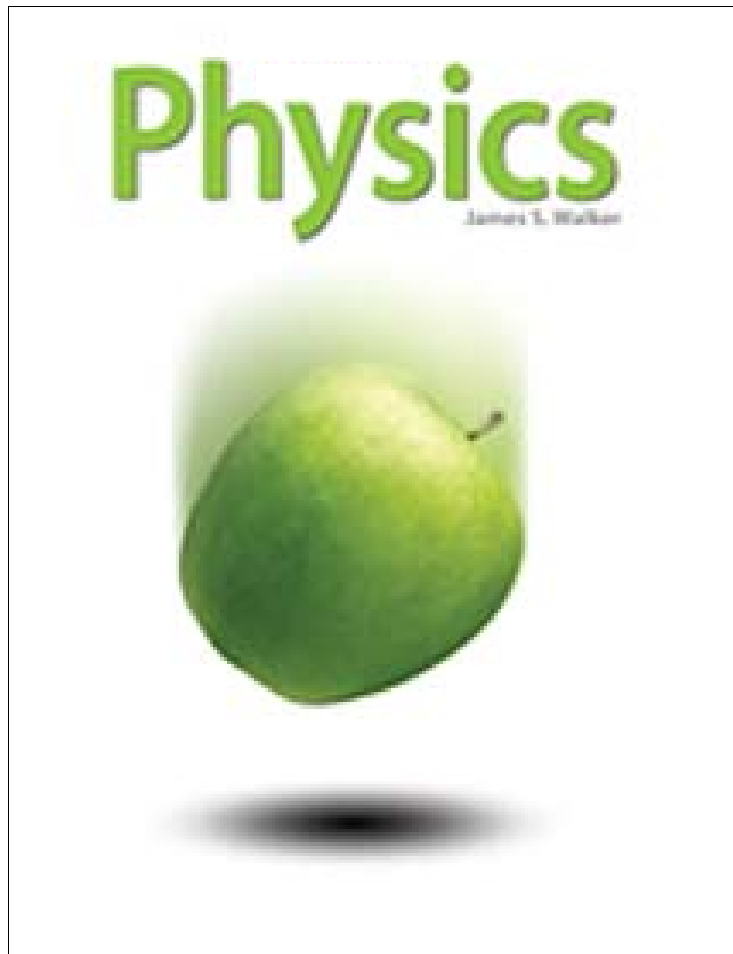


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Physics, High School**

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INTRODUCTION

This document demonstrates how *Pearson Physics, ©2014* meets the Virginia Standards of Learning Curriculum Framework for Physics. Correlation page references are to the Student and Teacher’s Editions.

Pearson Physics offers a new path to mastery— a “concepts first” approach that supports a superior, step-by-step problem solving process.

Pearson Physics is the only high school program that blends conceptual development and quantitative problem solving. The conversational and engaging writing style, numerous and varied examples, annotated art program, and dual emphasis on concepts and math— together with MasteringPhysics®— deliver a superior program.

Pearson Physics Key Features:

Four distinct example types—and their related Practice Problems-build problem-solving skills for both math-based and conceptual-based problems.

- **Conceptual Examples** reinforce basic concepts and make connections to numerical calculations
 - **Quick Examples** present short, simple calculations to aid in understanding a new equation
 - **Active Examples** bridge the gap between examples and homework problems
 - **Guided Examples** use detailed strategies and solutions to develop problem-solving skills and deepen student understanding of concepts
- ✓ The chapter-opening Big Idea statement outlines the chapter’s overarching theme.
 - ✓ The chapter-opening Inquiry Lab provides a simple exploratory activity that stimulates interest and provides a glimpse of the chapter concepts.
 - ✓ The end-of-chapter Physics Lab provides an in-depth, full-page traditional lab activity that applies the concepts learned.

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PHYSICS	
PH.1 The student will plan and conduct investigations using experimental design and product design processes. Key concepts include	
a) the components of a system are defined;	This standard is addressed throughout the text. See, for example: SE/TE: 36, 64, 103, 151, 178, 218, 229, 298, 307, 334, 385, 415, 444, 555, 565, 666, 675, 696, 808, 817, 874, 904, 969-970
b) instruments are selected and used to extend observations and measurements;	This standard is addressed throughout the text. See, for example: SE/TE: 36, 64, 103, 142, 178, 258, 298, 334, 376, 408, 444, 484, 521, 627, 668, 696, 736, 773, 842
c) information is recorded and presented in an organized format;	This standard is addressed throughout the text. See, for example: SE/TE: 36, 64, 103, 142, 178, 218, 258, 298, 334, 376, 408, 444, 484, 521, 588, 627, 666, 696, 736, 773, 808, 842, 874, 804, 842
d) the limitations of the experimental apparatus and design are recognized;	SE/TE: 36, 142, 218, 258, 376, 408, 521, 588
e) the limitations of measured quantities are recognized through the appropriate use of significant figures or error ranges;	SE/TE: 36, 142, 178, 408, 521, 696, 773
f) models and simulations are used to visualize and explain phenomena, to make predictions from hypotheses, and to interpret data; and	This standard is addressed throughout the text. See, for example: SE/TE: 43, 113, 151, 267, 307, 385, 453, 597, 637, 705, 745, 783, 883, 942
g) appropriate technology, including computers, graphing calculators, and probeware, is used for gathering and analyzing data and communicating results.	SE/TE: 103, 444, 627, 666, 696, 736, 773, 842, 874

