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 or in a paper the results of an experiment or a calculation 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 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 of each of these groups differ, and the approach for attaining them varies, the associated assessment methods differ as well. Consequently, our response for each of these categories 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 solutions of problems. Some of these require mathematical calculations or the analysis of graphs.

   Learning Goal 3 is addressed through classroom discussions and laboratory and project experiences, as well as through assignments and exams. In Physics 101B and Physics 102B there is a laboratory component in which students are required to make careful observations and measurements, and to interpret their significance. In Physics 100N and Physics 107N, student-designed projects are required; these projects involve a certain amount
of creative thinking and independent research. The effectiveness of these activities is assessed through some combination of written reports, discussion with the instructor (at designated checkpoints), and assignment and examination questions.

Learning Goal 4 is assessed in similar ways. For example, in Physics 107N (Astronomy), various types of telescopes are described to explain how astronomers gather information. In Physics 102B, applications of concepts to “real world” issues, such as medical uses and health effects of radiation, and the meaning of “uncertainty” in science, are discussed at designated lab checkpoints. Students’ understanding is assessed through both formal and informal discussions and by assignment and examination questions.

In addition to assessment of specific learning goals, formative feedback on the perceived effectiveness of instruction is also obtained through focus groups or written feedback forms (different faculty use different methods). In the focus group (or quality circle) approach, one or more times during the course 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 excellent opportunity to make mid-course adjustments, and they give the students some ownership of the course. These 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 will all take Physics 200B. Those who take a second course will 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, more use is made of laboratories than projects in teaching and assessing Learning Goal 3.

In addition to traditional assessment instruments such as written and/or oral examinations, quizzes, problem assignments, laboratory experiments and laboratory reports, and student evaluations, we have incorporated several standard, validated instruments to evaluate the extent to which students have mastered fundamental concepts. We use the Force and Motion Conceptual Evaluation (FMCE) in Physics 200 and the Electric Circuits Conceptual Evaluation (ECCE) and Conceptual Survey of Electricity and Magnetism (CSEM) 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

Since all physics majors are required to take our introductory sequence of courses, it is our expectation that they have mastered Learning Goals 1-4 in some depth. In addition to the assessment methods described above for these learning goals, we further assess Learning Goals 1 and 2 for our majors through our Junior Comprehensive Examination, which is given at the beginning of the second semester of the students’ junior year. The Junior Comprehensive consists of two parts, a qualitative (conceptual) part, and a quantitative (problem-solving) part. The qualitative part covers 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 part on the first try are required to take an oral exam over similar concepts. 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 those sections until they are passed. The opportunity for retakes and for oral exams allows students the opportunity for remediation of
weaknesses in fundamental areas of physics. The qualitative part of the exam was added since the last
departmental assessment in order to further our assessment of conceptual understanding.

Learning Goals 5 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 5 is assessed throughout the
physics curriculum using the techniques mentioned above as well as through the Junior Comprehensive for
majors. In addition to these, one-on-one discussions between the student and the instructor increase in
frequency and importance.

Learning Goal 6 is clearly laboratory oriented. Laboratory work is closely monitored by the faculty and
evaluation is carried out either individually or in small groups of two or three. 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. Formal written laboratory reports, and sometimes oral lab
reports, are required in both Physics 220 and 312. In Physics 313, laboratory skills are assessed by means of
exams in which each student has to demonstrate these skills (such as assembling and debugging electrical
circuits, and then making and interpreting measurements on those circuits) to the instructor. Learning Goal 6 is
also assessed through the senior project, as described below, since most senior projects have at least some
experimental or observational component.

Learning Goal 7 is assessed through the oral and written laboratory work described above, as well as through
presentations in the Junior and Senior Seminars (Physics 360 and 460), which are required of all physics majors.
Relevant presentation skills are developed in Junior/Senior Seminar. Students’ presentations are evaluated by
the physics faculty not only as an evaluation of individual students’ work, but also to provide additional insights
into the curriculum. The culmination of Senior Seminar is the senior research project, which requires a student
to work independently, generating, analyzing, and presenting material. Many students also present their work at
Wittenberg student research symposia, or at regional or national professional meetings.

Learning Goals 8 and 9 are addressed throughout the physics curriculum. Mathematical skills are assessed in
problem sets and examinations. Under these conditions, difficulty with the mathematics becomes readily
apparent. Computer skills are often evaluated in connection with laboratory work. The use of computers in the
laboratory includes both data acquisition and analysis. Since these components of an experiment are absolutely
essential, significant assessment occurs as the experiment is being done. The computer is also used in many
courses as a problem-solving tool, with the results assessed in the same manner as mathematical skills.

For general assessment, activities such as professional meetings, dinners, picnics, and Society of Physics
Students meetings create opportunities for students to informally express their perceptions of the Physics
Department and its curriculum. As a more formal method of assessment, we invited our junior and senior majors
to share their perceptions of the department in a focus group session at the end of the Spring 2008 semester.
Several students, physics majors as well as other science majors, also met with our external reviewer, Dr Robert
Teese, during his visit in fall 2006. 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
consequently learn of their accomplishments on an informal basis, and often informally also ask them about
what they found to be particularly helpful in our curriculum. For example, nearly every one of our alumni who
graduated after the senior project presentation was instituted mentions that aspect of the physics major as having
been important in improving their technical oral presentation skills.

