Pennsylvania State Standards in Physics Education

According to academic standards set forth by the Pennsylvania Department of Education, in the physics sciences, chemistry and physics students receive an education that covers the following areas. (See table below).

3.4. Physical Science, Chemistry and Physics	Physics and chemistry involve the study of objects and their properties. Students examine changes to materials during mixing, freezing, heating and dissolving and then learn how to observe and measure results. In chemistry students study the relationship between matter, atomic structure and its activity. Laboratory investigations of the properties of substances and their changes through a range of chemical interactions provide a basis for students to understand atomic theory and a variety of reaction types and their applications in business, agriculture and medicine. Physics deepens the understanding of the structure and properties of materials and includes atoms, waves, light, electricity, magnetism and the role of energy, forces and motion.

Students must "know" what science is. According to the PA DOE,

> "Knowledge of what science is incorporates carefully developed and integrated components:
>
> • **Nature of science**—the ways in which scientists search for answers to questions and explanations of observations about the natural world; includes process knowledge of observing, classifying, inferring, predicting, measuring, hypothesizing, experimenting and interpreting data
>
> • **Unifying themes of science**—concepts, generalizations and principles that result from and lead to inquiry
>
> • **Knowledge**—facts, principles, theories and laws verifiable through scientific inquiry by the world community of scientists; includes physics, chemistry, earth science and biological sciences
>
> • **Inquiry**—an intellectual process of logic that includes verification of answers to questions about and explanations for natural objects, events and phenomena
>
> • **Process skills**—Recognition by students how knowledge is acquired and applied in science by observing, classifying, inferring, predicting, measuring, computing, estimating, communicating, using space/time relationships, defining operationally, formulating hypotheses, testing and experimenting, designing controlled experiments, recognizing variables, manipulating variables, interpreting data, formulating models, designing models and producing solutions.
>
> • **Problem solving**—application of concepts to problems of human adaptation to the environment that often leads to recognition of new problems; has social implications and

leads to personal decision-making and action; a process which forms the link for interactions between scientific and technological results or findings; involves operational definitions, recognizing variables, formulating models and asking questions

• **Scientific thinking**—the disposition to suspend judgment, not make decisions and not take action until results, explanations or answers have been tested and verified with information."

Specifically, the PA State Standards state:

3.4. Physical Science, Chemistry and Physics			
3.4.10. GRADE 10		**3.4.12. GRADE 12**	
Pennsylvania's public schools shall teach, challenge and support every student to realize his or her maximum potential and to acquire the knowledge and skills needed to. . .			
A.	Explain concepts about the structure and properties of matter. • Know that atoms are composed of even smaller sub-atomic structures whose properties are measurable. • Explain the repeating pattern of chemical properties by using the repeating patterns of atomic structure within the periodic table. • Predict the behavior of gases through the use of Boyle's, Charles' or the ideal gas law, in everyday situations. • Describe phases of matter according to the Kinetic Molecular Theory. • Explain the formation of compounds and their resulting properties using bonding theories (ionic and covalent).	A.	Apply concepts about the structure and properties of matter. • Apply rules of systematic nomenclature and formula writing to chemical substances. • Classify and describe, in equation form, types of chemical and nuclear reactions. • Explain how radioactive isotopes that are subject to decay can be used to estimate the age of materials. • Explain how the forces that bind solids, liquids and gases affect their properties. • Characterize and identify important classes of compounds (e.g., acids, bases, salts).

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	• Recognize formulas for simple inorganic compounds. • Describe various types of chemical reactions by applying the laws of conservation of mass and energy. • Apply knowledge of mixtures to appropriate separation techniques. • Understand that carbon can form several types of compounds.		• Apply the conservation of energy concept to fields as diverse as mechanics, nuclear particles and studies of the origin of the universe. • Apply the predictability of nuclear decay to estimate the age of materials that contain radioactive isotopes. • Quantify the properties of matter (e.g., density, solubility coefficients) by applying mathematical formulas.

