Department of Physics
Illinois State University

STUDENT LEARNING OBJECTIVES

(updated 5/02)

B.S. in Physics, B.S. in Computational Physics, B.S. in Physics Teacher Education

The discipline of physics seeks to determine, verify, and apply the basic laws governing matter and energy in order to benefit society. Today, increasingly important new sub-fields of physics are emerging at the boundaries between physics and other disciplines. The rapid development of computer-based technologies is accelerating this trend toward interdisciplinary science. Contemporary physicists apply their skills to areas such as biological physics, chemical physics, computational physics, computer science, medical physics, and space sciences, and, indeed, open entire new technological fields with broad impact such as laser technology. Given this breadth, which cannot be covered in an undergraduate program, a contemporary physics education should focus on the theories and tools which provide a common underlying structure supporting all of these myriad applications, with selected, relevant examples. The Illinois State University program is characterized by an innovative and flexible curriculum that emphasizes fundamental principles and broadly applicable problem-solving skills. It is designed to educate versatile students who can enter these interdisciplinary fields or pursue post-graduate studies.

Learning Goals

The physics department seeks to provide students with the following:

1. A foundation of knowledge in classical and quantum physics.
2. The modeling, computational, experimental, and mathematical skills to solve scientific and technological problems and to provide technical expertise on complex societal issues.
3. Experience in independent learning.
4. Skills in communicating technical knowledge.

These broad goals are shared by all three of the department's degree sequences: *Physics (including Engineering Physics), Computer Physics, and Physics Teacher Education.* This document articulates specific learning objectives and expected student outcomes consistent with these goals.

Learning Objectives shared by all physics degree programs

Learning objectives, listed below, are keyed to goals of the same number. Common objectives typically cover introductory and intermediate coursework. Specific expected outcomes are in italics. In all of the physics department's degree programs, students will (and be able to):

1. Acquire a basic understanding of the laws of physics and their applications;

- Newton's law of motion; Energy conservation

- set up and solve a variety of given motion and energy problems

- Maxwell's theory of electricity and magnetism; geometrical and physical optics

- set up and solve a variety of given problems with static fields and elementary problems with waves and optics

- Quantum physics of microscopic systems; elementary atomic physics.

- set up and solve given problems with quantum potential wells, harmonic oscillator; describe quantum numbers and electron states in atoms.

2. Become proficient with tools used to solve physics and engineering problems:

- math: calculus, vector analysis, elementary differential equations

- use these mathematical methods in the solution of physics problems

- computer: basic scientific programming and graphics

- write simple computer programs to solve physics problems and analyze the results graphically

- experiment: basic laboratory measurement techniques, uncertainty analysis

- use measurement techniques to measure a variety of physical quantities with estimated uncertainties and analyze the results

- modeling: judicious simplification of real world problems into physical models

- understand how physicist build a physics model system: take a realistic physical system and simplify it down to its essential physical properties

3. Begin experience independent learning, such as

- exploratory problems and lab exercises

    - take a set of measurements, observations, equations, etc. describing a physical system and draw valid conclusions

- out-of-class research and teaching

- participate in a research project under the direction of a faculty member and/or teach an elementary lab section

4. Communicate effectively in all classroom situations

- lab and other reports

    - write an organized and clear report, understandable by student peers

- written problem solutions

- explain assumptions and logic steps in the solution of a physics problem

- in-class verbal communication

- answer questions clearly and participate in discussions

Additional Learning Objectives of the Physics Sequence

In addition to those listed above, students in the Physics sequence will (and be able to)

1. Acquire a deeper understanding of the laws of physics and their applications

- set up and solve a variety of advanced problems in these sub-fields

- Lagrangian mechanics; Energy conservation
- Maxwell's theory of electromagnetic waves
- Quantum physics of microscopic systems; atomic physics
- Thermodynamics and statistical physics
- Symmetry and conservation laws

2.Become proficient with tools used to solve physics and engineering problems:

- math: ordinary and partial differential equations, Fourier analysis

- apply these advanced methods to the solution of physics problems

- computer: basic simulation of physical systems, scientific visualization

- write a program to simulate a physical system and analyze the results with scientific visualization techniques

