutions with an average of 30 faculty. It is clear to me that the physics faculty at CWU are spread very thin. Increases in the number of majors, such as is anticipated based on the current numbers of freshman and sophomore students, will severely strain the Department's resources. In particular, it is not obvious to me how the active undergraduate research program can be sustained if the number of junior and senior majors were to increase to double the present size or more.

There are several areas in which an additional faculty member could allow the Department to expand its activities to better serve CWU students. More energetic programs of recruitment and alumni relations take faculty time to organize and sustain. A greater profile in secondary teacher preparation could also be accomplished with an additional faculty member. (Joining the 175-member Physics Teacher Education Coalition would also enhance this process.)

It is not possible for CWU to achieve parity with its peer institutions in number of faculty positions, but I believe a more viable physics program would be enhanced with one additional tenure-track position. A hire in an interdisciplinary area such as biophysics or geophysics could offer a new dimension to instruction and could provide useful research collaborations with other departments.

It would also be appropriate for this new hire to enhance the diversity of the Department's faculty – I don't think it sends a very positive message to your female undergraduates when the tenure-track faculty are exclusively male while the only female faculty member is not on the tenure track.

Staff. I was very impressed with the dedication and commitment of the support staff, the full-time technician and the half-time secretary. While this number of staff is small, they are enthusiastic about their jobs and very supportive of the faculty and students.

Space. I commented about the Department's lack of space in my 2005 review. This unacceptable situation has been slightly relieved with the acquisition of some additional office space as well as the space for the new studio classroom. However, the amount of space available to the Department remains inadequate for a physics program. Given the difficulty of a small department in providing for a stimulating research environment for students and in acquiring state-of-the-art equipment, it seems quite shocking to me that the new department chair was required to abandon half his research equipment in moving

to CWU because there was not space available for it. I hope that plans for the new science building continue to advance and that physics will be allotted both more space and higher quality space than it now has.

I was very pleased to see the new teaching room being developed for a studio format in introductory physics. This is becoming an increasingly popular and successful mode of teaching in U.S. physics departments. While the present facility is being developed with an enrollment of 40 students in mind, most of the programs with which I am familiar use facilities designed for 80-100 students. I urge the Department in planning for a facility in the new science building to visit other facilities and to consider the optimal design based on the space available and the faculty instructional time available. For example, with limited faculty time a facility that serves 80 students seems to me to make more sense than a facility for 40 that will require two sections of faculty instructional time. With adequate training, student lab assistants can be very helpful in teaching larger numbers of students in this instructional mode. For example, the SCALE-UP model, which was developed at North Carolina State University and is in wide use throughout the U.S., is based on a classroom that serves approximately 100 students.

As was the case in 2005, the physics computer room remains inadequate to serve the instructional needs of physics undergraduates. Not only does the room offer at best a cramped workspace, the computer hardware and software are not adequate. Students complained that the software available on the physics facility was often an older version that was not always compatible with what is available on the central CWU computing facility. It is very helpful for students to have a small computing facility in the physics department, so that they can work on their instructional or research projects with faculty nearby to provide assistance, but outdated hardware and software can be troubling for students.

Finances. While it is not possible to make objective comments on the Department's financial resources without a detailed institutional history and a comparison with other CWU departments, I do have a concern about the adequacy of the funds available for upkeep and maintenance of the equipment used for the instructional labs in the service courses and in the advanced lab courses for physics majors. The National Science Foundation has recommended an annual upkeep budget equal to 5% of the estimated replacement value of the current equipment inventory. Whatever the level of support available, the instructional lab equipment must be maintained in good working order; otherwise the course experience proves especially frustrating to students, and the important pedagogical goals of the laboratory are unachievable.

5. Student Support Outside of Class

A listing of the departmental characteristics that provide support for students can be found in the SPIN-UP criteria. The extent to which the CWU Physics Department satisfies those criteria is detailed in Section II.D. of the self-study report and need not be

reproduced here. Overall I believe that the Department is doing an excellent job at providing support for students outside the classroom environment.

I do want to single out the Department's commitment to undergraduate research, which is one of the key elements common to thriving departments. The CWU Physics Department has made a noteworthy commitment to having all of its undergraduates involved in research under the supervision of a faculty member. This admirable effort could be difficult to sustain, especially as the large number of freshman and sophomore students advance through the curriculum.

Other key features of the Department's program include a student study room that the students consider essential to their instructional satisfaction, the use of students as assistants in lab instruction, and the exceptionally successful activities of the undergraduate physics club (Society of Physics Students). All of these contribute to the students' sense of "belonging" to the Department.

The level of engagement of the faculty in the undergraduate program is also obvious to the external reviewer. It is clear to me that the faculty share a common vision of where the Department needs to go and how it can get there. There is a sense of a collective responsibility for the Department's future, and there is clearly strong and visionary departmental leadership provided by the recently hired chair.

Areas of the SPIN-UP survey in which I see CWU as deficient include administrative support, recruitment, and alumni relations. In my conversations with CWU administrators, I did not come away with a sense of a strong commitment to the future of the Physics Department. Without such a commitment, it will be difficult to sustain the energy and enthusiasm that characterize the present physics faculty. It is rare to find an undergraduate physics program in which all tenure-track faculty are engaged in some sort of externally-funded activity, as is the case at CWU. Administrative support can provide faculty with the incentive to continue such an outstanding record.

