Utah Learning Outcomes for Bachelor's Degrees in Physics

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1. Physics Knowledge

- Demonstrate understanding of how science and physics work in practice by one or more of the following activities:
    - 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.
    - 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.
- Outline and explain major 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.
- Use mathematics correctly to solve physics problems. Demonstrate this understanding by the following activities:
    - 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 multivariable algebra, vector algebra, and calculus.
        - Discuss the context for the equations, i.e. assumptions and simplifications, and explain how the equations would change with different assumptions.
    - Use dimensional analysis to verify physical meaning and check results.
    - 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.

    - 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.
- Build and work with mathematical models by
    - Distinguishing problem solving and modeling, identifying differences and relationships.
    - Modeling 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;
    - Analyzing what one can learn from simple models and what their limitations are;
    - 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;

<u>2. Laboratory & Computer Skills</u>

- Demonstrate understanding of the role of computation in physics and appropriate computer skills by the following activities:
    - Create a simple computer program to calculate physical effects.
    - Demonstrate the use of any of the scientific software packages associated with the usual bachelor's degree curriculum, including the use of a spreadsheet to solve physics problems and the use of computer algebra tools similar to Matlab, Maple or other standard 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.
- Evaluate the quality of laboratory data; explain the importance of such evaluation. For example,
    - carry out error analysis on laboratory data; explain what the errors mean for data interpretation.
    - 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.
    - apply critical analysis of the generation and collection of data to computer experiments.
- 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.
- 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. Evaluate safety practices in a particular

undergraduate lab, and if possible, suggest how safety could be improved..

3. Research & Communication

Physics is a research discipline that requires the ability both to carry out meaningful research and to communicate the results. Knowledge and skills acquired in courses typically culminate in a capstone project or senior thesis involving both research skills and communication of results depending on broad understanding of physics concepts.

- Demonstrate physics research skills and understanding by one or more of the following activities:
  - 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.
  - Find information in the physics research or teaching literature on an assigned topic from a typical bachelor's degree physics text.
- Demonstrate the ability to communicate about science by one or more of the following activities:
  - 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.
- 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.