- experiment: advanced laboratory measurement techniques, statistical analysis

- use these techniques to measure a variety of physical quantities, with estimated uncertainties, and analyze the results using statistical data analysis

- modeling: judicious simplification of real world problems into physical models

- build a physics model system: take a realistic physical system and simplify it down to its essential physical properties

3. Experience independent learning, such as

- open ended laboratory experiments

- Design new laboratory investigations or determine by doing how to make measurements of an existing experiment

- out-of-class research projects and teaching

- participate in a research project under the direction of a faculty member and/or teach an elementary lab section

4. Communicate effectively in all classroom situations

- full lab and computational project reports

- write a complete, self-contained report, understandable by student peers

- presentations of scientific results

- present results of a research project or lab exercise to peers and/or faculty

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Additional Learning Objective of the Engineering Physics Program

In additional to those listed above, students in the Engineering Physics program will (and be able to)

1. Learn how to apply the laws of physics to their chosen engineering discipline:

- use modeling skills and physical laws to solve engineering problems

2. Become proficient with the tools used to solve physics and engineering problems

   - use the tools appropriate to the chosen engineering discipline, for example:

     - math: differential equations, Fourier analysis
     - computer: CAD and engineering design systems
     - experiment: engineering measurement techniques and analysis

3. Experience independent learning, such as

   - engineering design

   - design new devices and/or software to deal with practical needs

4. Communicate effectively in all classroom situations

- through written or verbal presentations, communicate engineering process, design, and results to a peer/faculty audience

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Additional Learning Objectives of the Computer Physics Sequence

In addition to those listed above, students in the Physics sequence will (and be able to)

1. Acquire a deeper understanding of the laws of physics in selected sub-fields

- set up and solve a variety of advanced problems in selected sub-fields:

  - Thermodynamics and statistical physics
  - Symmetry and conservation laws
  - Mechanics, electromagnetism, and/or quantum/atomic physics

2. Become proficient with the tools used to solve physics and engineering problems:

- math: ordinary and partial differential equations, Fourier analysis

- apply these advanced methods to the solution of physics problems

  - computer: simulation of physical systems, 3D and stereo scientific visualization

- write programs to simulate nontrivial physical systems, analyzing results with scientific visualization techniques

  - experiment: data analysis

- use the techniques of experimental data analysis which are applicable to simulation data

- modeling: judicious simplification of real world problems into computational physics models

- build a computational physics model system: take a realistic physical system and simplify it down to its essential physical properties to be simulated numerically

3. Experience independent learning, such as

   - exploratory computational projects focused on specific systems
   - apply techniques or computer simulation to explore practical problems
   - research projects and teaching
   - participate in a research project under the direction of a faculty member and/or teach an elementary lab section

4. Communicate effectively in all classroom situations

   - full computational project reports
   - write a complete, self-contained report, understandable by student peers
   - scientific presentations
   - present results of a research project or lab exercise to peers and/or faculty

Additional Learning Objectives of the Physics Teacher Education Program

The PTE sequence is unique in being accredited at the state and national levels and has well-defined learning objectives based on standards of the National Science Teacher Association, and the American Association of Physics Teachers. These are spelled our in detail in the document Knowledge Base for Prospective Secondary-level Physics Teachers, prepared by the director of the program. This document is appended beginning on the next page.

Knowledge Base for Prospective Secondary-level Physics Teachers

Physics Teacher Education Program

Prepared by Carl J. Wenning, Program Director

What prospective physics teachers need to know and be able to do should be grounded in what their students need to know and be able to do in order to live in and contribute to life in a democratic society. National goals and standards reflect these needs, and have strongly converged in recent years on what it is that future teachers of science must know and be able to do. Therefore, a knowledge base has been established for the prospective physics teacher that is grounded in a wide range of science and teacher education standards.

A. Content Knowledge

The prospective teacher should have a broad and current understanding of the major content areas of physics. These areas include: mechanics, electricity and magnetism, heat and thermodynamics, optics, and modern physics. The prospective teacher's understanding will be at a level consistent with appropriate national and state standards, and includes a familiarity of the unifying principles of physics such as conservation of energy, momentum, mass, and charge. This presupposes that the prospective teacher will possess a general understanding of the closely allied fields of mathematics and chemistry, and will be aware of the major findings of the biological sciences.

