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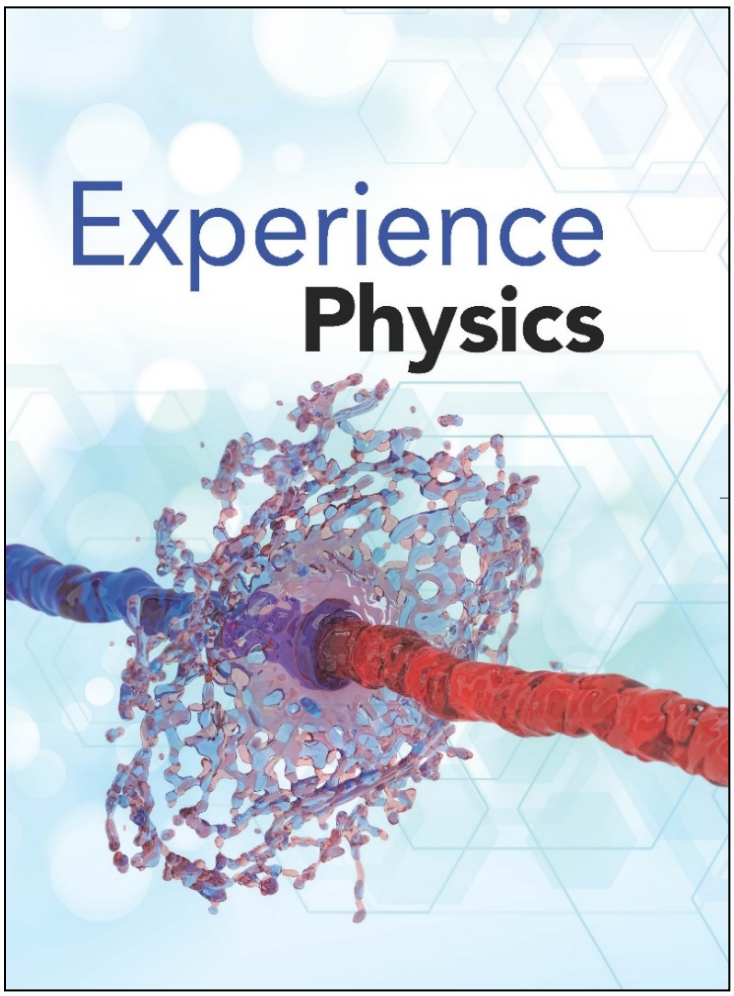

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to the

Virginia Standards of Learning for Science Curriculum Framework 2018 High School Physics

Prepared by Savvas Learning Company, formerly Pearson K12 Learning

A Correlation of Experience Physics ©2022 to the
Virginia Standards of Learning for Science Curriculum Framework 2018
High School Physics

Introduction

This document demonstrates how ***Experience Physics*** **©2022** supports the Virginia Standards of Learning for Science Curriculum Framework 2018: High School Physics. Correlation references include the Student Experience Notebook, Teacher Guide, and online digital assets.

Savvas Learning Company is excited to introduce ***Experience Physics***!

Students best learn science when they *do* science! Therefore ***Experience Physics*** puts the focus on the student experience. This modern program implements a learning model that organizes learning around phenomena giving students an authentic, real-world experience. ***Experience Physics*** includes a variety of hands-on and digital activities designed to reach every learner, and partners with Flinn Scientific to deliver high-quality inquiry labs, engineering workbenches, and performance assessments.

Phenomenal Experiences Begin with a relevant and engaging phenomenon. Learning is organized around learning around phenomena, giving students an authentic, real-world experience. ***Experience Physics*** includes a variety of hands-on and digital activities designed to reach every learner, encouraging students to ask and answer questions, gather evidence, and organize their reasoning as they experience the concepts of physics firsthand.

Flinn Scientific Partnership Labs, Engineering Workbenches, dataset activities, and performance tasks enhance the student experience and encourage your class to do more science! Hands-on inquiry labs are available in open-ended, guided, shortened, and advanced versions, perfect for meeting the needs of every student.

Personalize Instruction The Teacher Guide allows instructors to personalize their course by selecting from our activities or embedding their own. Enhance instructional plan with Got More Time? Activities, or substitute with Related Phenomena when you want to make a change! Additionally, storyline and Investigation Planners use the 5E model to streamline your prep time.

Build Mathematical Fluency Stepped-out examples in the Experience Handbook break down sample problems for clarity and process guidance, while math tutorial videos reinforce mathematical processes. The Physics and Math Skills Workbook includes four pages of review and practice problems for every learning experience. These activities and more guide students as they become more proficient with math and physics concepts.

Savvas Realize™ Award-Winning Digital Platform Access all your digital content, virtual labs, simulations, assessments, and student data in ONE location. Savvas Realize has offline accessibility, so students can study from anywhere.

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Physics	
Scientific and Engineering Practices	
PH.1 The student will demonstrate an understanding of scientific and engineering practices by:	
a) asking questions and defining problems	
● ask questions that arise from careful observation of phenomena, examination of a model or theory, or unexpected results, and/or to seek additional information	**Student Experience Notebook:** SEP Ask Questions, 11 SEP Ask Questions, 51 SEP Ask Questions, 117 SEP Ask Questions, 155 SEP Ask Questions, 159 SEP Ask Questions, 165 SEP Ask Questions, 202 SEP Ask Questions, 243 SEP Ask Questions, 250 SEP Ask Questions, 281 SEP Ask Questions, 282 SEP Ask Questions, 547 SEP Ask Questions, 569 SEP Ask Questions, 621 SEP Ask Questions, 651
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● make hypotheses that specify what happens to a dependent variable when an independent variable is manipulated	**Student Experience Notebook:** SEP Plan an Investigation, 54 SEP Plan an Investigation, 67 **Teacher Guide:** **Inquiry Labs:** Friction
● generate hypotheses based on research and scientific principles	**Student Experience Notebook:** SEP Make a Hypothesis, 268 SEP Form a Hypothesis, 537 CCC Energy and Matter, 577

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● define design problems that involves the development of a process or system with interacting components and criteria and constraints	**Student Experience Notebook:** SEP Design a Solution, 84 SEP Design a Solution, 219 SEP Design a Solution, 232 SEP Design a Solution, 393 SEP Design a Solution, 434 SEP Design a Solution, 497 SEP Identify Criteria, 528 SEP Design a Solution, 564 **Teacher Guide:** **Engineering Workbenches:** Design an Airdrop System; Landslide Prevention; Design an Electronic Quiz Board; Build a Flashlight Without Batteries; Earthquake-Resistant Structures; Design a Roller Coaster; Build an Efficient Travel Mug; The Colors of Light
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● individually and collaboratively plan and conduct observational and experimental investigations	**Student Experience Notebook:** SEP Plan an Investigation, 54 SEP Plan an Investigation, 163 SEP Plan an Investigation, 167 SEP Plan an Investigation, 170 SEP Plan an Investigation, 198 SEP Plan an Investigation, 365 SEP Plan an Investigation, 367 SEP Plan an Investigation, 423 SEP Plan an Investigation, 472 **Teacher Guide:** **Inquiry Labs:** Free Fall Acceleration; The Buoyant Force; Investigate Gravity Using Pendulums; Electric Resistance and Resistivity; Gas Particles and Work; Heat Transfer; Diffraction; Converting Sunlight to Electricity
● plan and conduct investigations or test design solutions in a safe manner	**Teacher Guide:** **Inquiry Labs:** Mechanical Weathering of Rock; Model the Orbital Motion of Planets; Electric Fields; Electromagnets and Magnetism; Gas Particles and Work; Convection, Conduction, and Radiation; Build a Battery; Elemental Composition of Stars **Engineering Workbenches:** Design an Electronic Quiz Board; Build an Efficient Travel Mug