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Essential Understandings	
The concepts developed in this standard include the following:	
<ul style="list-style-type: none"> Appropriate instruments are used to measure position, time, mass, force, volume, temperature, motion, fields, electric current, and potential. 	SE/TE: 64, 73, 103, 142, 151, 178, 258, 298, 334, 444, 696, 736, 773, 842
<ul style="list-style-type: none"> No measurement is complete without a statement about its uncertainty. 	SE/TE: 36, 218, 258, 376, 588, 696
<ul style="list-style-type: none"> Experimental records, including experimental diagrams, data, and procedures, are kept concurrently with experimentation. 	This standard is addressed throughout the text. See, for example: SE/TE: 36, 64, 73, 103, 142, 178, 218, 258, 298, 334, 376, 408, 444, 484, 521, 588, 627, 666, 696, 736, 773, 874, 969-970
<ul style="list-style-type: none"> Tables, spreadsheets, and graphs are used to interpret, organize, and clarify experimental observations, possible explanations, and models for phenomena being observed. 	This standard is addressed throughout the text. See, for example: SE/TE: 64, 73, 103, 142, 178, 218, 258, 298, 334, 376, 408, 444, 484, 521, 588, 627, 666, 696, 773, 874, 969-970
<ul style="list-style-type: none"> Accuracy is the difference between the accepted value and the measured value. 	SE/TE: 24-25, 142, 408, 521, 773
<ul style="list-style-type: none"> Precision is the spread of repeated measurements. 	SE/TE: 24-25, 142, 218, 258, 666
<ul style="list-style-type: none"> Results of calculations or analyses of data are reported in appropriate numbers of significant digits. 	This standard is addressed throughout the text. See, for example: SE/TE: 25-26, 64, 103, 142, 178, 218, 258, 298, 376, 408, 444, 484, 521, 588, 627, 666, 696, 773, 874, 969-970
<ul style="list-style-type: none"> Data are organized into tables and graphed when involving dependent and independent variables. 	SE/TE: 64, 103, 178, 334, 444, 696, 773, 874, 942, 969-970
Essential Knowledge and Skills	
In order to meet this standard, it is expected that students will	
<ul style="list-style-type: none"> measure and record position, time, mass, force, volume, temperature, motion, fields, and electric current and potential, using appropriate technology. 	SE/TE: 64, 73, 103, 142, 151, 178, 258, 298, 334, 444, 696, 736, 773, 842

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<ul style="list-style-type: none"> determine accuracy of measurement by comparing the experimental averages and the theoretical value. 	SE/TE: 142, 258, 376, 408, 521, 588, 773
<ul style="list-style-type: none"> determine precision of measurement using range or standard deviation. 	Opportunity to address this standard can be found on the following pages: SE/TE: 142, 258, 408, 521, 773
<ul style="list-style-type: none"> follow safe practices in all laboratory procedures. 	This standard is addressed throughout the text. See, for example: SE/TE: 64, 103, 142, 178, 218, 258, 298, 334, 376, 408, 444, 484, 521, 555, 588, 627, 666, 696, 773, 874, 969-970, R72-R73
<ul style="list-style-type: none"> use simulations to model physical phenomena. 	SE/TE: 942
<ul style="list-style-type: none"> draw conclusions and provide reasoning using supporting data. 	This standard is addressed throughout the text. See, for example: SE/TE: 64, 103, 142, 178, 218, 258, 298, 334, 376, 408, 444, 484, 521, 555, 588, 627, 666, 696, 773, 808, 842, 874, 969-970
PH.2 The student will investigate and understand how to analyze and interpret data. Key concepts include	
a) a description of a physical problem is translated into a mathematical statement in order to find a solution;	This standard is addressed throughout the text. See, for example: SE/TE: 23, 64, 103, 142, 178, 218, 376, 408, 484, 521, 588, 666, 773, 969
b) relationships between physical quantities are determined using the shape of a curve passing through experimentally obtained data;	SE/TE: 31-32, 103, 218, 334, 696, 736, 942
c) the slope of a linear relationship is calculated and includes appropriate units;	SE/TE: 178, 444, 773, 874, R13-R14
d) interpolated, extrapolated, and analyzed trends are used to make predictions; and	SE/TE: 64, 178, 334, 376, 444, 484, 942
e) situations with vector quantities are analyzed utilizing trigonometric or graphical methods.	SE/TE: 32, 258, 298, R23

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Essential Understandings	
The concepts developed in this standard include the following:	
<ul style="list-style-type: none"> Mathematics is a tool used to model and describe phenomena. 	This standard is addressed throughout the text. See, for example: SE/TE: 23, 64, 103, 178, 218, 258, 298, 334, 408, 444, 484, 521, 588, 627, 666, 696, 773, 874, 969
<ul style="list-style-type: none"> Graphing and dimensional analysis are used to reveal relationships and other important features of data. 	SE/TE: 31-32, 64, 103, 178, 218, 334, 444, 696, 736, 773, 847, 942
<ul style="list-style-type: none"> Predictions are made from trends based on the data. 	SE/TE: 64, 178, 334, 376, 484
<ul style="list-style-type: none"> The shape of the curve fit to experimentally obtained data is used to determine the relationship of the plotted quantities. 	SE/TE: 31-32, 64, 103, 218, 384, 696, 736, 942
<ul style="list-style-type: none"> All experimental data do not follow a linear relationship. 	SE/TE: 31-32, 103, 334, 696, 736, 942, R15
<ul style="list-style-type: none"> The area under the curve of experimentally obtained data is used to determine related physical quantities. 	Opportunity to address this standard can be found on the following pages: SE/TE: 86, 103, 444, 773, 874, 942
<ul style="list-style-type: none"> Not all quantities add arithmetically. Some must be combined using trigonometry. These quantities are known as vectors. 	SE/TE: 121-125
<ul style="list-style-type: none"> Physical phenomena or events can often be described in mathematical terms (as an equation or inequality). 	SE/TE: 64, 103, 178, 218, 376, 408, 484, 521, 588, 666, 773, 969-970
Essential Knowledge and Skills	
In order to meet this standard, it is expected that students will	
<ul style="list-style-type: none"> recognize linear and nonlinear relationships from graphed data. 	SE/TE: 64, 178, 218, 334, 444, 696, 736, 773, 874, 942
<ul style="list-style-type: none"> where appropriate, draw a straight line through a set of experimental data points and determine the slope and/or area under the curve. 	SE/TE: 64, 178, 444, 773, 874