B. Procedural Knowledge

The prospective teacher must have an accurate understanding of the nature of science, and its underlying assumptions. The prospective teacher should see scientific knowledge as emergent, and not absolute. Ideally, the prospective teacher will have learned content knowledge though methods of inquiry thereby acquiring closely associate procedural knowledge. The prospective teacher should have had an opportunity to experience the processes of scientific investigation: observing; defining a problem; hypothesizing from a theory base; creating an experiment; identifying and controlling variables; collecting, graphically representing, and interpreting data; conducting an error analysis; drawing conclusions; and communicating results. Knowledge so gained and communicated should help pupils understand that science is a way of knowing, and help them distinguish information that is not so derived.

C. Curricular Knowledge

The prospective teacher must possess a broad understanding of the practices of physics teaching as reflected in the aims, goals, and objectives of both national and state science teaching standards. This includes a working knowledge of long-term and short-term planning required for teaching an inquiry-based program; an ability to align teaching goals, objectives, and assessment with these standards; an ability to provide needs-based rationales for inclusion of material in the curriculum based upon students interests, community values, teacher strengths, and societal needs. The prospective teacher must be able to identify the various curricula that are available for physics teaching.

D. Pedagogical Knowledge

The prospective teacher must understand what constitutes effective teaching, and be able to distinguish true teaching practices from instructing, informing, and training. The prospective teacher should have a demonstrable understanding of:

1. planning and preparation – Prospective teachers must demonstrate an ability to prepare lesson plans for a variety of lesson types, create a unit plan, and deal with the broad implications of year-long curriculum planning. The prospective teacher must know how to integrate lecture-demonstrations, laboratory work, homework, discussion , presentations, assessment, student research projects, and out-of-class activities in a way that maximizes student learning.

2. inquiry practices – Prospective teachers must be able to use inquiry practices effectively to help students construct knowledge, be familiar with concept change and its relationship to constructivism, be able to assist students participate in the procedures whereby knowledge of nature and technology is constructed.

3. cooperative learning – Prospective teachers must demonstrate an ability to utilize any of a number of cooperative learning strategies, and be able to distinguish these strategies from traditional group learning.

4. collaborative learning – Prospective teachers must demonstrate an ability to utilize any of a number of collaborative learning strategies and distinguish these strategies from traditional group learning.

5. problem-based learning – Prospective teachers must demonstrate an ability to utilize problem-based learning as a means to promote problem solving and enhance critical thinking skills, and as a way to integrate diverse elements of the physical and biological sciences.

6. constructivism and concept change – Prospective teachers must demonstrate an understanding of a student's need for construction of knowledge and its relationship to misconceptions derived though casual observations of the world.

7. learning cycles – Prospective teachers must demonstrate an understanding of the relationship between learning cycles and classroom activities, and their effects on individual lessons and the broader curriculum. The complex interrelationship of lecture-demonstrations, laboratory work, homework, discussion, presentations, assessment, and student research projects, and out-of-class activities must be understood.

8. resources – Prospective teachers must demonstrate an ability to select, use, and adapt instructional resources to the needs of the students.

E. Understanding What it Means to be Scientifically Literate

The prospective teacher must have a working definition of what it means for a person to be scientifically literate, and must be so. That is, the prospective teacher will have a well-grounded "knowledge and understanding of scientific concepts and processes required for personal decision making, participating in civic and cultural affairs, and economic productivity" (National Science Education Standards, 1996, p. 22).

F. Understanding Students

The prospective teacher must be aware of the psychological basis for effective science teaching. The prospective teacher must also demonstrate an ability to come to know pupils as individuals, to assess their knowledge and background, and show a willingness to work with parents to serve the best interests of students. This includes dealing effectively with different pupil learning styles, sources of interest, motivation and inspiration, and cultural and emotional differences. This also includes identifying and correcting learning difficulties where possible using personal knowledge and experiences, or through the processes of conferral or referral.

G. Classroom Management Skills

The prospective teacher must demonstrate excellent student management skills by maintaining classroom discipline using a firm, fair, and friendly demeanor. The skilled student manager will effectively manage lessons so that students will perceive time in the classroom as of significant positive value. The atmosphere so maintained should not be rigid and regimented, but should be flexible and conducive to student inquiry.