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● select and use appropriate tools and technology to collect, record, analyze, and evaluate data	**Teacher Guide:** **Inquiry Labs:** Motion Plots; Free Fall Acceleration; Forces and Motion; The Buoyant Force; Electric Fields; The Impact of Position on Energy; Elastic and Inelastic Collisions; Diffraction
c) interpreting, analyzing, and evaluating data	
● record and present data in an organized format that communicates relationships and quantities in appropriate mathematical or algebraic forms	**Student Experience Notebook:** SEP Analyze and Interpret Data, 478 SEP Analyze and Interpret Data, 489 **Teacher Guide:** **Inquiry Labs:** Motion Plots; Free Fall Acceleration; Model Projectile Motion; Investigate Gravity Using Pendulums; Magnetic Force and Separation Distance; Gas Particles and Work; Kinetic Energy; Heat Transfer
● use data in building and revising models, supporting explanation for phenomena, or testing solutions to problems	**Student Experience Notebook:** SEP Analyze Data, 350 SEP Interpret Data, 399 **Teacher Guide:** **Inquiry Labs:** Model Projectile Motion; Magnetic Force and Separation Distance; Gas Particles and Work; The Impact of Position on Energy; Pendulums and the Conservation of Energy; Kinetic Energy; Heat Transfer; Convection, Conduction, and Radiation; Diffraction; Converting Sunlight to Electricity; Half-Life Simulation
● analyze data using tools, technologies, and/or models (e.g., computational, mathematical, statistical) in order to make valid and reliable scientific claims or determine an optimal design solution	**Student Experience Notebook:** SEP Argue from Evidence, 205 **Teacher Guide:** **Inquiry Labs:** Reflection and Refraction; Diffraction; Particle Nature of Light; Electromagnetic Radiation and Matter; Converting Sunlight to Electricity

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● analyze data graphically and use graphs to make predictions;	**Student Experience Notebook:** SEP Analyze and Interpret Data, 20 SEP Analyze and Interpret Data, 21 SEP Analyze and Interpret Data, 34 SEP Analyze and Interpret Data, 64 SEP Analyze and Interpret Data, 66 SEP Analyze and Interpret Data, 116 SEP Analyze and Interpret Data, 189 SEP Analyze Data, 375 SEP Analyze Data, 467 SEP Analyze and Interpret Data, 478 SEP Analyze Data, 664 **Teacher Guide:** **Inquiry Labs:** Motion Plots **Digital Activities:** Acceleration; Circular and Projectile Motion; Force, Mass, and Acceleration; Hooke's Law and Elastic Potential Energy; Mechanical Energy; Temperature; Valley of Stability; Solar Cycle and Sunspots
● consider limitations of data analysis when analyzing and interpreting data	**Teacher Guide:** **Digital Activities:** Solar Cycle and Sunspots **Performance Based Assessments:** Uranium-Lead Dating
● evaluate the impact of new data on a working explanation and/or model of a proposed process or system	**Student Experience Notebook:** SEP Construct an Explanation, 242
● analyze data to optimize a design	**Teacher Guide:** **Inquiry Labs:** Converting Sunlight to Electricity **Performance Based Assessments:** Generator Testing **Engineering Workbenches:** Defy Gravity; Egg Supply Drop; Build an Efficient Travel Mug
d) constructing and critiquing conclusions and explanations	
● make quantitative and/or qualitative claims based on data	**Student Experience Notebook:** SEP Argue from Evidence, 455 SEP Engage in Argument from Evidence, 647 **Teacher Guide:** **Inquiry Labs:** Reflection and Refraction; Diffraction; Particle Nature of Light; Electromagnetic Radiation and Matter

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● construct and revise explanations based on valid and reliable evidence obtained from a variety of sources	**Student Experience Notebook:** SEP Construct an Explanation, 27 SEP Construct an Explanation, 128 SEP Construct an Explanation, 276 **Teacher Guide:** **Digital Activities:** Fast Cars; Topography; Forces Between Atoms
● apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena or design solutions	**Student Experience Notebook:** SEP Construct an Explanation, 60 SEP Construct an Explanation, 84 SEP Design a Solution, 94 SEP Construct an Explanation, 231 SEP Design a Solution, 238 SEP Construct an Explanation, 274 SEP Construct an Explanation, 363 SEP Construct an Explanation, 393 SEP Construct an Explanation, 434 SEP Design a Solution, 492 SEP Construct an Explanation, 508 SEP Construct an Explanation, 635 **Teacher Guide:** **Inquiry Labs:** Model Projectile Motion; Electric Fields; Momentum and Impulse During Collisions; Build a Battery; Converting Electrical Signals to Sounds **Digital Activities:** Fast Cars; Topography; Forces Between Atoms **Engineering Workbenches:** Landslide Prevention; Earthquake-Resistant Structures; Build an Efficient Travel Mug
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● construct arguments or counterarguments based on data and evidence	**Student Experience Notebook:** SEP Argue from Evidence, 44 SEP Argue from Evidence, 47 SEP Argue from Evidence, 53 SEP Argue from Evidence, 125 SEP Argue from Evidence, 157 SEP Argue from Evidence, 182 SEP Argue from Evidence, 455 SEP Construct an Argument, 459 SEP Construct an Argument, 516 SEP Argue from Evidence, 537 SEP Construct an Argument, 561 SEP Argue from Evidence, 564 **Teacher Guide:** **Inquiry Labs:** Electromagnetic Radiation and Matter **Digital Activities:** Horizontal Motion of Falling Objects; Force, Mass, and Acceleration in Action; Repelling Water; Breaking Magnets; Kinetic Energy and Collisions; Wave Speed; Antennas; Penetrating Particles; The Role of the Sun
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e) developing and using models	
● evaluate the merits and limitations of models	**Teacher Guide:** **Digital Activities:** Evaluate Acceleration on a Ramp; Evaluate Pinball Launcher Model; Evaluate Atmospheric Pressure on a Sealed Container; Evaluate Eccentric Orbits; Evaluate Modeling Electric Fields; Evaluate Asteroid Impact Models; Evaluate Interference; Evaluate Creating Code; Evaluate Nuclear Forces; Evaluate Discovering Exoplanets