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<ul style="list-style-type: none"> use dimensional analysis to verify appropriate units. 	This standard is addressed throughout the text. See, for example: SE/TE: 20-22, 64, 103, 142, 178, 218, 258, 298, 334, 376, 408, 444, 484, 521, 588, 666, 696, 773, 969-970
<ul style="list-style-type: none"> combine vectors into resultants utilizing trigonometric or graphical methods. 	SE/TE: 125, 128-129
<ul style="list-style-type: none"> resolve vectors into components utilizing trigonometric or graphical methods. 	SE/TE: 117, 119
PH.3 The student will investigate and demonstrate an understanding of the nature of science, scientific reasoning, and logic. Key concepts include	
a) analysis of scientific sources to develop and refine research hypotheses;	SE/TE: 8-9, 11
b) analysis of how science explains and predicts relationships;	SE/TE: 9, 97, 152-155, 158, 308, 317-318, 319, 327, 328-330, 437-438, 440-441, 462, 507, 530-531, 534, 817-818, 823-824, 883, 885, 895-896, 950-951
c) evaluation of evidence for scientific theories;	SE/TE: 9, 97, 103 (#4), 308-309, 317, 328-330, 534, 817-818, 823, 937-938, 950-951
d) examination of how new discoveries result in modification of existing theories or establishment of new paradigms; and	SE/TE: 9, 160, 317, 328-330, 530-531, 534, 888, 895-896, 937-938, 951
e) construction and defense of a scientific viewpoint.	SE/TE: 9, 11, 103 (#4), 309
Essential Understandings	
The concepts developed in this standard include the following:	
<ul style="list-style-type: none"> The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world. The nature of science includes the following concepts 	
a) the natural world is understandable;	SE/TE: 6, 97, 130, 160, 307, 312, 325-326, 327, 328-329, 438, 469, 823, 902, 950
b) science is based on evidence - both observational and experimental;	SE/TE: 7, 97, 130, 317, 328-330, 462, 507, 530, 817-818, 883-885, 950-951

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c) science is a blend of logic and innovation;	SE/TE: 6-7, 97, 317, 328-330, 530, 883-885, 950
d) scientific ideas are durable yet subject to change as new data are collected;	SE/TE: 9, 530-531, 884-885, 895
e) science is a complex social endeavor; and	SE/TE: 10-11, 318, 327-330, 530-531, 883-885, 951
f) scientists try to remain objective and engage in peer review to help avoid bias.	SE/TE: 10-11
<ul style="list-style-type: none"> • Experimentation may support a hypothesis, falsify it, or lead to new discoveries. 	SE/TE: 7-9, 530
<ul style="list-style-type: none"> • The hypothesis may be modified based upon data and analysis. 	SE/TE: 7-8, 531
<ul style="list-style-type: none"> • A careful study of prior reported research is a basis for the formation of a research hypothesis. 	SE/TE: 7
<ul style="list-style-type: none"> • A theory is a comprehensive and effective explanation, which is well supported by experimentation and observation, of a set of phenomena. 	SE/TE: 9, 534, 950-951
<ul style="list-style-type: none"> • Science is a human endeavor relying on human qualities, such as reasoning, insight, energy, skill, and creativity as well as intellectual honesty, tolerance of ambiguity, skepticism, and openness to new ideas. 	SE/TE: 3, 6, 10-11, 97, 317, 327-330, 530-531, 883-885, 951
Essential Knowledge and Skills	
In order to meet this standard, it is expected that students will	
<ul style="list-style-type: none"> • identify and explain the interaction between human nature and the scientific process. 	SE/TE: 3-7, 10-11
<ul style="list-style-type: none"> • identify examples of a paradigm shift (e.g., quantum mechanics). 	SE/TE: 160, 897-898

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PH.4 The student will investigate and understand how applications of physics affect the world. Key concepts include	
a) examples from the real world; and	This standard is addressed throughout the text. See, for example: SE/TE: 35, 97-98, 137, 157, 166, 226 (#144, 145), 230, 312, 323, 332, 356, 399, 437-438, 483, 508, 550-552, 601, 610-611, 823, 836-837, 862-863, 870, 902
b) exploration of the roles and contributions of science and technology.	This standard is addressed throughout the text. See, for example: SE/TE: 4-5, 13-14, 35, 102, 130, 141, 217, 246, 314, 333, 375, 407, 465, 483, 506, 512, 520, 542, 550, 554, 573, 587, 620-621, 665, 732, 734, 735, 772, 801, 807, 841, 871-872, 887, 900-901, 903, 934-935, 968
Essential Understandings	
The concepts developed in this standard include the following:	
<ul style="list-style-type: none"> Discoveries in physics, both theoretical and experimental, have resulted in advancements in communication, medicine, engineering, transportation, commerce, exploration, and technology. 	SE/TE: 35, 130, 141, 217, 257, 317-319, 327-329, 331, 407, 520, 552, 653, 660, 754-756, 821, 823-824
<ul style="list-style-type: none"> Journals, books, the Internet, and other sources are used in order to identify key contributors and their contributions to physics as well as their impact on the real world. 	SE/TE: 63, 102, 110 (#133, #134), 449 (#111), 665, 735
Essential Knowledge and Skills	
In order to meet this standard, it is expected that students will	
<ul style="list-style-type: none"> be aware of real-world applications of physics, and the importance of physics in the advancement of various fields, such as medicine, engineering, technology, etc. 	This standard is addressed throughout the text. See, for example: SE/TE: 35, 63, 102, 130, 141, 217, 246, 313, 331, 407, 465, 483, 506, 512, 520, 542, 550, 554, 573, 587, 620-621, 665, 732, 734, 735, 772, 801, 807, 841, 871-872, 887, 900-901, 903, 934-935, 968