H. Communication Skills

The prospective teacher must be an excellent and effective communicator, both in imparting instruction, questioning, and receiving and responding to information. The prospective teacher will demonstrate excellence in communication by using proper vocalization (diction, grammar, enunciation, and projection). The prospective teacher will demonstrate effectiveness in communication by presenting information systemically and logically, by questioning students using appropriate means (variety of questions, effective use of wait time, etc.), and by listening effectively and responding appropriately to student answers and comments.

I. Knowledge of the Relationship between Teaching and Learning

The prospective teacher should be aware that teaching is what teachers do, that learning is what pupils do, and that there may be no direct relationship between teaching and learning. The prospective teacher sees the role of teacher as that of a science guide who facilitates learning, and is aware of the major principles of learning.

J. Scientific and Philosophical Dispositions

The prospective teacher should demonstrate scientific dispositions (beliefs, behaviors, attitudes, values) and should be able to engage pupils in activities that help clarify the need for a consistent scientific ethic. The prospective teacher should demonstrate the habits of mind closely associated with the intellectual rigor of scientific inquiry and attitudes and values conducive to science learning. The prospective teacher should understand the assumptions and limitations of scientific knowledge.

K. Social and Technological Context

The prospective teacher must demonstrate an understanding of and an appreciation for the broad applicability of physics to real world situations. Prospective teachers must be able to provide a rationale for including physics in the school curriculum as it relates to any area of life in general, and technology in particular. The rationale must deal with the value of scientific knowledge to their pupils, to society, and to the scientific professions. The prospective teacher must demonstrate an understanding of the relationship between science and technology, and the relationship between scientific values and social values.

L. Learning Environment

The prospective teacher should have an understanding of how to create among pupils a disposition in favor of science, and scientific ways of knowing. The learning environment should be physically and emotionally safe, and one in which questioning is valued as much as knowing, and process is valued as much as product. The prospective teacher should know how to provide stimulating learning environments that develop a community of learners who share time, space, and materials to learn science. The prospective teacher should know the meaning, differences, benefits, and consequences of competitive, cooperative, and individualistic learning atmospheres. The prospective teacher should know the effect of expectations on pupil achievement, and how to exert appropriate classroom control measures.

M. Engaged Learning

The prospective teacher should have an understanding of how to teach in an engaging way that creates and sustains pupil interest in science generally, and in physics in particular. This engagement should sustained pupil participation in learning activities and incorporate inclusive practices. The prospective teacher must ensure equitable participate by all students independent of gender, disability, and cultural differences. The prospective teacher must teach in such a way as to provide for gender differences, physical and mental disabilities, and racial and cultural differences.

N. Student Assessment

The prospective teacher should have an understanding of the goals and procedures of both “regular” and alternative assessment. The prospective teacher should know ho to use a variety of means to assess stated objectives that are fair, valid, and reliable, and consistent with the decisions they are intended to inform. The prospective teacher will see ongoing assessment of pupil learning as a valuable adjunct to teaching. The prospective teacher should be aware of sources, and uses for standardized tests, and be able to accurately interpret results.

O. Self-Assessment and Reflective Practice

The prospective teacher should demonstrate the habit of regular self-assessment -- reflecting objectively upon personal teaching practice with an eye toward improving professional practice and increasing student learning. The prospective teacher will engage in ongoing assessment of personal teaching practice, in cooperation with formative feedback provided through clinical supervision. The prospective teacher should demonstrate the disposition of a life-long learner in all areas of professional life.

P. Technology of Teaching

The prospective teacher should have knowledge of and first-hand experience with the wide range of instructional and scientific technology to be used in the classroom. This includes demonstration and laboratory equipment, computers and their applications, microcomputer – and calculator-based laboratory equipment, and the software associated with accessing the Internet to be used by pupils.

Q. Professional Responsibilities

The prospective teacher should abide by a code of professional ethical conduct. It is incumbent upon the teacher to improve educational practice personally, and at the level of the school and the wider academic community. The prospective teacher should perceive professional organizations and publications as instrumental in professional improvement.