To summarize, the Physics Department assesses its students and its effectiveness as a department in various
ways. We use oral and written examinations, which include both quantitative and qualitative types of questions.
We give quizzes and problem assignments. We require projects and laboratory work with associated oral and
written reports. The Junior Comprehensive is an important instrument in evaluating both our students and
ourselves. We make use of standard, research-based assessment instruments, and seek evaluations from experts
outside the department. Juniors and seniors give oral presentations in our seminar courses and poster presentations at Wittenberg events and at professional meetings. We invite our students to participate in focus groups and other similar activities. We solicit observations from our alums. Our senior project requirement serves as an effective culminating experience.

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

As might be expected, the assessment instruments have yielded a wide variety of results. The most significant results will be discussed below.

The results of the *standard conceptual assessment instruments* (the FMCE in Physics 200, the ECCE and CSEM in Physics 218) continue to be statistically similar to results reported in our last assessment (post/pre gains of between 35 and 60%). These results are better than those typically obtained in courses that use traditional pedagogy, and are similar to those obtained in so-called exemplary "reform" courses that make use of pedagogical methods based on physics education research. Given that we have made only modest changes to these courses since our last assessment (for example, using online homework systems in order to give rapid feedback to students on assignments), the fact that these results have not changed significantly is as expected. Improvement in these results is still possible, but the most likely way to get significant improvement is to go to a "workshop" (combined lecture/lab) method of offering these courses, which current staffing levels do not permit. Instructor perception of *in-class assessments* such as exams and student projects also indicates that these metrics of student learning do not indicate any major difficulties.

Giving a *Junior Comprehensive examination* to our majors has achieved our objective of being able to provide an opportunity for remediation to students who do not perform adequately in specific areas. The qualitative section that we added since the last assessment report serves a useful function in that it gives us a fuller picture of strengths and weaknesses, both of individual students and of our curriculum. Overall for the last two years first-try passing rates for most sections is 75-100%, indicating good student mastery of the material. The only exceptions are the Modern Physics sections, which have had 33-60% first-try passing rates. This is not surprising, given the fact that Modern is by far the most difficult conceptually of any of the introductory courses, but it does point to a need to reexamine that part of the curriculum. Student focus groups also point to a somewhat artificial division of traditional modern physics material between Physics 215 and Physics 220, which may cause some of the difficulty. We are looking at this issue.

Since the last assessment, we have twice had *focus groups* of junior and senior science majors comment on all aspects of the Physics Department. They provided extensive, thoughtful comments on many topics. Those that are most relevant to this assessment are included here.

Some students felt that the introductory mechanics course, Physics 200, was a good introduction to physics, and they enjoyed being in a large class with a wide variety of students. Others (especially our stronger majors) felt that this class was too large, and that they didn’t feel appropriately challenged, especially at the beginning of the course. This mixed reaction agrees with the sense of the faculty that as currently configured Physics 200 is perhaps trying to address too wide a range of student preparations. This is an issue we’ll be looking at in the next few years.

One almost universal comment was the desire for a wider variety of courses, especially on solid state and on nuclear physics. The faculty agrees with this, but with current staffing levels finds it difficult to offer these additional courses as often as students would like. In the reexamination of the Modern Physics part of our curriculum, we will take these comments into account, as these topics could be introduced there at a basic level, assuming that we can find other topics that could be cut.

The majors made many comments which would be helpful to future physics majors, particularly in regard to specific cognate and general education courses that would be helpful to physics majors interested in particular
career paths. These specific comments are useful for individual advising, and will also be used as we evaluate the idea of different “tracks” within the physics major.

The research experienced by students for their senior project is recognized as being highly beneficial. Attending professional meetings, tutoring, and going on field trips were also mentioned as positive experiences, which should continue to be encouraged and supported by the department. Students recognized that the department is seeking to get students involved earlier in the life of the department through activities such as research and the Society of Physics Students, and see this as a good thing. Students felt that the lab sequence for majors makes a good progression to independence, although they don’t necessarily see it as helping them prepare for their senior thesis project.

Two other aspects of the physics major that received particularly positive comments in these focus groups were the close interaction with the faculty and the new computers in the Student Study (obtained from Computational Science funds). Better technical support for the other computers and printers in the department continues to be an issue for the students as well as faculty.

Finally, it is worth noting that we continue to graduate an average of five physics majors per year. According to the most recent (2005) American Institute of Physics statistics, 65% of physics departments whose highest degree was the bachelors graduated four or fewer physics majors per year, whereas only 11% graduated 10 or more per year. While we are doing well by this measure, there is still room for growth.

4. Program Modifications to be Implemented

The observations noted above suggest several modifications to our program to be considered over the next few years.