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PH.5 The student will investigate and understand the interrelationships among mass, distance, force, and time through mathematical and experimental processes. Key concepts include	
a) linear motion;	SE/TE: 44-45, 46, 47 (#7-9), 58-59, 61, 64, 66 (#52, #58), 69 (#97-99, #111)
b) uniform circular motion;	SE/TE: 307, 320-323, 325, 334, 337-338
c) projectile motion;	SE/TE: 131-133, 134-135, 137, 139-140, 142, 146-147, 148
d) Newton's laws of motion;	SE/TE: 151-152, 153-155, 156-157, 158-159, 160, 162-164, 165, 180-182
e) gravitation;	SE/TE: 203-204, 307-308, 309-311, 312, 313-315, 316-317, 325, 336-337
f) planetary motion; and	SE/TE: 327, 329, 338
g) work, power, and energy.	SE/TE: 189-191, 192-193, 194-196, 197-202, 205, 206, 211-214, 215, 216, 218, 220-222
Essential Understandings	
The concepts developed in this standard include the following:	
• Newton's three laws of motion are the basis for understanding the mechanical universe.	SE/TE: 151-159, 160, 165-169, 170-172, 173-174, 235, 286-287
• Linear motion graphs include	
- displacement (d) vs. time (t)	SE/TE: 31, 92-96
- velocity (v) vs. time (t)	SE/TE: 76-77, 79, 81, 82, 84, 86, 105
- acceleration (a) vs. time (t)	SE/TE: 92-96, 103
• Position, displacement, velocity, and acceleration are vector quantities.	SE/TE: 44, 121-122, 125, 126, 144-145
• Motion is described in terms of position, displacement, time, velocity, and acceleration.	SE/TE: 45-47, 73-79, 80-81, 82-83, 84-85, 87-88, 89, 91 (#37, #41), 92-96, 101, 103

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<ul style="list-style-type: none"> Velocity is the change in displacement divided by the change in time. A straight-line, position-time graph indicates constant velocity. The slope of a displacement-time graph is the velocity. 	SE/TE: 77, 79, 82-83, 84-85, 86, 90, 91, 105 (#75, #76)
<ul style="list-style-type: none"> Forces are interactions that can cause objects to accelerate. When one object exerts a force on a second object, the second exerts a force on the first that is equal in magnitude but opposite in direction. 	SE/TE: 151-153, 154-157, 158-159, 160, 164-165, 180-183
<ul style="list-style-type: none"> An object with no net force acting on it is stationary or moves with constant velocity. 	SE/TE: 152, 155 (#1)
<ul style="list-style-type: none"> Acceleration is the change in velocity divided by the change in time. A straight-line, velocity-time graph indicates constant acceleration. A horizontal-line, velocity-time graph indicates zero acceleration. The slope of a velocity-time graph is the acceleration. 	SE/TE: 76-77, 78-79, 81, 82, 84, 86
<ul style="list-style-type: none"> The acceleration of a body is directly proportional to the net force on it and inversely proportional to its mass. 	SE/TE: 73, 153-155, 156-157
<ul style="list-style-type: none"> In a uniform vertical gravitational field with negligible air resistance, horizontal and vertical components of the motion of a projectile are independent of one another with constant horizontal velocity and constant vertical acceleration. 	SE/TE: 131-133, 134-135, 139-140, 142, 146-147
<ul style="list-style-type: none"> An object moving along a circular path with a constant speed experiences an acceleration directed toward the center of the circle. 	SE/TE: 307 (Inquiry Lab), 320-321
<ul style="list-style-type: none"> The force that causes an object to move in a circular path is directed centripetally, toward the center of the circle. The object's inertia is sometimes falsely characterized as a centrifugal or outward-directed force. 	SE/TE: 320-323
<ul style="list-style-type: none"> Weight is the gravitational force acting on a body. 	SE/TE: 163-165

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<ul style="list-style-type: none"> Newton’s Law of Universal Gravitation can be used to determine the force between objects separated by a known distance, and describes the force that determines the motion of celestial objects. The total force on a body can be represented as a vector sum of constituent forces. 	SE/TE: 308-309, 310-312, 325, 327-328
<ul style="list-style-type: none"> For a constant force acting on an object, the impulse by that force is the product of the force and the time the object experiences the force. The impulse also equals the change in momentum of the object. 	SE/TE: 234-238, 239, 241
<ul style="list-style-type: none"> Work is the mechanical transfer of energy to or from a system and is the product of a force at the point of application and the parallel component of the object’s displacement. The net work on a system equals its change in velocity. 	SE/TE: 189-190, 191, 218
<ul style="list-style-type: none"> Forces within a system transform energy from one form to another with no change in the system’s total energy. 	SE/TE: 189 (Inquiry Lab), 197-198, 199-201, 202-203, 204, 206-207
<ul style="list-style-type: none"> For a constant force acting on an object, the work done by that force is the product of the force and the distance the object moves in the direction of the force. The net work performed on an object equals its change in kinetic energy. 	SE/TE: 199-201
<ul style="list-style-type: none"> Power is the rate of doing work. 	SE/TE: 211-214, 215, 216
Essential Knowledge and Skills	
In order to meet this standard, it is expected that students will	
<ul style="list-style-type: none"> qualitatively explain motion in terms of Newton’s Laws. 	SE/TE: 151-155, 155 (#1), 156-159, 160 (#9-14), 180 (#43-52), 186 (#123)
<ul style="list-style-type: none"> solve problems involving force (F), mass (m), and acceleration (a). 	SE/TE: 155 (#2), 157, 158 (#3-5), 159 (#6-8), 160 (#15-18), 164 (#19-20), 176 (#39-42), 180-183 (#53-89), 186 (#124-126)