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● identify and communicate components of a system orally, graphically, textually, and mathematically	**Student Experience Notebook:** CCC System Models, 59 CCC Systems and System Models, 80 CCC Systems and System Models, 138 CCC Systems and System Models, 174 CCC Systems and System Models, 319 CCC Systems and System Models, 380 CCC Systems and System Models, 450 CCC Systems and System Models, 511 CCC Systems and System Models, 624 **Teacher Guide:** **Inquiry Labs:** Forces and Motion **Digital Activities:** Displacement and Velocity
● develop and/or use models (including mathematical and computational) and simulations to visualize, explain, and predict phenomena and to interpret data sets	**Student Experience Notebook:** SEP Develop and Use a Model, 20 SEP Develop a Model, 48 SEP Develop a Model, 85 SEP Develop and Use a Model, 178 SEP Develop and Use a Model, 191 SEP Develop and Use a Model, 222 SEP Develop a Model, 238 SEP Develop Models, 330 SEP Develop and Use a Model, 407 SEP Develop and Use a Model, 444 SEP Develop and Use Models, 665 **Teacher Guide:** **Inquiry Labs:** Friction; Mechanical Weathering of Rock; Model the Orbital Motion of Planets; Mechanical Waves **Digital Activities:** Pinball Launcher Model; Mercury's Resonant Orbit; Combining Magnetic Fields; Energy in a Moving Cart; Light Interactions with Molecules

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f) obtaining, evaluating, and communicating information	
● compare, integrate, and evaluate sources of information presented in different media or formats to address a scientific question or solve a problem.	**Student Experience Notebook:** SEP Obtain and Communicate Information, 141 SEP Obtain Information, 186 SEP Obtain, Evaluate, and Communicate Information, 199 SEP Obtain, Evaluate, and Communicate Information, 238 SEP Obtain Information, 555 SEP Obtain and Communicate Information, 660 SEP Obtain, Evaluate, and Communicate Information, 674 **Teacher Guide:** **Inquiry Labs:** Indirect Observations of the Atom; Cohesive Forces and Surface Tension; Structures and Properties of Polymers; Collisions at a Fault Line; Electromagnetic Radiation and Matter
● gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and credibility of each source	**Student Experience Notebook:** SEP Obtain, Evaluate, and Communicate Information, 199 SEP Obtain Information, 555 **Teacher Guide:** **Digital Activities:** Skills in Displacement and Velocity; Skills in Earth's Surface Forces; Skills in Coulomb's Law; Skills in Inducing Current; Skills in Structure and Function; Skills in Temperature; Skills in Energy Resources and Conservation; Skills in Electromagnetic Waves and Their Properties; Skills in the Big Bang

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● communicate scientific and/or technical information about phenomena and/or a design process in multiple formats	**Student Experience Notebook:** SEP Communicate Information, 22 SEP Communicate Information, 57 SEP Obtain, Evaluate, and Communicate Information, 238 SEP Communicate Technical Information, 425 SEP Communicate Information, 461 SEP Communicate Scientific Information, 465 SEP Communicate Scientific Information, 606 **Teacher Guide:** **Inquiry Labs:** Cohesive Forces and Surface Tension; Physical Properties of Solid Materials; Structures and Properties of Polymers; Collisions at a Fault Line; Interference of Sound Waves; Reflection and Refraction; Electromagnetic Radiation and Matter; Converting Electrical Signals to Sound; Converting Sunlight to Electricity; Elemental Composition of Stars
Physics Content	
PH.2 The student will investigate and understand, through mathematical and experimental processes, that there are relationships between position and time. Key topics include	
a) displacement, velocity, and uniform acceleration;	**Student Experience Notebook:** Displacement, 6-7 Speed and Velocity, 13 Speed and Velocity Graphs, 15 Acceleration, 23 Constant Acceleration, 26-27 Acceleration Due to Gravity, 31 **Teacher Guide:** **Inquiry Labs:** Motion Plots; Free Fall Acceleration **Digital Activities:** Position vs. Time Graphs; Velocity and Speed Are Different; Fast Cars; Acceleration; Acceleration on a Ramp
b) linear motion;	**Student Experience Notebook:** Position Graphs, 12 Speed and Velocity, 13 Modeling Uniform Motion, 16-17 **Teacher Guide:** **Inquiry Labs:** Motion Plots; Free Fall Acceleration **Digital Activities:** Acceleration on a Ramp

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c) uniform circular motion; and	**Student Experience Notebook:** Circular Motion, 44-45 Graphing Circular Motion, 47 **Teacher Guide:** **Digital Activities:** Satellites in Circular Orbits
d) projectile motion.	**Student Experience Notebook:** Projectile Motion, 38-39 Modeling Projectile Motion, 40-41 **Teacher Guide:** **Inquiry Labs:** Model Projectile Motion **Digital Activities:** Circular and Projectile Motion; Demonstrating the Components of Projectile Motion
Enduring Understandings	
Because all motion is relative, all positions of objects and the directions of forces and motions must be described in a chosen frame of reference.	
• Kinematics is the branch of mechanics concerned with the motion of objects without reference to forces (PH.2 b).	For supporting content, please see: **Student Experience Notebook:** Modeling Motion, 5 Displacement, 6-7 Dot Diagrams, 11 Position Graphs, 12 Speed and Velocity, 13 Speed and Velocity Graphs, 15 Modeling Uniform Motion, 16-17 Acceleration, 23 Projectile Motion, 38-39 Circular Motion, 44-45 **Teacher Guide:** **Inquiry Labs:** Motion Plots; Model Projectile Motion **Digital Activities:** Satellites in Circular Orbits
• Position, displacement, velocity, and acceleration are vector quantities (PH.2 a).	**Student Experience Notebook:** Displacement, 6-7 Vector Mathematics, 8-9 Speed and Velocity, 13 Acceleration, 23 **Teacher Guide:** **Digital Activities:** Displacement and Velocity

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• Motion is described in terms of position, displacement, time, velocity, and acceleration (PH.2 b).	**Student Experience Notebook:** Displacement, 6-7 Dot Diagrams, 11 Position Graphs, 12 Speed and Velocity, 13 Speed and Velocity Graphs, 15 Modeling Uniform Motion, 16-17 Acceleration, 23 **Teacher Guide:** **Inquiry Labs:** Motion Plots; Free Fall Acceleration **Digital Activities:** Position vs. Time Graphs; Fast Cars; Acceleration; Acceleration on a Ramp
• Velocity is the change in position (i.e., displacement) divided by the change in time. A straight-line, position-time graph indicates constant velocity. The slope of a position time graph is the velocity and the sign of the slope describes the direction of the velocity (PH.2 a).	**Student Experience Notebook:** Speed and Velocity, 13 Speed and Velocity Graphs, 15 Modeling Uniform Motion, 16-17 **Teacher Guide:** **Digital Activities:** Position vs. Time Graphs
• 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 and the sign of the slope describes the direction of the acceleration (PH.2 a).	**Student Experience Notebook:** Acceleration, 23 Instantaneous Acceleration, 25 Constant Acceleration, 26-27 Acceleration Due to Gravity, 31 **Teacher Guide:** **Inquiry Labs:** Free Fall Acceleration **Digital Activities:** Fast Cars; Acceleration; Acceleration on a Ramp **Performance Based Assessments:** Speed, Acceleration, and Trajectory
• Uniform circular motion is when an object travels in a circle with a constant speed. The constant change in direction of the object is caused by an acceleration that is directed toward the center of the circle and is always perpendicular to the velocity of the object (PH.2 c).	**Student Experience Notebook:** Circular Motion, 44-45 Graphing Circular Motion, 47 **Teacher Guide:** **Digital Activities:** Satellites in Circular Orbits

