Utah Physics Learning Outcomes

March 28, 2012

Using the competencies developed in the first part of this project, the Physics Team wrote the following Learning Outcomes for Bachelor's degrees in physics:

1. The Nature of Science and Nature of Physics

- Give examples of what constitutes convincing evidence for a scientific explanation; analyze the roles of experiment, interpretation of experimental results, and argument in establishing evidence. Define physical cause and effect; suggest how cause-effect relationships can be inferred from experimental data.
- Explain how experimental evidence can falsify scientific hypotheses and how it can contribute to acceptance of scientific concepts.
- Categorize the variety of approaches to research in physics; analyze the distinctive roles each approach plays in the development of physical explanations.
- Distinguish physics from other sciences by explaining the differences in focus on subject matter, kinds of questions, kinds of explanations, and techniques.
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- Identify main points of scientific ethics and responsibility relating to laboratory practice, work with students and collaborators, co-authorship, publication and public advocacy.
- Explain how science is a community effort and argue both the necessity of scientific cooperation and the advantages and disadvantages of solitary science.
- Identify and relate the major historical threads in the development of physics. Identify major contemporary issues in physics and a range of applications of physics in today's economy.

2. Mathematical Skills, Modeling Skills, and Problem Solving Skills

- Solve correctly algebraic and calculus problems from typical bachelor's degree physics texts.
- Interpret the meaning of the mathematics that occurs in a particular physics context from typical bachelor's degree physics texts:
  - Explain what physics quantities are represented by the algebraic symbols.
  - Explain the physics meaning of vector algebra.
  - Discuss the context for the equations, i.e. assumptions and simplifications, and explain how the equations would change with different assumptions.
- Estimate orders of magnitude of physics quantities; estimate orders of magnitude of solutions to physics problems; explain how to identify quickly whether a problem solution or other physics quantity is of reasonable magnitude.
- Graph related physics quantities in ways that illuminate underlying physical interpretations; interpret graphs from typical bachelor's degree physics texts.
- Build a model for an effect from a typical bachelor's degree physics text; identify the most important physics concepts in the phenomena that must be included in the model.
  - Analyze what one can learn from simple models and what their limitations are.
- Build and work with mathematical models by
  - Casting a story problem from a typical bachelor's degree physics text into a

mathematical model;
    - Identifying the physics concepts in a given mathematical model;
    - Distinguishing problem solving and modeling, identifying differences and relationships.
- Give examples of physics problems with similar mathematics but different physics.
- Organize a problem from a typical bachelor's degree physics text by identifying the relevant physics principles, identifying relevant vs. irrelevant quantities, and making appropriate diagrams.
- Organize quantitative information in a problem from a typical bachelor's degree physics text by clearly stepping through the mathematics of the problem solution.

3. Understanding of Physics Concepts

- Explain the major threads of physics concepts: conservation laws, forces (gravity, e&m), fields, Newton's laws, work and energy, optics, thermal and statistical physics, relativity, quantum mechanics.
- Identify key elements in the functioning of a physical system and relate them to the construction of a model.

4. Laboratory Skills

- Follow practices necessary for safety in using undergraduate research or teaching laboratory equipment. Explain these practices to others, including identifying both potential dangers and ethical issues. Suggest how safety could be improved in a particular undergraduate research or teaching laboratory.
- Carry out error analysis on laboratory data; explain what the errors mean for data interpretation.
- Evaluate the quality of laboratory data; explain the importance of such evaluation.
- Design a laboratory measurement to answer a physics question on the level of typical bachelor's degree physics texts.
- Analyze the connections between what one measures and how one infers the physics interpretation of the measurements.
- Outline ethical laboratory practices and make arguments for their importance. Include ethics of reporting laboratory procedures and results as well as ethical practices in carrying out an experiment and reporting data.
- Apply critical analysis of the generation and collection of data to computer experiments.

5. Scientific Presentation Skills (written, oral, and visual communication)

- Write essays on physics topics and problem explanations in complete, correctly punctuated sentences that are well organized and clearly express careful arguments.
- Explain physics concepts clearly in writing both with and without mathematics.
- Present physics topics clearly to peers and in the more formal setting of local or regional meetings.
- Impart knowledge of physics understandably to less advanced students in a teaching situation.
- Present research results clearly and coherently, identifying significant motivations for the work, describing and interpreting the findings, and explaining the significance of the results.

6. Computational and Information Skills

- Demonstrate the use of any of the scientific software packages associated with the usual bachelor's degree curriculum.
- Create a simple computer program to calculate physical effects.
- Demonstrate the use of a spreadsheet to solve physics problems; demonstrate the use of Maple, MatLab or a similar computer algebra system to solve physics problems.
- Explain the major issues of numerical analysis, such as error estimation, in the context of a problem from a typical bachelor's degree physics text or in the context of a computer program related to such a problem.
- Find information in the physics research or teaching literature on an assigned topic from a typical bachelor's degree physics text.

7. Research Skills

- Apply physics competencies in a research setting by designing an experiment that involves multiple concepts, interpreting experimental results that involve multiple concepts, suggesting an hypothesis for a physical effect and how to test it, or building a mathematical model that gives a coherent interpretation of a physical effect.
- Explain your role and the roles of your advisors and collaborators in a complex research project, such as envisioned in the previous bullet point. Explain how collaborations work in your physics subfield, both in the ideal and in reality.
- Synthesize physics principles and applications to explain an effect observed in the laboratory or in a thought experiment; i.e. make hypotheses about the physical causes of the effect that has been observed, propose tests of the hypotheses, debug both equipment and ideas that do not work, etc.
- Outline ethical research practices and explain why they are important. Include ethics of giving credit to prior related work, of coauthorship, of reporting data, and of retaining or destroying data.