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<ul style="list-style-type: none"> construct and analyze displacement (d) vs. time (t), velocity (v) vs. time (t), and acceleration (a) vs. time (t) graphs. 	SE/TE: 56 (#26), 57 (#30, #31, #33, #34), 64 (Chapter Lab), 67-69 (#74-87, #111), 70 (#113, #119-122), 73 (Inquiry Lab), 79 (#7), 81 (#12, #18), 91 (#41), 93 (#42), 96 (#46, #47, 50), 103 (Chapter Lab), 105 (#68, 69, #75-77), 106 (#81), 107 (#93-97), 108 (#122), 109 (#129), 110 (#131, #132, #135, #136)
<ul style="list-style-type: none"> solve problems involving displacement, velocity, acceleration, and time in one and two dimensions (only constant acceleration). 	SE/TE: 47 (#2, #3-9), 52 (#14-17), 53 (#23), 56 (#26), 57 (#32, 34), 59 (#35, #36), 62 (#43-45), 64 (Chapter Lab), 66 (#51-59), 67 (#64, #65), 69 (#92, #93, #97-101, #107-109), 70 (#119-122), 76 (#1-3), 78 (#4-6), 81 (#15-17, #19), 85 (#23-25), 88 (#26-29), 91 (#38-40), 95 (#43-45), 96 (#49, #50), 103 (Chapter Lab), 105 (#70-77), 106 (#84-91), 107 (#98-104), 108 (#120-122), 109 (#123-128), 130 (#31), 145 (#73)
<ul style="list-style-type: none"> resolve vector diagrams involving displacement and velocity into their components along perpendicular axes. 	SE/TE: 114 (#1, #2), 117 (#3-6), 120 (#15, #17), 126 (#19, #22, #23), 128, 129, 144 (#51, #55), 145 (#68)
<ul style="list-style-type: none"> draw vector diagrams of a projectile's motion. Find range, trajectory, height of the projectile, and time of flight (uniform gravitational field, no air resistance). 	Opportunity to address this standard can be found on the following pages: SE/TE: 137, 140 (#49), 142 (Chapter Lab), 147 (#89)
<ul style="list-style-type: none"> distinguish between centripetal and centrifugal force. 	SE/TE: 321-322
<ul style="list-style-type: none"> solve problems related to free-falling objects, including 2-D motion. 	SE/TE: 97-101, 107 (#105-112), 108 (#113-119), 109 (#124), 110 (#134-136)
<ul style="list-style-type: none"> solve problems using Newton's Law of Universal Gravitation. 	SE/TE: 309 (#1, #2), 310-311, 312 (#12-15), 336 (#55-59)
<ul style="list-style-type: none"> solve problems involving multiple forces, using free-body diagrams. 	SE/TE: 161-162, 164 (#20), 169 (#28), 182 (#77), 183 (#93)

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<ul style="list-style-type: none"> • solve problems involving mechanical work, power, and energy. 	SE/TE: 191, 193, 194-196, 196 (#12-15), 199 (#16-18), 200, 201 (#19-20), 201-202, 203 (#21), 204 (#22-24), 205 (#25, 26), 206 (#27-36), 208, 209 (#37-39), 210, 211 (#40-46), 214 (#49-50), 215 (#51), 216 (#52-59), 218 (Chapter Lab), 220-223
<ul style="list-style-type: none"> • describe the forces involved in circular motion. 	SE/TE: 307 (Inquiry Lab), 320-323, 324, 326 (#31-39), 334 (Chapter Lab), 337 (#74-81), 338 (#82-85)
PH.6 The student will investigate and understand that quantities including mass, energy, momentum, and charge are conserved. Key concepts include	
a) kinetic and potential energy;	SE/TE: 197-199, 202-204, 205, 207, 208, 217
b) elastic and inelastic collisions; and	SE/TE: 248—249, 249-252, 252-254, 254-255, 256 (#49-54), 257, 258 (Chapter Lab), 264 (#127-128)
c) mass/energy equivalence.	SE/TE: 914-915, 919-920, 958-959
Essential Understandings	
The concepts developed in this standard include the following:	
<ul style="list-style-type: none"> • Kinetic energy is the energy of motion. Potential energy is the energy due to an object's position or state. 	SE/TE: 197-199, 202-204
<ul style="list-style-type: none"> • Total energy and momentum are conserved. 	SE/TE: 232-233, 242, 244-245, 246-247, 254-255
<ul style="list-style-type: none"> • For elastic collisions, total momentum and total kinetic energy are conserved. For inelastic collisions, total momentum is conserved and some kinetic energy is transformed to other forms of energy. 	SE/TE: 248-252, 253, 254-255, 257, 258 (Chapter Lab)
<ul style="list-style-type: none"> • Electrical charge moves through electrical circuits and is conserved. 	SE/TE: 678-679, 723-724, 748-749
<ul style="list-style-type: none"> • In some systems the conservation of mass and energy must take into account the principle of mass/energy equivalence. 	SE/TE: 914-915, 919-920, 958-959