A. Physics 220 (Modern Physics) is clearly the most difficult course in the introductory sequence, as Junior Comprehensive and student feedback data indicate. We will be looking carefully at how this course fits in the curriculum and how to improve student learning of the concepts introduced in this course. We will first try a restructuring of the material within this course and the related course, Physics 215, along with more active learning techniques.

B. Enrollment figures suggest that since our rearrangement of the introductory curriculum several years ago, non-physics majors are increasingly choosing to take Physics 200 in the spring rather than the fall since the natural follow-on courses (Physics 205 and 218) are offered in the fall. In addition, focus groups of majors have given mixed feedback on the efficacy of a single large introductory Mechanics course such as Physics 200. We will begin addressing this issue by gathering demographic data, consulting with other departments, and evaluating the structure and timing of these courses, given staffing constraints and the needs of all the students these courses serve.

C. We are examining the path of experimental, computational, and research work physics majors experience, from the introductory courses through intermediate courses and the senior project. We want to make sure students are exposed to necessary tools and patterns of thinking necessary in creative work, and that they’re prepared for the senior thesis project and then for graduate school or the job market. We are in the process of making up a matrix with goals and tools for each of the courses in the major sequence to make sure students have the opportunity to get the experience they need, and we’re also making use of feedback from focus group meetings as well as informal alumni feedback. We will most likely make some changes to our laboratory courses based on this analysis.

D. We are investigating whether “tracks” that help students focus cognate and elective courses toward particular interests, such as engineering, medical physics, astronomy, etc. would be worthwhile in preparing students for careers and for recruiting prospective students. This may involve simply a repackaging of the curriculum, or
perhaps changes to the curriculum in the form of new or substantially revised courses. Some information from the focus groups is helpful here, and it would also be particularly helpful to survey alumni and/or prospective students.

Finally, we report on the main program modifications mentioned in the previous (2004) departmental assessment document:

1. **Add a qualitative section to the Junior Comprehensive.** This has been done, and it appears to have achieved its goal of allowing students to remediate any weaknesses in their conceptual understanding, as well as alerting us to some common student difficulties in the introductory sequence.

2. **Modify Junior/Senior Seminar to allow more detailed feedback to students on their presentations, greater flexibility in presentation topics, and distribution of information on careers and grad school.** This has been done, though we continue to make slight changes in response to continued feedback from students.

3. **Modify Physics 205 to introduce more problems based on biological systems.** This is on hold due to staffing changes, but may be resumed in the future.

4. **Increase emphasis on uncertainty analysis and lab reports in some of the introductory labs.** We have made a number of changes in this direction; further changes will be part of goal C above.

5. **Additional Resource Needs**

A. **We need to have all our classrooms and laboratories equipped with Internet access and computers in order to use best-practices pedagogy and to give our students a strong background in important computational tools.** As effective physics teaching increasingly utilizes teaching methods that involve the use of computers, it becomes difficult to use classrooms that are not appropriately equipped. In particular, modifications to the upper-level classroom and lab areas to add Internet connections and computers are urgently needed. In addition, a computer lab along with a suite of small telescopes for exploration and analysis would add significantly to the educational and outreach capabilities of Weaver Observatory.

B. **It is becoming increasingly important for us to obtain up-to-date equipment and computer hardware and software for many of our courses so that our students have an opportunity to learn techniques and concepts that reflect current practices in research and industry.** In particular, we wish to strengthen Physics 312 (Wave Phenomena) by obtaining modern optics equipment such as an optical table and tunable diode lasers. Modern, reliable oscilloscopes are needed in Physics 218 (Introductory Electricity and Magnetism). Obtaining data acquisition and signal processing hardware and software such as National Instruments DAQ boards and LabVIEW software would bring a number of our upper-level courses (Physics 313, 321, and 325) up to date and would also provide increased support for the Computational Science minor.

C. **The Physics Department has no laboratory coordinator, although we have been able to obtain some student help with setting up labs.** In addition to repairing and maintaining laboratory equipment, the faculty also do much of the maintenance and upgrading of computer hardware and software in the department. There is an opportunity cost associated with having the faculty spend 20 hours a week on these routine technical activities. Even part-time dedicated technical support would free up significant amounts of faculty time for other activities (recruitment, outreach, seeking external funding, mentoring students). 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.

D. **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 include Admissions. We have had some discussions with Admissions about new initiatives for recruiting prospective physics/engineering students, but implementing many of these initiatives seems to be beyond the current resources of Admissions.
E. It would be very helpful to have a mechanism by which we are able to learn about the activities of our alumni and their observations regarding their Wittenberg education in general and the physics component specifically. We have just put out a short alumni newsletter with the help of Bill Dollhopf, who has a reduced teaching load due to retirement phaseout, and hope to get 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 student focus groups every year or two. As time and staffing permits, we want to add more in-depth analysis of the Junior Comprehensive and the evaluations of senior thesis presentations (the basic data exists, but time to analyze in depth is limited). We also want to improve our formal data collection and analysis of student involvement in areas such as research participation, involvement in SPS, etc. Finally, it’s been several assessment cycles since we’ve globally examined our learning goals and assessment methods, and this is an opportune time to do so with new faculty in the department and a university-wide emphasis on curriculum and general education assessment.