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• 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 (PH.2 d).	**Student Experience Notebook:** Projectile Motion, 38-39 Modeling Projectile Motion, 40-41 **Teacher Guide:** **Inquiry Labs:** Model Projectile Motion **Digital Activities:** Circular and Projectile Motion; Demonstrating the Components of Projectile Motion
Essential Knowledge and Practices	
In order to meet this standard, it is expected that students will	
• construct and analyze graphs showing position vs. time, velocity vs. time, and acceleration vs. time (PH.2 a)	**Student Experience Notebook:** Position Graphs, 12 SEP Develop a Model, 12 Speed and Velocity, 13 SEP Analyze and Interpret Data, 13 Sample Problem: An Ant on a Meter Stick, 14 Practice Problem, #13, 14 Speed and Velocity Graphs, 15 Modeling Uniform Motion, 16-17 SEP Develop a Model, 16 Practice Problems, #19-#23, 19 SEP Analyze and Interpret Data, 20 SEP Use Mathematics, 20 SEP Analyze and Interpret Data, 21 Graphs of Changing Velocity, 22 SEP Communicate Information, 22 SEP Develop a Model, 23 SEP Develop a Model, 26 Practice Problem, #48, 33 SEP Analyze and Interpret Data, 34 **Teacher Guide:** **Inquiry Labs:** Motion Plots **Digital Activities:** Acceleration; Acceleration on a Ramp
• design a model, illustration, and/or graph to explain how distance and velocity change for a free-falling object (PH.2 a)	**Student Experience Notebook:** Acceleration Due to Gravity, 31 SEP Develop a Model, 31 Sample Problem: Smashing Watermelons, 32 Practice Problems, #46, #47, 33 **Teacher Guide:** **Inquiry Labs:** Free Fall Acceleration **Performance Based Assessments:** Coin Drop

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• solve problems involving displacement, velocity, acceleration, and time in one and two dimensions (only constant acceleration) (PH.2 a, b, d)	**Student Experience Notebook:** SEP Use Mathematics, 6 Sample Problem: Row, Row, Row Your Boat, 10 Practice Problems, #8, #9, 10 Sample Problem: An Ant on a Meter Stick, 14 Practice Problems, #13, #14, 14 Sample Problem: Driving Distance, 18 Practice Problems, #19-#23, 19 SEP Use Mathematics, 20 Sample Problem: Rolling Down the Hill, 24 Practice Problems, #30, #31, 24 **Teacher Guide:** **Inquiry Labs:** Motion Plots; Free Fall Acceleration **Digital Activities:** Fast Cars **Performance Based Assessments:** Coin Drop; Speed, Acceleration, and Trajectory
• resolve vector diagrams involving displacement and velocity into their components along perpendicular axes (PH.2 b)	**Student Experience Notebook:** Displacement, 6-7 SEP Develop a Model, 7 Vector Mathematics, 8-9 SEP Use Mathematics, 9 Sample Problem: Row, Row, Row Your Boat, 10 Practice Problems, #8, #9, 10 **Teacher Guide:** **Digital Activities:** Displacement and Velocity
• 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) (PH.2 d)	**Student Experience Notebook:** Modeling Projectile Motion, 40-41 Sample Problem: Hang Time, 42 Practice Problems, #59-#64, 43 **Teacher Guide:** **Inquiry Labs:** Model Projectile Motion **Digital Activities:** Circular and Projectile Motion
• solve problems related to free-falling objects, including 2-D motion (PH.2 b, d)	**Student Experience Notebook:** Acceleration Due to Gravity, 31 Sample Problem: Smashing Watermelons, 32 Practice Problems, #43-#48, 33 **Teacher Guide:** **Inquiry Labs:** Free Fall Acceleration **Performance Based Assessments:** Coin Drop

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• solve problems using uniform circular motion (PH.2 c)	**Student Experience Notebook:** Circular Motion, 44-45 Sample Problem: Artificial Gravity, 46 **Teacher Guide:** **Digital Activities:** Satellites in Circular Orbits
• plan, conduct, and communicate the results of experiments using kinematics (PH.2 b).	**Student Experience Notebook:** SEP Plan an Investigation, 5 **Teacher Guide:** **Inquiry Labs:** Motion Plots; Free Fall Acceleration; Model Projectile Motion **Performance Based Assessments:** Speed, Acceleration, and Trajectory
PH.3 The student will investigate and understand, through mathematical and experimental processes, that there are relationships among force, mass, and acceleration. Key laws include	
a) Newton's laws of motion; and	**Student Experience Notebook:** Changing Motion, 52 Force Causes an Acceleration, 54 I Push You, You Push Back, 57 **Teacher Guide:** **Inquiry Labs:** Forces and Motion **Digital Activities:** Newton's Third Law of Motion **Performance Based Assessments:** Force, Mass, and Acceleration
b) Newton's law of universal gravitation.	**Student Experience Notebook:** Gravitational Force, 118-119 **Teacher Guide:** **Inquiry Labs:** Investigate Gravity Using Pendulums **Digital Activities:** Universal Gravitation; Newton's Law of Universal Gravitation
Enduring Understandings	
The interactions of an object with other objects can be described by forces. These forces can transfer energy between objects which can cause a change in their motion.	**Student Experience Notebook:** Forces, 51 Changing Motion, 52 I Push You, You Push Back, 57 Gravitational Force, 118-119 **Teacher Guide:** **Inquiry Labs:** Forces and Motion **Digital Activities:** Force, Mass, and Acceleration in Action; Forces and Movement

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• Dynamics is the branch of mechanics concerned with the effect of forces on motion of a body or a system of bodies (PH.3 a).	**Student Experience Notebook:** Modeling Force, 60-61
• Newton's three laws of motion are the basis of understanding the mechanical universe (PH.3 a).	**Student Experience Notebook:** Changing Motion, 52 Force Causes an Acceleration, 54 I Push You, You Push Back, 57 **Teacher Guide:** **Inquiry Labs:** Forces and Motion **Digital Activities:** Newton's Third Law of Motion **Performance Based Assessments:** Force, Mass, and Acceleration
• Net force is the vector sum of all forces acting on an object (PH.3 a).	**Student Experience Notebook:** Force Causes an Acceleration, 54 **Teacher Guide:** **Performance Based Assessments:** Force, Mass, and Acceleration
• An object with no net force acting on it is stationary or moves with constant velocity (PH.3 a).	**Student Experience Notebook:** Changing Motion, 52 Modeling Force, 60
• 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 (PH.3 a).	**Student Experience Notebook:** Force Causes an Acceleration, 54 I Push You, You Push Back, 57 **Teacher Guide:** **Inquiry Labs:** Forces and Motion **Digital Activities:** Force, Mass, and Acceleration in Action; Newton's Third Law of Motion
• The acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass (PH.3 a).	**Student Experience Notebook:** Force Causes an Acceleration, 54 **Teacher Guide:** **Inquiry Labs:** Forces and Motion **Performance Based Assessments:** Force, Mass, and Acceleration