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Essential Knowledge and Skills	
In order to meet this standard, it is expected that students will	
<ul style="list-style-type: none"> provide and explain examples of how energy can be converted from potential energy to kinetic energy and the reverse. 	SE/TE: 206-208, 209, 217, 222 (#97-99), 718-719, 723, 727 (#28), 901
<ul style="list-style-type: none"> provide and explain examples showing linear momentum is the product of mass and velocity, and is conserved in a closed system. 	SE/TE: 229 (Inquiry Lab), 230, 242-246, 247 (#34-36)
PH.7 The student will investigate and understand that energy can be transferred and transformed to provide usable work. Key concepts include	
a) transfer and storage of energy among systems including mechanical, thermal, gravitational, electromagnetic, chemical, and nuclear systems; and	SE/TE: 189 (Inquiry Lab), 203-205, 206-207, 217, 333, 354-356, 358, 385 (Inquiry Lab), 718, 723, 830-831, 925-928, 929-930
b) efficiency of systems.	SE/TE: 390-392, 401-403
Essential Understandings	
The concepts developed in this standard include the following:	
<ul style="list-style-type: none"> Energy can be transformed from one form to another. 	SE/TE: 206-207, 402
<ul style="list-style-type: none"> Efficiency is the ratio of output work to input work. 	SE/TE: 390 391 (#4-5)
Essential Knowledge and Skills	
In order to meet this standard, it is expected that students will	
<ul style="list-style-type: none"> illustrate that energy can be transformed from one form to another, using examples from everyday life and technology. 	SE/TE: 206-207, 250-251, 389, 408 (Chapter Lab), 831, 862-863, 929-930
<ul style="list-style-type: none"> calculate efficiency by identifying the useful energy in a process. 	SE/TE: 390-392, 401-403, 406 (#38-41), 411 (#70-71, #74, #82)
<ul style="list-style-type: none"> qualitatively identify the various energy transformations in simple demonstrations. 	SE/TE: 189 (Inquiry Lab), 202, 203, 204, 207, 211 (#42-43), 217, 225 (#141-143), 385 (Inquiry Lab), 718-719
PH.8 The student will investigate and understand wave phenomena. Key concepts include	
a) wave characteristics;	SE/TE: 453 (Inquiry Lab), 470-472, 473-475

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b) fundamental wave processes; and	SE/TE: 476-477, 478-479, 484 (Chapter Lab)
c) light and sound in terms of wave models.	SE/TE: 493 (Inquiry Lab), 493-494, 498, 501-503, 505, 507-508, 536-537, 545
Essential Understandings	
The concepts developed in this standard include the following:	
• Mechanical waves transport energy as a traveling disturbance in a medium.	SE/TE: 470, 474
• In a transverse wave, particles of the medium oscillate in a direction perpendicular to the direction the wave travels.	SE/TE: 471
• In a longitudinal wave, particles of the medium oscillate in a direction parallel to the direction the wave travels.	SE/TE: 471
• Wave velocity equals the product of the frequency and the wavelength.	SE/TE: 473-474
• For small angles of oscillation, a pendulum exhibits simple harmonic motion.	SE/TE: 462
• Frequency and period are reciprocals of each other.	SE/TE: 454-455
• Waves are reflected and transmitted when they encounter a change in medium or a boundary.	SE/TE: 474-475
• The overlapping of two or more waves results in constructive or destructive interference.	SE/TE: 476-478, 498
• When source and observer are in relative motion, a shift in frequency occurs (Doppler effect).	SE/TE: 507-508
• Sound is a longitudinal mechanical wave that travels through matter.	SE/TE: 474, 493, 495
• Light is a transverse electromagnetic wave that can travel through matter as well as a vacuum.	SE/TE: 474, 536-537

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<ul style="list-style-type: none"> Reflection is the change of direction of the wave in the original medium. 	SE/TE: 475, 565-569
<ul style="list-style-type: none"> Refraction is the change of direction of the wave at the boundary between two media. 	SE/TE: 597, 599-600, 601-605
<ul style="list-style-type: none"> Diffraction is the spreading of a wave around a barrier or an aperture. 	SE/TE: 654-656
<ul style="list-style-type: none"> The pitch of a note is determined by the frequency of the sound wave. 	SE/TE: 497, 514
<ul style="list-style-type: none"> The color of light is determined by the frequency of the light wave. 	SE/TE: 529 (Inquiry Lab), 537, 541-543
<ul style="list-style-type: none"> As the amplitude of a sound wave increases, the loudness of the sound increases. 	SE/TE: 514
<ul style="list-style-type: none"> As the amplitude of a light wave increases, the intensity of the light increases. 	SE/TE: 536-537
<ul style="list-style-type: none"> Electromagnetic waves can be polarized by reflection or transmission. 	SE/TE: 545-546, 552
<ul style="list-style-type: none"> Polarizing filters allow light oriented in one direction (or component of) to pass through. 	SE/TE: 546-547, 548, 549-551, 555 (Chapter Lab)
Essential Knowledge and Skills	
In order to meet this standard, it is expected that students will	
<ul style="list-style-type: none"> identify examples of and differentiate between transverse and longitudinal waves, using simulations and/or models. 	Opportunity to address this standard can be found on the following pages: SE/TE: 453 (Inquiry Lab), 475 (#39), 484 (Chapter Lab)
<ul style="list-style-type: none"> illustrate period, wavelength, and amplitude on a graphic representation of a wave. 	Opportunity to address this standard can be found on the following pages: SE/TE: 489 (#108), 491 (#1)

