Assessment Report, Physics Department  
August, 2012

1. Learning Goals

A. Learning goals applicable for all students completing course work in the department

After completing one or more physics courses, a student should be able to:

1. Qualitatively describe the behavior of some natural world phenomena in terms of fundamental physical laws.
2. Quantitatively solve problems that describe some physical processes.
3. Have some understanding as to what constitutes a physical measurement and some of the techniques by which physical measurements are made.
4. Have an understanding of some aspects of the relationship between science and technology, such as how technologically-advanced scientific instruments are used to make observations and measurements, or ways in which specific physical principles are employed in everyday technologies.

B. Learning goals for majors/minors

After completing the physics major, a student should be able to (in addition to those items listed above):

5. Demonstrate a basic understanding of fundamental physical principles particularly in the areas of mechanics, waves, optics, thermodynamics, electricity and magnetism, and modern physics.
6. Design and conduct experiments at a reasonably sophisticated level.
7. Present orally and in writing the results of experiments and calculations in a logical, coherent manner, using a format that is accepted by the physics community.
8. Apply a variety of mathematical techniques to the theoretical analysis of physical phenomena.
9. Apply computer techniques to the acquisition, analysis and presentation of data, and to the solution of physics problems.

Students who minor in physics should have developed most of these skills, but to a lesser degree of sophistication than that which is attained by physics majors.

2. Assessment Methods

The Physics Department’s mission is threefold: 1) provide basic instruction in physics and astronomy to students who are not science majors, 2) provide non-physics science majors with a survey of physics at a level appropriate to their needs, and 3) provide physics majors with both depth and breadth in physics. Since the learning goals for each of these groups differ somewhat, and the approach for attaining them varies, the assessment methods for each of these three groups will be described separately.

A. Non-Science Majors

For this group, Learning Goals 1-4 are the pertinent goals, encompassing the General Education goals for Natural World courses. For non-science majors, Learning Goals 1 and 2 are primarily assessed through written assignments and examinations. Assignments are typically given weekly or every other week; they serve a formative purpose, allowing students and instructors to evaluate understanding during the course. Examinations are given during the semester as well as at the end, so that they serve both a formative and a summative purpose. Short answer or essay questions on assignments and exams permit the assessment of Learning Goal 1. Learning Goal 2 is assessed through questions that require the quantitative solution of problems, including numerical calculations as well as analysis of graphs and figures.

Learning Goal 3 is addressed in different ways, depending on whether the course has a laboratory or not. In Physics 102B students are required to make careful observations and measurements in the lab and to draw appropriate conclusions from them, which they discuss with the instructor at designated checkpoints. In Physics 100N and Physics 107N, student-designed projects are required; these projects involve a certain amount of creative thinking and independent research. In-class activities in these courses also familiarize students with basic measurement and observational techniques. The effectiveness of these projects and activities is assessed through a combination of written reports, discussion with the instructor, and assignment and examination questions.
Learning Goal 4 is assessed in similar ways. For example, in Physics 107N (Astronomy), various types of telescopes are discussed to explain how astronomers gather information. Physics 102B includes applications of concepts to issues such as medical uses and health effects of radiation, and energy considerations in heating and cooling buildings. Students’ understanding is assessed through discussions and assignment and examination questions.

In addition to assessment of these specific learning goals, formative feedback on instruction is also obtained through focus groups or written feedback forms (different faculty use different methods). In the focus group (or quality circle) approach, students are invited to meet with the course instructor at a location away from the classroom to informally discuss their perceptions regarding the effectiveness of the course. Instructors who make use of written formative feedback design a feedback form and give it to students at about the time of the first exam. This form allows students to submit agree/disagree responses and open-ended responses and suggestions to the instructor anonymously. Both of these methods provide an opportunity to make mid-course adjustments and give the students some ownership of the course. These feedback methods are used in courses for science majors, as well.

B. Non-Physics Science Majors
Science and Math majors who take physics as part of their degree requirements all take Physics 200B. Those who take a second course choose it from the other courses in our introductory sequence: Physics 213/214/215; Physics 218; or Physics 205. Learning Goals 1 – 4 are addressed in all of these courses, and are assessed using methods similar to those described for the non-science majors’ classes. Because all of these courses have laboratory components, laboratory work is used in teaching and assessing Learning Goal 3.