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• Position, displacement, velocity, and acceleration are vector quantities (PH.3 a).	**Student Experience Notebook:** Displacement, 6-7 Vector Mathematics, 8-9 Speed and Velocity, 13 Acceleration, 23 **Teacher Guide:** **Digital Activities:** Displacement and Velocity
• Motion is described in terms of position, displacement, time, velocity, and acceleration (PH.3 a).	**Student Experience Notebook:** Displacement, 6-7 Dot Diagrams, 11 Position Graphs, 12 Speed and Velocity, 13 Speed and Velocity Graphs, 15 Modeling Uniform Motion, 16-17 Acceleration, 23 **Teacher Guide:** **Inquiry Labs:** Motion Plots; Free Fall Acceleration **Digital Activities:** Position vs. Time Graphs; Fast Cars; Acceleration; Acceleration on a Ramp
• Free body diagrams are used to show the relative magnitude and direction of all forces acting upon a system in a given situation (PH.3 a).	**Student Experience Notebook:** Representing Forces, 58-59 Modeling Force, 60-61 Modeling Force in Two Dimensions, 72-73 Modeling Systems, 84-86 Gravitational Force, 118-119 **Teacher Guide:** **Digital Activities:** What Forces Are Acting on You?
• An object moving along a circular path with a constant speed experiences an acceleration directed toward the center of the circle (PH.3 a).	**Student Experience Notebook:** Circular Motion, 44-45 Centripetal Force, 76 Forces in Orbit, 131-133 **Teacher Guide:** **Inquiry Labs:** Model the Orbital Motion of Planets

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• Friction is the force resisting the relative motion between surfaces in contact with each other (PH.3 a).	**Student Experience Notebook:** Surface Forces, 70-71 **Teacher Guide:** **Inquiry Labs:** Friction **Digital Activities:** Introduction to Static and Kinetic Friction **Performance Based Assessments:** Sliding Down
• Weight is the gravitational force acting on a body (PH.3 b).	**Student Experience Notebook:** Weight, 66 What Causes Free Fall?, 116-117
• Newton's law of universal gravitation states that any two bodies in the universe attract each other with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them (PH.3 b).	**Student Experience Notebook:** Gravitational Force, 118-119 **Teacher Guide:** **Inquiry Labs:** Investigate Gravity Using Pendulums **Digital Activities:** Universal Gravitation; Newton's Law of Universal Gravitation
Essential Knowledge and Practices	
In order to meet this standard, it is expected that students will	
• qualitatively explain motion in terms of Newton's laws (PH.3 a)	**Student Experience Notebook:** Changing Motion, 52 CCC Cause and Effect, 52 Force Causes an Acceleration, 54 CCC Scale, Proportion, and Quantity, 54 I Push You, You Push Back, 57 SEP Develop and Use a Model, 57 **Teacher Guide:** **Digital Activities:** Force, Mass, and Acceleration in Action
• solve problems involving force, mass, and acceleration (PH.3 a)	**Student Experience Notebook:** Sample Problem: Mowing the Lawn, 55 Practice Problems, #9, #10, 55 Sample Problem: Will the Wire Break?, 62 Practice Problems, #21-#27, 63 SEP Analyze and Interpret Data, 64 **Teacher Guide:** **Inquiry Labs:** Forces and Motion; The Buoyant Force **Performance Based Assessments:** Force, Mass, and Acceleration

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• construct and analyze position vs. time, velocity vs. time, and acceleration vs. time, and force vs acceleration graphs (PH.3 a)	**Student Experience Notebook:** SEP Use Models, 56 SEP Develop and Use a Model, 64 SEP Analyze and Interpret Data, 64 **Teacher Guide:** **Inquiry Labs:** Forces and Motion **Digital Activities:** Force, Mass, and Acceleration **Performance Based Assessments:** Force, Mass, and Acceleration
• solve problems involving force(s), displacement, velocity, acceleration, and time in one and two dimensions (PH.3 a)	**Student Experience Notebook:** Sample Problem: Mowing the Lawn, 55 Practice Problems, #9, #10, 55 Solving Force Problems, 61 Sample Problem: Will the Wire Break?, 62 Practice Problems, #21-#27, 63 SEP Use Mathematics, 64 Solving Two-Dimensional Force Problems, 73 Sample Problem: Pulling a Sled, 74 Practice Problems, #44-#51, 75 Sample Problem: Atwood Machine, 87 Sample Problem: Disappearing Actor, 88 Practice Problems, #74-#81, 89 **Teacher Guide:** **Inquiry Labs:** Forces and Motion; The Buoyant Force **Performance Based Assessments:** Force, Mass, and Acceleration
• resolve vector diagrams involving force, displacement and velocity into their components along perpendicular axes (PH.3 a)	**Student Experience Notebook:** Modeling Force in Two Dimensions, 72-73 SEP Use Mathematics, 72 Sample Problem: Pulling a Sled, 74 Practice Problems, #44, #45, 75 SEP Develop a Model, 78
• 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) (PH.3 a)	**Student Experience Notebook:** Modeling Projectile Motion, 40-41 Sample Problem: Hang Time, 42 Practice Problems, #59-#64, 43 **Teacher Guide:** **Inquiry Labs:** Model Projectile Motion **Digital Activities:** Circular and Projectile Motion

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• solve problems involving multiple forces, using free-body diagrams (PH.3 a)	**Student Experience Notebook:** Representing Forces, 58-59 CCC System Models, 59 SEP Develop a Model, 59 Modeling Force, 60-61 SEP Develop and Use a Model, 64 Solving Two-Dimensional Force Problems, 73 Solving System Problems, 86 **Teacher Guide:** **Inquiry Labs:** Friction **Performance Based Assessments:** Force, Mass, and Acceleration
• describe the forces involved in circular motion (PH.3 a)	**Student Experience Notebook:** Circular Motion, 44-45 Centripetal Force, 76 Sample Problem: Sticking to the Wall, 77 Forces in Orbit, 131-133 SEP Use Math, 131 **Teacher Guide:** **Inquiry Labs:** Model the Orbital Motion of Planets
• plan and conduct experiments involving dynamics, including one dealing with Newton's second law (PH.3 a)	**Student Experience Notebook:** SEP Plan an Investigation, 54 **Teacher Guide:** **Inquiry Labs:** Forces and Motion; The Buoyant Force; Friction **Performance Based Assessments:** Force, Mass, and Acceleration
• communicate results of experiments involving dynamics (PH.3 a)	**Teacher Guide:** **Inquiry Labs:** Forces and Motion; The Buoyant Force; Friction **Performance Based Assessments:** Force, Mass, and Acceleration
• design a model, illustration, and/or graph to explain how distance and velocity change for a free-falling object (PH.3 a)	**Student Experience Notebook:** Acceleration Due to Gravity, 31 SEP Develop a Model, 31 Sample Problem: Smashing Watermelons, 32 Practice Problems, #46, #47, 33 **Teacher Guide:** **Inquiry Labs:** Free Fall Acceleration **Performance Based Assessments:** Coin Drop