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<ul style="list-style-type: none"> • solve problems involving frequency, period, wavelength, and velocity. 	SE/TE: 455 (#1-4), 458 (#6), 459 (#8), 461 (#12, #14, #16-20), 464 (#22-23), 467 (#25-26), 469 (#31), 474 (#36-38), 475 (#42-44), 484 (Chapter Lab), 486 (#60-62), 488 (#87-92), 496 (#6), 501 (#14), 521 (Chapter Lab), 523 (#65, 68), 532 (#3), 534 (#5), 536 (#13), 538 (#14-17), 544 (#24-26), 558 (#57-60, #71-72, #75)
<ul style="list-style-type: none"> • distinguish between superimposed waves that are in-phase and those that are out-of-phase. 	SE/TE: 478
<ul style="list-style-type: none"> • graphically illustrate reflection and refraction of a wave when it encounters a change in medium or a boundary. 	SE/TE: 453 (Inquiry Lab), 569 (#2, #4), 574 (#13, #16), 590 (#37, #45, #47), 600 (#3-5), 603 (#6-8), 605 (#15), 627 (Chapter Lab)
<ul style="list-style-type: none"> • graphically illustrate constructive and destructive interference. 	SE/TE: 477 (#45-46)
<ul style="list-style-type: none"> • identify a standing wave, using a string. 	SE/TE: 478-480, 482 (#54-55), 488 (#99-100)
PH.9 The student will investigate and understand that different frequencies and wavelengths in the electromagnetic spectrum are phenomena ranging from radio waves through visible light to gamma radiation. Key concepts include	
a) the properties, behaviors, and relative size of radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays;	SE/TE: 539-541
b) wave/particle dual nature of light; and	SE/TE: 534, 866-867
c) current applications based on the respective wavelengths.	SE/TE: 539-541
Essential Understandings	
The concepts developed in this standard include the following:	
<ul style="list-style-type: none"> • Frequency, wavelength, and energy vary across the entire electromagnetic spectrum. 	SE/TE: 537-538

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<ul style="list-style-type: none"> The long wavelength, low frequency portion of the electromagnetic spectrum is used for communication (e.g., radio, TV, cellular phone). 	SE/TE: 539
<ul style="list-style-type: none"> Medium wavelengths (infrared) are used for heating and remote control devices. 	SE/TE: 539-540
<ul style="list-style-type: none"> Visible light comprises a relatively narrow portion of the electromagnetic spectrum. 	SE/TE: 540
<ul style="list-style-type: none"> Ultraviolet (UV) wavelengths (shorter than the visible spectrum) are ionizing radiation and can cause damage to humans. UV is responsible for sunburn, and can be used for sterilization and fluorescence. 	SE/TE: 540-541 544 (#19)
<ul style="list-style-type: none"> X-rays and gamma rays are the highest frequency (shortest wavelength) and are used primarily for medical purposes. These wavelengths are also ionizing radiation and can cause damage to humans. 	SE/TE: 541
Essential Knowledge and Skills	
In order to meet this standard, it is expected that students will	
<ul style="list-style-type: none"> describe the change in observed frequency of waves due to the motion of a source or a receiver (the Doppler effect). 	SE/TE: 533, 534 (#4-5), 557 (#47)
<ul style="list-style-type: none"> identify common uses for radio waves, microwaves, X-rays and gamma rays. 	SE/TE: 539-541
PH.10 The student will investigate and understand how to use the field concept to describe the effects of gravitational, electric, and magnetic forces. Key concepts include	
a) inverse square laws (Newton's law of universal gravitation and Coulomb's law); and	SE/TE: 308, 310, 325, 327-328, 683-685, 696 (Chapter Lab)
b) technological applications.	SE/TE: 310-311
Essential Understandings	
The concepts developed in this standard include the following:	
<ul style="list-style-type: none"> The electrostatic force (Coulomb's law) can be either repulsive or attractive, depending on the sign of the charges. 	SE/TE: 683-685

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<ul style="list-style-type: none"> The gravitational force (Newton's Law of Gravitation) is always an attractive force. 	SE/TE: 308, 325-326, 685
<ul style="list-style-type: none"> The force found from Newton's Law of Gravitation and in Coulomb's law is dependent on the inverse square of the distance between two objects. 	SE/TE: 310, 683
<ul style="list-style-type: none"> The interaction of two particles at a distance can be described as a two-step process that occur simultaneously: the creation of a field by one of the particles and the interaction of the field with the second particle. 	SE/TE: 308, 684
<ul style="list-style-type: none"> The force a magnetic field exerts on a moving electrical charge has a direction perpendicular to both the velocity and field directions. Its magnitude is dependent on the velocity of the charge, the magnitude of the charge, and the strength of the magnetic field. 	SE/TE: 796, 797, 799-801, 808 (Chapter Lab)
Essential Knowledge and Skills	
In order to meet this standard, it is expected that students will	
<ul style="list-style-type: none"> describe the attractive or repulsive forces between objects relative to their forces and distance between them (Coulomb's law). 	SE/TE: 683, 685, 689 (#15)
<ul style="list-style-type: none"> describe the attraction of particles (Newton's Law of Universal Gravitation). 	SE/TE: 308, 309 (#1, #2), 310
<ul style="list-style-type: none"> describe the effect of a uniform magnetic field on a moving electrical charge. 	SE/TE: 796, 797-798, 799 (Figure 22.17), 808 (Chapter Lab)
PH.11 The student will investigate and understand how to diagram, construct, and analyze basic electrical circuits and explain the function of various circuit components. Key concepts include	
a) Ohm's law;	SE/TE: 751, 767, 773 (Chapter Lab)
b) series, parallel, and combined circuits;	SE/TE: 757-759, 759-762, 762-763
c) electrical power; and	SE/TE: 765-769