In addition to traditional assessment instruments such as written and/or oral examinations, quizzes, problem assignments, laboratory checkpoint discussions and laboratory reports, we have incorporated several standard, validated, externally-normed instruments to evaluate the extent to which students have mastered fundamental concepts. We use the Force and Motion Conceptual Evaluation (FMCE) and the newly-available Projectile Motion Conceptual Evaluation (PMCE) in Physics 200, the Heat and Temperature Conceptual Evaluation (HTCE) in Physics 213, and the Electric Circuits Conceptual Evaluation (ECCE) in Physics 218. These instruments enable us to quantitatively evaluate the progress of each student taking the course and compare this progress to national norms.

C. Physics Majors
We expect that physics majors and minors will master Learning Goals 1-4 in some depth as a result of completing the 200-level courses. In addition to the assessment methods described above, for our majors we assess these goals as well as Learning Goal 5 through our Junior Comprehensive Examination, which is given at the beginning of the second semester of the junior year. The Junior Comprehensive consists of two parts, a qualitative (conceptual) exam, and a quantitative (problem-solving) exam. Both parts are locally developed and cover material from the four required introductory courses: Mechanics and Waves (PHYS 200B); Thermodynamics, Optics, and Special Relativity (PHYS 213/214/215); Electricity and Magnetism (PHYS 218); and Modern Physics (PHYS 220). Students who do not pass the qualitative exam on the first try are required to demonstrate their understanding of the concepts either by correctly revising their answers to the exam, or through an oral examination. The quantitative part consists of four sections, each corresponding to one of the four required introductory courses. Each student is required to pass all four of these sections. If a student does not pass one or more sections the first time, he or she is required to retake these sections until achieving a passing score. The opportunity for retakes and for oral exams allows students the opportunity to remediate weaknesses in these fundamental areas of physics.

Learning Goals 6 through 9 pertain specifically to physics majors (and to a lesser extent to minors). The junior and senior level courses are designed to address them specifically. Learning Goal 6 is clearly laboratory oriented. Laboratory work in upper-level courses is more sophisticated than in the introductory courses,
requiring students to exercise more independent judgment in performing and interpreting experiments, and there are opportunities for students to engage in experimental design. Lab work is closely monitored by the faculty and evaluation is carried out either individually or in small groups. Formal written papers, and sometimes oral lab reports, are required in Physics 220 and 312. In Physics 313, laboratory skills are assessed by means of practical exams in which each student has to demonstrate these skills to the instructor by assembling and debugging an electrical circuit and then making and interpreting measurements on that circuit. Learning Goal 6 is also assessed through the senior project, as described below, since most senior projects have some experimental or observational component.

Learning Goal 7 is assessed through the oral and written laboratory reports described above, as well as through presentations in Junior and Senior Seminars (Physics 360 and 460), which are required of all physics majors. The culmination of Senior Seminar is the senior research project, which requires each student to work independently, generating, analyzing, and presenting the results of an investigation. Many students also present research results at Wittenberg student research symposia, or at regional or national professional meetings. All of these presentations give faculty the opportunity to evaluate students’ ability to integrate and express their knowledge, as well as to assess the extent to which our curriculum prepares our majors to do and communicate about science.

Learning Goals 8 and 9 are addressed throughout the physics curriculum. Mathematical skills are assessed in problem sets and examinations. Computer skills are evaluated in connection with laboratory data acquisition and analysis; computer applications such as Mathematica and MATLAB are also used in many courses as a problem-solving tool, with the results assessed in the same manner as mathematical skills.

Finally, we have several means by which we make a more general assessment of our curriculum and practices, including seeking student feedback and looking at data collected by national physics organizations.

We invited junior and senior physics majors and minors to share their perceptions of the department in two focus group sessions at the beginning of the Spring 2012 semester. The focus group results are summarized in the next section. There is no formal post-graduate assessment, although many of us continue to correspond with our alumni and we often informally ask them about what they found to be particularly helpful in their education. For example, our recent alumni consistently mention the oral presentation skills they develop in Junior/Senior Seminar as being particularly valuable.

We continue to graduate an average of between 5 and 6 physics majors per year. According to recent (2008) American Institute of Physics statistics, this places us in the top third of physics departments whose highest degree is the bachelors. While we are doing well by this measure, there is still room for growth.

3. **Summary and Interpretation of the Findings**

The results of the standard conceptual assessment instruments (the FMCE and PMCE in Physics 200, the HTCE in Physics 213, and the ECCE in Physics 218) continue to be similar to results reported in our last assessment (post/pre gains of between 40 and 65%), as shown in the table below. These results are better than those typically obtained in courses that use traditional pedagogy, and are similar to those obtained in exemplary "reform" courses that make use of pedagogical methods based on physics education research. (We use a number of such methods, including RealTime Physics labs, Peer Instruction, and Just-in-time teaching.)