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• use Newton's laws of motion to predict the effect of motion on objects (PH.3 a)	**Student Experience Notebook:** Changing Motion, 52 CCC Cause and Effect, 52 Force Causes an Acceleration, 54 CCC Scale, Proportion, and Quantity, 54 I Push You, You Push Back, 57 SEP Develop and Use a Model, 57 **Teacher Guide:** **Performance Based Assessments:** Force, Mass, and Acceleration
• explain with words, charts, diagrams, and models the effects of distance and the amount of mass on the gravitational force between objects (PH.3 a)	**Student Experience Notebook:** Gravitational Force, 118-119 SEP Use a Model, 119 SEP Develop a Model, 119 Sample Problem: Earth and the Moon, 120 **Teacher Guide:** **Digital Activities:** Universal Gravitation
• solve problems using Newton's law of universal gravitation (PH.3 b).	**Student Experience Notebook:** Gravitational Force, 118-119 Sample Problem: Earth and the Moon, 120 Practice Problem, #11, 120 SEP Use Mathematics, 128 **Teacher Guide:** **Inquiry Labs:** Investigate Gravity Using Pendulums
PH.4 The student will investigate and understand, through mathematical and experimental processes, that conservation laws govern all interactions. Key ideas include	
a) momentum is conserved unless an impulse acts on the system; and	**Student Experience Notebook:** Conserving Momentum, 331 Impulse-Momentum Theorem, 336-337 **Teacher Guide:** **Inquiry Labs:** Elastic and Inelastic Collisions **Digital Activities:** Collisions

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b) mechanical energy is conserved unless work is done on, by, or within the system.	**Student Experience Notebook:** Energy - A Conserved Quantity, 309 Defining Systems, 310-311 **Teacher Guide:** **Inquiry Labs:** Pendulums and the Conservation of Energy **Digital Activities:** Conservation of Energy; Pendulum Decay **Performance Based Assessments:** Rocket Launch
Enduring Understandings	
Changes that occur as a result of interactions are constrained by conservation laws.	
• Kinetic energy is the energy of motion. Potential energy is the energy due to an object's position or state (PH.4 b).	**Student Experience Notebook:** Defining Energy of Motion, 287 Potential Energy, 294 Gravitational Potential Energy, 295 Elastic Potential Energy, 296-297 Electromagnetic Potential Energy, 300-301 **Teacher Guide:** **Inquiry Labs:** Gas Particles and Work; The Impact of Position on Energy **Digital Activities:** Energy in a Moving Cart; Introduction to Kinetic Energy
• Forces within a system transform energy from one form to another with no change in the system's total energy (PH.4 b).	**Student Experience Notebook:** Energy Transformed Within a System, 313 **Teacher Guide:** **Performance Based Assessments:** Rocket Launch
• 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 (PH.4 b).	**Student Experience Notebook:** Positive, Negative, and Zero Work, 282-283 Calculating Work, 284 Work Done by a Gas, 285-286 **Teacher Guide:** **Inquiry Labs:** Gas Particles and Work
• Power is the rate of change of the energy of the system (PH.4 b).	**Student Experience Notebook:** Power, 292 Power - The Rate of Energy Transfer, 316-317 **Teacher Guide:** **Performance Based Assessments:** Energy Conversion

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• 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 the momentum of the object (PH.4 b).	**Student Experience Notebook:** Impulse, 327 Impulse-Momentum Theorem, 336-337 **Teacher Guide:** **Inquiry Labs:** Momentum and Impulse During Collisions **Digital Activities:** Momentum and Impulse
• Total energy and momentum are conserved PH.4 a, b).	**Student Experience Notebook:** Energy - A Conserved Quantity, 309 Conserving Momentum, 331 **Teacher Guide:** **Inquiry Labs:** Pendulums and the Conservation of Energy; Elastic and Inelastic Collisions **Digital Activities:** Conservation of Energy; Collisions **Performance Based Assessments:** Rocket Launch
• 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 (PH.4 a).	**Student Experience Notebook:** Impulse and Momentum in Collisions, 338-339 Types of Collisions, 342-343 **Teacher Guide:** **Inquiry Labs:** Elastic and Inelastic Collisions **Digital Activities:** Kinetic Energy and Collisions; Collisions **Performance Based Assessments:** Minimizing Car Crash Injuries
• In all systems, the principal of mass/energy applies, but only in a small number of systems is it significant enough to be considered (PH.4 b).	For supporting content, please see: **Student Experience Notebook:** Defining Systems, 310-311 Nuclear Mass and Energy, 575

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Essential Knowledge and Practices	
In order to meet this standard, it is expected that students will	
• illustrate that energy can be transformed from one form to another, using examples from everyday life (PH.4 b)	**Student Experience Notebook:** Energy, 281 CCC Energy and Mater, 308 Energy Transformed Within a System, 313 SEP Use Mathematics, 318 CCC Energy and Matter, 318 **Teacher Guide:** **Inquiry Labs:** Pendulums and the Conservation of Energy **Digital Activities:** Conservation of Energy; Simple Harmonic Motion **Performance Based Assessments:** Energy Conversion; Rocket Launch
• qualitatively identify the various energy transformations in a simple scenario (PH.4 b)	**Student Experience Notebook:** CCC Energy and Mater, 308 CCC Energy and Matter, 318 **Teacher Guide:** **Inquiry Labs:** Pendulums and the Conservation of Energy **Digital Activities:** Simple Harmonic Motion **Performance Based Assessments:** Energy Conversion; Rocket Launch
• investigate conservation of energy in a mechanical system in which energy is transformed from one form into another (b)	**Student Experience Notebook:** Energy - A Conserved Quantity, 309 SEP Construct an Explanation, 309 Defining Systems, 310-311 Energy Transformed Within a System, 313 SEP Evaluate Information, 318 **Teacher Guide:** **Inquiry Labs:** Pendulums and the Conservation of Energy **Performance Based Assessments:** Energy Conversion; Rocket Launch