I believe that the Department could undertake a more active program of recruitment directed at high-school seniors, students attending two-year colleges, and CWU students enrolled in the introductory physics course. Enhanced contacts with high-school and two-year-college physics instructors would assist this process. An active program of involvement of alumni in the Department's affairs could also pay long-term dividends in enrollment and career mentoring. No alumni information is present on the Physics web site. (As was the case in 2005, the Geological Sciences web site is outstanding.) Because few entering students understand what professional physicists actually do in their careers, having exemplary alumni visible on the web site could aid recruitment. The Department could also benefit from occasional visits by alumni who could talk about their careers and meet informally with students. Physics graduates often leave a recognizable footprint on the web, so the Department can often locate missing alumni through web searches.

Additional areas in which the Department could notch up its support program would be to maintain contact with employers of its graduates and with graduate schools in which CWU students pursue their studies. These contacts will help to ascertain that students are adequately prepared for the next stage of their careers.

6. The Departmental Climate

To the outside visitor, the climate in the Physics Department appears to be exceptionally positive. There is a definite sense of community within the student group, among the faculty, and between faculty and students. The involvement of undergraduate students in research contributes to this climate at CWU. Additional possibilities for enhancing the climate include informal social activities (sports, picnics, etc.), which can be very helpful in building this sense of community. Another way to involve undergraduates is through departmental governance – having undergraduates on departmental operating committees or on an advisory committee, for example.

7. Additional Issues

In our initial meeting, Associate VP for Undergraduate Studies Tracy Pellett asked me to consider two specific issues concerning the Physics Department:

- (A) Given that Physics is such a small department, would there be a gain in efficiency in consolidation with another department?** I don't think there are any advantages to such a strategy, and there will almost certainly be several disadvantages for physics. There are few physics departments that either thrive or maintain their identity after consolidation with another department. Such combined departments as Chemistry and Physics or Mathematics and Physics seldom result in a successful physics program, because physics is always such a small component of the combined department. It is unreasonable to expect a chemist or a mathematician who might chair such a combined department to provide the curricular or pedagogical leadership that a successful physics program requires.
- (B) Is the 30% failure rate in PHYS181 a cause for concern?** This rate seems fairly typical for calculus-based introductory physics courses throughout the U.S. It may seem high, but on most campuses it is not significantly different from, for example, the failure rate in the first term of calculus. It may reflect the inadequate mathematics preparation of some students in the calculus-based physics course, or perhaps the lack of the self-discipline required for success in the traditional physics course. Personal tutoring through a physics learning center (usually run by graduate students at PhD institutions) often addresses this problem, but that may not be practical for CWU. Another approach that might be workable at CWU is a tutoring session run by undergraduates, possibly as an activity of the Society of Physics Students. However, I think the most likely strategy that will improve the failure rate is the new studio physics course that is

under development at CWU. Courses taught in this mode throughout the U.S. have generally been characterized by significantly lower failure rates in comparison with traditionally taught courses.

8. Conclusions and Recommendations

The undergraduate program offered by the CWU Physics Department in many ways matches the standard U.S. criteria for “thriving” physics programs. The faculty are extraordinarily successful in their instructional roles, and all tenure-track faculty are currently involved in externally funded scholarly programs. Students are required to have a research experience mentored by one of the faculty members, and the Department has compiled an impressive record of student research presentations. The content of the B.S. program is rigorous and challenging, and it provides the necessary preparation for graduate work in physics or employment in a physics-related industry.

Recommendations:

- A. Because the CWU Physics Department cannot continue to compete successfully with institutions in its peer group that have 2 to 3 times as many faculty, a new tenure-track position should be created, possibly in an interdisciplinary research specialty such as biophysics or geophysics.
- B. Planning should go forward for the completion of the new science building, with adequate research and instructional space for physics.
- C. The Department should improve its tracking of alumni and consider ways that alumni career experiences can provide guidance in shaping the curriculum and advising students. Alumni should be featured on the Department’s web site.
- D. The development of the new studio classroom should go forward, with guidance from similar national programs (SCALE-UP, for example) on optimum class sizes and configurations. Investments should be made in equipment and furnishings necessary to launch the program, with due regard for how purchases to outfit the present classroom can be carried over to the studio classroom in the new building.
- E. Recruitment activities should be targeted at high-school seniors, students in two-year colleges, and students who perform strongly in the PHYS 181 sequence. If the number of students currently enrolled in freshman and sophomore physics courses can be sustained, the number of physics degrees awarded should about double. Although the faculty may be stretched a bit to provide research experiences for twice as many students, there is ample capacity for doubling in other aspects of the curriculum.
- F. The University should approve pending cooperative agreements for 3-2 programs in engineering with undergraduate engineering programs in Washington.
- G. The Department should have a realistic maintenance and replacement schedule for its instructional lab equipment, along with an appropriate budget.
- H. Active contacts should be established with the graduate schools and employers of CWU physics students, in order to assess the adequacy of their preparation.
- I. The Department should affiliate with PTEC and promote the B.A. degree as a vehicle for the preparation of secondary physics teachers.