Given that the only major change to these courses since our last assessment is that we switched to a new textbook in Fall 2010, the fact that these results have not changed significantly is not surprising. Improvement in these results is still possible, but the most likely way to get significant improvement is to go to a studio (combined lecture/lab) method of offering these courses, which our staffing levels do not permit. (Note that pretests are not always given in Physics 200; our experience over the years has been that the FMCE pretest scores are consistently in the low 20% range.) (The pretest scores for the HTCE may be high because many students have learned some of the basics of thermodynamics in a previous chemistry course.)
<table>
<thead>
<tr>
<th>Course</th>
<th>Semester</th>
<th>Instrument</th>
<th>Pretest %</th>
<th>Posttest %</th>
<th>Gain (as % of possible gain)</th>
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<tr>
<td>PHYS 200B</td>
<td>Fall 2009</td>
<td>FMCE</td>
<td>-</td>
<td>51</td>
<td>-</td>
</tr>
<tr>
<td>PHYS 200B</td>
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<td>FMCE</td>
<td>-</td>
<td>50</td>
<td>-</td>
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<td>FMCE</td>
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<td>62</td>
<td>51</td>
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<tr>
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<tr>
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<td>PMCE</td>
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<td>80</td>
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<tr>
<td>PHYS 213</td>
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<td>37</td>
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<td>45</td>
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<tr>
<td>PHYS 218</td>
<td>Fall 2011</td>
<td>ECCE</td>
<td>33</td>
<td>63</td>
<td>44</td>
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</table>

Instructor perception of in-class assessments such as exams and student projects also confirms that these measures of student learning do not indicate any major difficulties.

Over the last four years the first-try passing rates for the different sections of the Junior Comprehensive examination for our majors have ranged from 63% (the quantitative Thermo/Optics/Special Relativity and E&M sections) to 89% (the qualitative Mechanics section). This range is slightly (but not significantly) lower than in past years. One area of improvement is the passing rate on the Modern Physics sections, which had been low (often below 50%) and is now comparable to the passing rates on the other sections. The improvement on this section is most likely attributable to an increased active learning approach in Physics 220.

Our focus groups of junior and senior science majors provided thoughtful comments on many aspects of the Physics Department. Those that are most relevant to this assessment are included here:

**Major/minor requirements and courses:**

Students said that the requirements for the major are reasonable. They appreciate having a choice of courses to take for electives. They did ask that PHYS 332 and 411 (Electromagnetism and Quantum Mechanics) be offered more often. There were also requests for 4-credit full-semester versions of our 2-credit half-semester electives, and for an upper-level fluid mechanics course. Students appreciate the faculty’s willingness to supervise independent studies and to schedule our courses so as not to conflict with other departments’ courses (especially Math/Computer Science). They also felt that the minor requirements are challenging but doable, and suggested that we should do more to publicize the minor to students taking the gateway course, Physics 200B.

There was general agreement that the 200-level courses and labs are helpful for learning. Many students feel that Math 201 should be a prerequisite for Physics 200, rather than a corequisite, so that students would have stronger math preparation and more calculus-based work could be included. One student suggested that Physics 218 should include more labs on topics other than electrical circuits.

Students wanted to get a start on computer programming earlier in the physics course sequence. They thought it would be helpful to have a crash course in software packages used in physics/engineering and also an introduction to the Linux/Unix operating system. A one-credit “introduction to research” course would also be helpful, focusing on general experimental tools and research skills (shop, data analysis, etc.).

The cognate courses for the major were generally felt to be useful, especially COMP 150. Some mismatch was noted between topics emphasized in MATH 212 and specific vector calculus topics that are useful in advanced physics courses (e.g. spherical and cylindrical coordinate systems).

**Junior/senior seminar:**

Students recognize that preparing/giving talks in seminar is good practice and appreciate the requirement. They suggested a few modifications to the seminar structure, including requiring the dry run to be done by Thursday or Friday before the talk so there’s more time to make significant changes. Also, they want more clarity in
defining what talks at different letter grade levels look like so they know exactly how their performance on a
given talk would translate into a grade. Students find it difficult to formulate good questions for the speakers,
and would appreciate some hints about how to do this. They would also like us to find a way to give the students
in audience feedback about how much they should have been able to understand from each talk—for example,
faculty could give the audience three main points that everyone should have gotten from the talk, or the
presenter could send out readings for the talk ahead of time.

Students find the faculty research talks in seminar to be helpful in communicating what research and project
opportunities are available. They would like us to include a unit in seminar on creating resumes; if this is done
early the in junior year, it might be extra motivation for them to apply for summer research or internship
opportunities.