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• solve problems with conservation of energy and work and power (b)	**Student Experience Notebook:** Calculating Work, 284 Work Done by a Gas, 285-286 SEP Use Mathematics, 286 Sample Problem: Work Done on a Book, 290-291 Practice Problems, #12-#17, 291 Power, 292 SEP Use Mathematics, 293 Energy - A Conserved Quantity, 309 Sample Problem: Roller Coaster Energy, 314-315 Practice Problems, #51-#55, 315 Power - The Rate of Energy Transfer, 316-317 SEP Use Mathematics, 317 SEP Use Mathematics, 318 **Teacher Guide:** **Inquiry Labs:** Gas Particles and Work; Pendulums and the Conservation of Energy
• investigate conservation of momentum in a mechanical system in which momentum is transferred between objects (PH.4 a)	**Student Experience Notebook:** Conserving Momentum, 331 Impulse and Momentum in Collisions, 338-339 Types of Collisions, 342-343 **Teacher Guide:** **Inquiry Labs:** Elastic and Inelastic Collisions **Performance Based Assessments:** Minimizing Car Crash Injuries
• use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system (PH.4 a)	**Student Experience Notebook:** Conserving Momentum, 331 Sample Problem: Conserving Momentum in Space, 332 **Teacher Guide:** **Inquiry Labs:** Elastic and Inelastic Collisions **Digital Activities:** Kinetic Energy and Collisions **Performance Based Assessments:** Minimizing Car Crash Injuries
• solve problems with conservation of momentum (PH.4 a)	**Student Experience Notebook:** Conserving Momentum, 331 Sample Problem: Conserving Momentum in Space, 332 **Teacher Guide:** **Inquiry Labs:** Elastic and Inelastic Collisions

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• apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision (PH.4 a)	**Teacher Guide:** **Performance Based Assessments:** Build Your Own Egg-Transport Vehicle; Minimizing Car Crash Injuries **Engineering Workbenches:** Egg Supply Drop
• plan and conduct an experiment to investigate the conservation of electric charge (PH.4 b).	For supporting content, please see: **Student Experience Notebook:** Electric Charge, 156 Energy - A Conserved Quantity, 309
PH.5 The student will investigate and understand, through mathematical and experimental processes, that waves transmit energy and move in predictable patterns. Key ideas include	
a) waves have specific characteristics;	**Student Experience Notebook:** Mechanical Waves, 466 Properties of Waves, 467 Transverse Waves, 468-469 Longitudinal Waves, 472-473 Properties of EM Waves, 514-515 **Teacher Guide:** **Inquiry Labs:** Mechanical Waves **Digital Activities:** Properties of Waves; Wave Speed **Performance Based Assessments:** Discovering the Speed of Sound in Open Air
b) wave interactions are part of everyday experiences; and	**Student Experience Notebook:** Wave Interactions, 479 Moving Wave Source, 480 Modeling Wave Interactions, 482-483 Beats, 484 Standing Waves, 485 Waves on a String, 486 **Teacher Guide:** **Inquiry Labs:** Interference of Sound Waves **Digital Activities:** Properties of Waves; Interference; Laster Interference
c) light and sound transmit energy as waves.	**Student Experience Notebook:** Mechanical Waves, 466 Transfer of Wave Energy, 488-499 Energy in Waves, 490-491 Electromagnetic Waves, 512-513 **Teacher Guide:** **Digital Activities:** Light Intensity and Energy

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Enduring Understandings	
Waves can transfer energy and momentum from one location to another without the permanent transfer of mass.	
• Mechanical waves transport energy as a traveling disturbance in a medium (PH.5 a).	**Student Experience Notebook:** Mechanical Waves, 466 **Teacher Guide:** **Inquiry Labs:** Mechanical Waves
• In a transverse wave, particles of the medium oscillate in a direction perpendicular to the direction the wave travels (PH.5 a).	**Student Experience Notebook:** Transverse Waves, 468-469 **Teacher Guide:** **Inquiry Labs:** Mechanical Waves
• In a longitudinal wave, particles of the medium oscillate in a direction parallel to the direction the wave travels (PH.5 a).	**Student Experience Notebook:** Longitudinal Waves, 472-473 **Teacher Guide:** **Inquiry Labs:** Mechanical Waves
• Wave velocity equals the product of the frequency and the wavelength (PH.5 a).	**Student Experience Notebook:** Properties of Waves, 467 **Teacher Guide:** **Inquiry Labs:** Mechanical Waves **Digital Activities:** Wave Speed **Performance Based Assessments:** Discovering the Speed of Sound in Open Air
• Frequency and period are reciprocals of each other (PH.5 a).	**Student Experience Notebook:** Properties of Waves, 467 **Teacher Guide:** **Digital Activities:** Properties of Waves
• Waves are reflected and transmitted when they encounter a change in medium or a boundary (PH.5 a).	**Student Experience Notebook:** Wave Interactions, 479 Diffraction, 494-495 Reflection, 496-497 Refraction, 498-499 **Teacher Guide:** **Inquiry Labs:** Reflection and Refraction **Digital Activities:** Refraction - Snell's Law; Wave Optics

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• The overlapping of two or more waves results in constructive or destructive interference (PH.5 a).	**Student Experience Notebook:** Modeling Wave Interactions, 482-483 Beats, 484 Standing Waves, 485 Waves on a String, 486 Wave Behavior of EM Radiation, 516 **Teacher Guide:** **Inquiry Labs:** Interference of Sound Waves; Diffraction **Digital Activities:** Properties of Waves; Interference; Laser Interference
• When source and observer are in relative motion, a shift in frequency occurs (Doppler effect) (PH.5 a).	**Student Experience Notebook:** Modeling Wave Source, 480 **Teacher Guide:** **Digital Activities:** Discovering Exoplanets
• Sound is a longitudinal mechanical wave that travels through matter (PH.5 c).	**Student Experience Notebook:** Mechanical Waves, 466 Longitudinal Waves, 472-473 **Teacher Guide:** **Inquiry Labs:** Mechanical Waves **Performance Based Assessments:** Discovering the Speed of Sound in Open Air
• Light is a transverse electromagnetic wave that can travel through matter as well as a vacuum (PH.5 c).	**Student Experience Notebook:** Transverse Waves, 468-469 Refraction, 498-499 Electromagnetic Waves, 512-513 **Teacher Guide:** **Inquiry Labs:** Reflection and Refraction; Diffraction
• Reflection is the change of direction of the wave in the original medium (PH.5 c).	**Student Experience Notebook:** Reflection, 496-497 **Teacher Guide:** **Inquiry Labs:** Reflection and Refraction
• Refraction is the change of direction of the wave at the boundary between two media (PH.5 c).	**Student Experience Notebook:** Refraction, 498-499 **Teacher Guide:** **Inquiry Labs:** Reflection and Refraction **Digital Activities:** Refraction - Snell's Law; Wave Optics; Refraction; Refraction in Animals