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d) alternating and direct currents.	SE/TE: 748-749, 755, 832, 839, 940, 941
Essential Understandings	
The concepts developed in this standard include the following:	
<ul style="list-style-type: none"> • Current is the rate at which charge moves through a circuit element. 	SE/TE: 745-747
<ul style="list-style-type: none"> • Electric potential difference (voltage) in a circuit provides the energy that drives the current. 	SE/TE: 719-723
<ul style="list-style-type: none"> • Elements in a circuit are positioned relative to other elements either in series or parallel. 	SE/TE: 757-759, 759-760, 761
<ul style="list-style-type: none"> • According to Ohm's law, the resistance of an element equals the voltage across the element divided by the current through the element. 	SE/TE: 750-751, 751 (#5), 775 (#61)
<ul style="list-style-type: none"> • Potential difference (voltage) is the change in electrical potential energy per unit charge across that element. 	SE/TE: 719-720
<ul style="list-style-type: none"> • The dissipated power of a circuit element equals the product of the voltage across that element and the current through that element. 	SE/TE: 766, 767-768, 769 (#35, #36)
<ul style="list-style-type: none"> • In a DC (direct current) circuit, the current flows in one direction, whereas in an AC (alternating current) circuit, the current switches direction several times per second (60Hz in the U.S.). 	SE/TE: 748-749, 832
Essential Knowledge and Skills	
In order to meet this standard, it is expected that students will	
<ul style="list-style-type: none"> • recognize a series and a parallel circuit. 	SE/TE: 758-759, 760, 775 (#69)
<ul style="list-style-type: none"> • apply Ohm's law to a series and a parallel circuit. 	SE/TE: 758-759, 760
<ul style="list-style-type: none"> • assemble simple circuits composed of batteries and resistors in series and in parallel. 	SE/TE: 773 (Chapter Lab), 776 (#74)
<ul style="list-style-type: none"> • solve simple circuits using Ohm's law. 	SE/TE: 759 (#16-18), 762 (#19-21), 765 (#27-31), 776 (#75-86)

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<ul style="list-style-type: none"> calculate the dissipated power of a circuit element. 	SE/TE: 769 (#35), 771 (#45-47), 777 (#99, #102, #104)
<ul style="list-style-type: none"> recognize that DC power is supplied by batteries and that AC power is supplied by electrical wall sockets. 	SE/TE: 748-749, 832
PH.12 The student will investigate and understand that extremely large and extremely small quantities are not necessarily described by the same laws as those studied in Newtonian physics. Key concepts may include	
a) wave/particle duality;	SE/TE: 534, 864-867
b) wave properties of matter;	SE/TE: 895-896
c) matter/energy equivalence;	SE/TE: 914-915, 919-920, 958-959
d) quantum mechanics and uncertainty;	SE/TE: 868-870, 897, 898
e) relativity;	SE/TE: 534, 949-952, 962-964
f) nuclear physics;	SE/TE: 911 (Inquiry Lab), 925-930
g) solid state physics;	SE/TE: 440-442
h) nanotechnology;	This falls outside of the program scope.
i) superconductivity; and	SE/TE: 407, 756 (Cool Physics)
j) radioactivity.	SE/TE: 917-919, 930-935

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Essential Understandings	
The concepts developed in this standard include the following:	
<ul style="list-style-type: none"> For processes that are important on the atomic scale, objects exhibit both wave characteristics (e.g., interference) as well as particle characteristics (e.g., discrete amounts and a fixed definite number of electrons per atom). 	SE/TE: 864-867, 886-887, 888-892, 893-895, 895-896
<ul style="list-style-type: none"> Nuclear physics is the study of the interaction of the protons and neutrons in the atom's nucleus. 	SE/TE: 911-913, 914-916
<ul style="list-style-type: none"> The nuclear force binds protons and neutrons in the nucleus. Fission is the breakup of heavier nuclei to lighter nuclei. Fusion is the combination of lighter nuclei to heavier nuclei. 	SE/TE: 920, 925-928, 929-930
<ul style="list-style-type: none"> Dramatic examples of mass-energy transformation are the fusion of hydrogen in the sun, which provides light and heat for Earth, and the fission process in nuclear reactors that provide electricity. 	SE/TE: 928-929, 930
<ul style="list-style-type: none"> Natural radioactivity is the spontaneous disintegration of unstable nuclei. Alpha, beta, and gamma rays are different emissions associated with radioactive decay. 	SE/TE: 917-919, 920-924
<ul style="list-style-type: none"> The special theory of relativity predicts that energy and matter can be converted into each other. 	SE/TE: 949-951
<ul style="list-style-type: none"> Objects cannot travel faster than the speed of light. 	SE/TE: 529-530, 950-952
<ul style="list-style-type: none"> The atoms and molecules of many substances in the natural world, including most metals and minerals, bind together in regular arrays to form crystals. The structure of these crystals is important in determining the properties of these materials (appearance, hardness, etc.). 	SE/TE: 665
<ul style="list-style-type: none"> Certain materials at very low temperatures exhibit the property of zero resistance called superconductivity. 	SE/TE: 756 (Cool Physics)

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<ul style="list-style-type: none"> Electrons in orbitals can be treated as standing waves in order to model the atomic spectrum. 	SE/TE: 895-896
<ul style="list-style-type: none"> Quantum mechanics requires an inverse relationship between the measurable location and the measurable momentum of a particle. The more accurately one determines the position of a particle, the less accurately the momentum can be known, and vice versa. This is known as the Heisenberg uncertainty principle. 	SE/TE: 868-870
<ul style="list-style-type: none"> Matter behaves differently at nanometer scale (size and distance) than at macroscopic scale. 	This falls outside of the program scope.
Essential Knowledge and Skills	
In order to meet this standard, it is expected that students will	
<ul style="list-style-type: none"> explain that the motion of objects traveling near or approaching the speed of light does not follow Newtonian mechanics but must be treated within the theory of relativity. 	SE/TE: 950-952
<ul style="list-style-type: none"> describe the relationship between the Big Bang theory timeline and particle physics. 	SE/TE: 936-938
<ul style="list-style-type: none"> describe the structure of the atomic nucleus, including quarks. 	SE/TE: 938-940
<ul style="list-style-type: none"> provide examples of technologies used to explore the nanoscale. 	This falls outside of the program scope.