**Junior Comprehensive:**
Students generally wanted more help from the department in studying for the Junior Comprehensive exam; the
department already gives out in advance a description of the exam, suggestions for studying, and the equation
sheet, and students suggested that the department should also provide study guides, sample questions, and/or
practice tests. Some suggested that we not wait till spring of junior year to give all four sections, but give some
sections earlier in the junior year. They also suggested that we mention the comprehensive exams at the end of
each 200-level course so students know to save exams, equation/review sheets, etc. to use in studying for the
comps. A few students pointed out that no equation sheet is provided for the GRE and that the comps would
better prepare students for the GRE by not allowing an equation sheet.

**Research/projects:**
Several students expressed appreciation for how much they’ve learned through doing research. It was suggested
that we better publicize how student projects can be funded (through department funds, Wittenberg research
grants, etc.).

**Community building:**
Students value the community of physics majors highly, and suggested several ways to further strengthen the
community. Several asked that we create more opportunities to get 1st and 2nd year potential majors together
with the juniors and seniors—for social events as well as opportunities to learn more about the department (for
example, giving tours of the research labs for interested 1st and 2nd year students, and inviting students to attend
faculty research talks). Having names and pictures of majors displayed in the department would also help
students get to know each other sooner. Students value the opportunity the department provides for them to
attend physics meetings, and suggested that we also consider having more frequent outside speakers, more
opportunities to visit research labs at other institutions, and additional incentives for them to attend outside
colloquia.

**Physical environment/equipment:**
Students value the student study (especially the big whiteboard), but they often feel overcrowded, and
sometimes need more access to computers. They mentioned that the Science 315 classroom/lab needs updating
with new computers and a better layout. They were appreciative of the new equipment the department has
obtained for electronics, although some thought a wider bandwidth oscilloscope would be useful for some
projects.

4. **Program Modifications to be Implemented**
First, we report on the main program modifications since the previous (2008) departmental assessment
document.

A. We did some restructuring of Physics 220 (Modern Physics) and introduced more active learning pedagogy
in response to Junior Comprehensive scores and student feedback. This appears to have been successful in
improving Junior Comprehensive scores in Modern Physics to the level of the other 200-level courses. No problems with Physics 220 were mentioned in the recent physics major focus groups.

B. We have begun examining the structure and timing of our introductory courses. Our current practice is to offer a single Mechanics course (Physics 200B), taught both semesters, which is taken by both physical and life science majors and uses little calculus. Offering a single course rather than separate courses for life science and physical science students is unusual among physics departments, and our own experience as well as that of students indicates that two separate courses would serve all students better. In addition, the National Academies’ BIO2010 report, and recent changes to medical school requirements and the MCAT, provide strong arguments for offering two separate courses with different emphases. There are other difficulties in the introductory sequence, including an awkward division of material between Physics 215 and 220. Changing the introductory sequence might also allow us to offer Physics 205 in the spring, which the Biology Department has indicated they would prefer. We held a departmental retreat focused on the introductory sequence in 2011, but finding a staffing-neutral way to create two separate Mechanics courses while still maintaining student scheduling flexibility is proving to be very difficult. We will continue to work on this issue.

C. We recently changed our upper-level major requirements to improve the lab experience and make it possible to offer core courses (such as Physics 332 and 411) more often. In place of the old requirement of a specific lab course on Wave Phenomena, we now require one of three core upper-level courses plus a new Advanced Physics Laboratory course. These changes were motivated by student feedback, our own perception of student needs, and national data on best practices in upper-level physics curricula.

D. We’ve done some preliminary work on identifying and developing tracks in the major (e.g. applied physics, biomedical physics, astronomy). For a variety of reasons (staffing changes, sabbaticals) this effort is on hold right now.

E. The goal from the 2004 self-assessment of modifying Physics 205 to introduce more problems based on biological systems had been on hold, but faculty who teach this course have resumed working on this in the last few years.

Additional modifications to be considered in the next few years:

Student comments and our own experience point to a need to re-examine the Junior Comprehensive exam format. Because in recent years we’ve had more transfer students and more students who start their physics sequence late, the number of students who have not completed the introductory sequence by their junior year is larger than in the past, causing logistical problems in administering the exam. In addition, students are requesting more assistance in studying for the exam, and some students need multiple tries in order to pass, increasing faculty workload associated with the exam. The information we get from the exams has been helpful, and we believe that it’s good for students (particularly those going on to graduate school) to have a chance to review fundamental physics concepts, but we need to think about whether alternative methods of assessment, or a different format for the exam, would serve our goals just as well.