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<tr><th colspan="4">3.4. Physical Science, Chemistry and Physics</th></tr>
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<tr><td colspan="4">Pennsylvania’s public schools shall teach, challenge and support every student to realize his or her maximum potential and to acquire the knowledge and skills needed to. . .</td></tr>
<tr><td>B.</td><td>Analyze energy sources and transfers of heat.
• Determine the efficiency of chemical systems by applying mathematical formulas.
• Use knowledge of chemical reactions to generate an electrical current.
• Evaluate energy changes in chemical reactions.
• Use knowledge of conservation of energy and momentum to explain common phenomena (e.g., refrigeration system, rocket propulsion).
• Explain resistance, current and electro-motive force (Ohm’s Law).</td><td>B.</td><td>Apply and analyze energy sources and conversions and their relationship to heat and temperature.
• Determine the heat involved in illustrative chemical reactions.
• Evaluate mathematical formulas that calculate the efficiency of specific chemical and mechanical systems.
• Use knowledge of oxidation and reduction to balance complex reactions.
• Apply appropriate thermodynamic concepts (e.g., conservation, entropy) to solve problems relating to energy and heat.</td></tr>
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<tr><td>C.</td><td>Distinguish among the principles of force and motion.
• Identify the relationship of electricity and magnetism as two aspects of a single electromagnetic force.
• Identify elements of simple machines in compound machines.
• Explain fluid power systems through the design and construction of appropriate models.
• Describe sound effects (e.g., Doppler effect, amplitude, frequency, reflection, refraction, absorption, sonar, seismic).
• Describe light effects (e.g., Doppler effect, dispersion, absorption, emission spectra, polarization, interference).
• Describe and measure the motion of sound, light and other objects.</td><td>C.</td><td>Apply the principles of motion and force.
• Evaluate wave properties of frequency, wavelength and speed as applied to sound and light through different media.
• Propose and produce modifications to specific mechanical power systems that will improve their efficiency.
• Analyze the principles of translational motion, velocity and acceleration as they relate to free fall and projectile motion.
• Analyze the principles of rotational motion to solve problems relating to angular momentum, and torque.
• Interpret a model that illustrates circular motion and acceleration.</td></tr>
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3.4. Physical Science, Chemistry and Physics			
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Pennsylvania's public schools shall teach, challenge and support every student to realize his or her maximum potential and to acquire the knowledge and skills needed to. . .			
	• Know Newton's laws of motion (including inertia, action and reaction) and gravity and apply them to solve problems related to forces and mass. • Determine the efficiency of mechanical systems by applying mathematical formulas.		• Describe inertia, motion, equilibrium, and action/reaction concepts through words, models and mathematical symbols.

3.4. Physical Science, Chemistry and Physics			
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D.	Explain essential ideas about the composition and structure of the universe. • Compare the basic structures of the universe (e.g., galaxy types, nova, black holes, neutron stars). • Describe the structure and life cycle of star, using the Hertzsprung-Russell diagram. • Describe the nuclear processes involved in energy production in a star. • Explain the ''red-shift'' and Hubble's use of it to determine stellar distance and movement. • Compare absolute versus apparent star magnitude and their relation to stellar distance. • Explain the impact of the Copernican and Newtonian thinking on man's view of the universe.	D.	Analyze the essential ideas about the composition and structure of the universe. • Analyze the Big Bang Theory's use of gravitation and nuclear reaction to explain a possible origin of the universe. • Compare the use of visual, radio and x-ray telescopes to collect data regarding the structure and evolution of the universe. • Correlate the use of the special theory of relativity and the life of a star.

3.4. Physical Science, Chemistry and Physics	
3.4.10. GRADE 10	
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	• Identify and analyze the findings of several space instruments in regard to the extent and composition of the solar system and universe.
Refer to Technology Standard Category 3.6 for applied uses of these concepts and principles.	

In the above sections, I have highlighted many of the standards and concepts covered in my introductory honors physics course. After completing physics, students will have a good idea of what science is because students are able to daily take on the identity of a physicist in my classroom (PA Standard: Nature of science). At the beginning of each unit, an example lab is conducted in which students make observations and predictions about future events (Nature of science, Inquiry, Knowledge). They discuss the best methods for proving their hypotheses (Problem solving, Unifying themes of science). As a student in my class, one learns to design and run his or her own experiment (Inquiry, Process skills, Problem solving, Scientific thinking). He or she learns to use technology and more classical methods to gather and present data to peers and supervisors (Nature of science, Knowledge, Process Skill). Furthermore, homework problems help students to behave like physicists. Students collaboratively solve problems and routinely present and defend their answers in front of the class (Unifying themes of science, Knowledge, Inquiry, Process skill, Problem Solving, Scientific thinking).

In terms of specific content standards, my introductory physics course covers many requirements for tenth and twelfth graders in the state of Pennsylvania. Since this is an introductory physics course, it covers basic mechanics, energy and some electricity and magnetism. The first part of physics begins with Newton's Laws of motion. As in all units, students build up the laws through experiments and solidify the ideas through homework and class presentations. Students study the relationship between mass, position, velocity and acceleration in the context of everyday situations. When studying energy, students learn the basic concept of conservation of energy. They do this by using energy bar graphs, remembering that there must be as many "units" of energy at the start of the system as at the end since no energy may be created or destroyed, just transferred. They attribute "lost" energy to dissipated energy in the form of heat. Besides considering this conceptually, students do homework and test problems that calculate the amount of energy lost/gained through these processes. After the energy unit, students study momentum where they are able to apply their knowledge of energy and basic mechanics to study the relationship between force, mass, velocity and momentum. Again, students learn to evaluate systems on a theoretical or conceptual level as well as use mathematical models to compute values. They then apply these concepts to real life situations such as a car crash. The final units involve projectiles, circular motion and if time permits, electricity and magnetism and light. Projectile motion is analyzed by breaking down the motion into the x and y directions so that students can apply basic mechanics concepts of velocity, acceleration, momentum and energy. Next, students study the basics of centripetal force and tangential acceleration and their relationship to mass, velocity and radius of the circle. Students then apply these concepts in a practical manner to banked curves on roads and roller coasters. As evidenced by this description, many state standards are incorporated into my introductory physics course, thus aiding students to graduate.