We will continue to consider modifications to our upper-level curriculum to make sure students have the opportunity to get the experience they need, particularly laboratory and computational work that will better prepare them for research and employment. The new Advanced Lab course will help with this goal. As a next step, we’ll be looking at possible changes to the lab associated with Physics 220.

The question of modifications to the introductory sequence is an important but difficult one, and we will continue to talk about it, subject to staffing constraints.

Finally, students in the focus groups brought up a number of suggestions having to do with Junior/Senior Seminar and community-building opportunities that we plan to implement.
5. **Additional Resource Needs**

Staffing is a serious concern. We teach many lab-based courses that are required for other science majors and pre-health students; in fact, more than 1 FTE of our teaching load goes to teach physics courses that are filled by other science (and some Education) majors who are required to take physics. With 3 FTE we cannot even cover the minimal number of courses required for these majors and our own majors without adjuncts or overloads—and we find it very difficult to get good adjuncts. Having four tenure-track or long-term visiting faculty is necessary for us to continue offering these courses as well as to contribute to the general education program, offer upper-level courses that will prepare our majors to succeed in graduate programs, and continue to involve students in research. Even at 4 FTE our staffing is below average for peer schools of our size, and when we have sabbaticals or phased retirements in the department we always must teach overloads and offer (uncompensated) independent studies in order to meet our service course needs and allow our students to graduate.

We also need technical support. Unlike most of our peer institutions, we have no technical support staff, although we are sometimes able to obtain student help with setting up labs. The physics faculty, in addition to repairing and maintaining laboratory equipment, also do much of the maintenance and upgrading of computer software in the department. Even part-time dedicated technical support for equipment and/or software would free up many hours per week of faculty time for other activities that benefit the university. We are engaged in discussions with other science departments about strategies for obtaining an appropriate level of technical support for all science departments, but in the end these resources will have to come from outside the physics department.

We have several classrooms and labs that haven’t been renovated since the original wing of the Science building was built; they don’t serve us well in teaching or in recruiting students. Two classroom/labs have poor setups for computer use (students have noticed and complained about this) and multimedia projection. Recent (and continuing) roof and HVAC leaks in offices, laboratories, and classrooms in the Physics Department have caused unsightly water damage that has been noticed by prospective students and their families, and the dripping water creates a slipping hazard in our hallways and puts valuable equipment in jeopardy.

One major equipment need is for a suite of small telescopes for Weaver Observatory to benefit astronomy classes and outreach. In addition, a new computer lab would add significantly to the educational and outreach capabilities of the Observatory. Equipment for modernizing our advanced laboratory (especially in the area of data acquisition and signal processing hardware and software, such as LabVIEW) is also needed so that our students have the opportunity to learn techniques and concepts that reflect current practices in research and industry. Maintaining support for software including Mathematica and MATLAB is an ongoing concern. Keeping lab computers/printers and other major equipment (e.g. oscilloscopes) updated is a significant drain on the departmental budget.

Although the number of physics majors we graduate each year compares favorably with national averages, and our majors have a good record of achievement both at Wittenberg and after graduation, it continues to be particularly challenging to recruit strong physics majors. Competition for strong potential physics majors is fierce, especially when most of our peer institutions have new physics facilities. Clearly an effective strategy to recruit excellent potential science majors must involve Admissions and Marketing. We have had some discussions with these offices about new initiatives for recruiting prospective physics and pre-engineering students, but how these initiatives can be implemented and sustained is an open question.

It would be very helpful to have a mechanism for learning about the activities of our alumni and their observations regarding their experiences at Wittenberg, and to involve them in recruiting new students and offering internships and research experiences for current students. In the last few years we’ve put out a short alumni newsletter with the help of emeritus Bill Dollhopf and have gotten some informal feedback from alums through this contact, but we lack the resources to develop this initiative to the extent we’d like (e.g. with a
concerted effort to survey alumni). Support in producing and analyzing such a survey or other mechanisms that would achieve these objectives would be particularly helpful.

6. **Plan for Continued Assessment**

We plan to continue assessing our program along the same lines as described above, including continuing with student focus groups at regular intervals. We will look at new standardized conceptual exams being developed by physics education researchers to see if any are suitable for assessing specific courses or the major as a whole. As time and staffing permits, we want to do more with the evaluations of senior thesis presentations and alumni data. In a couple of years we should have a several year stretch with no sabbaticals, and that would be an opportune time to globally re-examine our learning goals and assessment methods.