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• Diffraction is the spreading of a wave around a barrier or an aperture (PH.5 c).	**Student Experience Notebook:** Diffraction, 494-495 Wave Behavior of EM Radiation, 516 **Teacher Guide:** **Inquiry Labs:** Diffraction
• The pitch of a note is determined by the frequency of the sound wave (PH.5 c).	**Teacher Guide:** **Inquiry Labs:** Mechanical Waves
Electromagnetic radiation travels in waves and occurs over a wide range of frequencies. The dual nature of light is addressed in PH.9.	
• The color of light is determined by the frequency of the light wave (PH.5 c).	For supporting content, please see: **Student Experience Notebook:** Properties of EM Waves, 514-515 Photon-Electron Interactions, 529 Color and Temperature of Stars, 669
• As the amplitude of a sound wave increases, the loudness of the sound increases (PH.5 c).	**Student Experience Notebook:** A Model for Loud and Quiet, 483 Beats, 484
• As the amplitude of a light wave increases, the intensity of the light increases (PH.5 c).	**Student Experience Notebook:** Electromagnetic Waves, 512-513 **Teacher Guide:** **Digital Activities:** Light Intensity and Energy
• Frequency, wavelength, and energy vary across the entire electromagnetic spectrum (PH.5 b).	**Student Experience Notebook:** Properties of EM Waves, 514-515
• The long wavelength, low frequency portion of the electromagnetic spectrum is used for communication (e.g., radio, TV, cellular phone) (PH.5 b).	**Student Experience Notebook:** Waves of the Electromagnetic Spectrum, 515 Antennas, 554
• Medium wavelengths (infrared) are used for heating and remote-control devices (PH.5 b).	**Student Experience Notebook:** Waves of the Electromagnetic Spectrum, 515
• Visible light comprises a relatively narrow portion of the electromagnetic spectrum (PH.5 b).	**Student Experience Notebook:** Properties of EM Waves, 514-515
• 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 (PH.5 b).	**Student Experience Notebook:** Waves of the Electromagnetic Spectrum, 515 Heat and Ionization, 531 Damage to Living Cells, 534-535 **Teacher Guide:** **Digital Activities:** Sunscreen and UV Protection **Performance Based Assessments:** Clothing and Sun Protection

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• 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 (PH.5 b).	**Student Experience Notebook:** Waves of the Electromagnetic Spectrum, 515 Heat and Ionization, 531 Damage to Living Cells, 534-535 Medical Imaging, 552-553 Radiotherapy, 563
Essential Knowledge and Practices	
In order to meet this standard, it is expected that students will	
• use simulations and models to differentiate between examples of transverse and longitudinal waves (PH.5 a)	**Student Experience Notebook:** Transverse Waves, 468-469 Longitudinal Waves, 472-473 **Teacher Guide:** **Inquiry Labs:** Mechanical Waves
• use a model representation of a wave to identify the period, wavelength, and amplitude (PH.5 a)	**Student Experience Notebook:** Properties of Waves, 467 Modeling Waves, 475 SEP Use Math, 475 Sample Problem: Modeling a Sound Wave, 476 Practice Problems, #16-#20, 477 SEP Analyze and Interpret Data, 478 **Teacher Guide:** **Inquiry Labs:** Mechanical Waves **Digital Activities:** Properties of Waves **Performance Based Assessments:** Discovering the Speed of Sound in Open Air
• solve problems involving frequency, period, wavelength, and velocity (PH.5 a)	**Student Experience Notebook:** Sample Problem: Wave on a Rope, 470 Practice Problems, #8, #9, 470 Sample Problem: Properties of Sound Waves, 474 Practice Problems, #13, #14, 474 SEP Use Math, 475 SEP Use Math, 475 Sample Problem: Modeling a Sound Wave, 476 Practice Problems, #16-#20, 477 SEP Use Mathematics, 478 SEP Analyze and Interpret Data, 478 **Teacher Guide:** **Digital Activities:** Waves and Shallow Water **Performance Based Assessments:** Discovering the Speed of Sound in Open Air

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• model or simulate reflection, refraction and diffraction of a wave when it encounters a change in medium or a boundary (PH.5 c)	**Student Experience Notebook:** Diffraction, 494-495 Reflection, 496-497 Refraction, 498-499 SEP Develop a Model, 498 SEP Develop a Model, 508 **Teacher Guide:** **Inquiry Labs:** Reflection and Refraction; Diffraction **Digital Activities:** Wave Optics
• explain the phenomena of constructive and destructive interference (PH.5 b)	**Student Experience Notebook:** Modeling Wave Interactions, 482-483 **Teacher Guide:** **Inquiry Labs:** Interference of Sound Waves; Diffraction **Digital Activities:** Interference; Laser Interference
• plan and conduct an experiment investigating standing waves (PH.5 a)	**Student Experience Notebook:** Standing Waves, 485 SEP Plan an Investigation, 485
• describe the change in observed frequency of waves due to the motion of a source or a receiver (Doppler effect) (PH.5 c)	**Student Experience Notebook:** Moving Wave Source, 480 SEP Construct an Explanation, 480
• identify technological applications throughout the electromagnetic spectrum (PH.5 b)	**Student Experience Notebook:** Waves of the Electromagnetic Spectrum, 515 Medical Imaging, 552-553 Antennas, 554 Capturing an EM Wave's Energy, 557-559 Cooking, 562 Radiotherapy, 563 **Teacher Guide:** **Inquiry Labs:** Converting Sunlight to Electricity
• identify common uses for radio waves, microwaves, X-rays and gamma rays (PH.5 b)	**Student Experience Notebook:** Waves of the Electromagnetic Spectrum, 515 Medical Imaging, 552-553 Antennas, 554 Cooking, 562 Radiotherapy, 563

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• use mathematical representations to support a claim regarding the relationships among the frequency, wavelength, and speed of waves traveling through various media (PH.5 a)	**Student Experience Notebook:** SEP Analyze and Interpret Data, 469 SEP Use Mathematics, 478 **Teacher Guide:** **Inquiry Labs:** Mechanical Waves **Digital Activities:** Waves and Shallow Water; Wave Speed **Performance Based Assessments:** Discovering the Speed of Sound in Open Air
• compare electromagnetic waves to mechanical waves (PH.5 b).	**Student Experience Notebook:** Electromagnetic Waves, 512-513
PH.6 The student will investigate and understand, through mathematical and experimental processes, that optical systems form a variety of images. Key ideas include	
a) the laws of reflection and refraction describe light behavior; and	**Student Experience Notebook:** Reflection, 496-497 Refraction, 498-499 **Teacher Guide:** **Inquiry Labs:** Reflection and Refraction **Digital Activities:** Refraction - Snell's Law; Wave Optics; Refraction
b) ray diagrams model light as it travels through different media.	**Student Experience Notebook:** Lenses, 501 Formation of Images, 502-503
Enduring Understandings	
Electromagnetic radiation travels in waves and occurs over a wide range of frequencies. Cause-and-effect relationships may be used to predict the path of light caused by interactions with other materials.	
• The ray model of light can be used to understand the behavior of optical systems (PH.6 b).	**Student Experience Notebook:** Reflection, 496-497 Refraction, 498-499 Formation of Images, 502-503 **Teacher Guide:** **Inquiry Labs:** Reflection and Refraction
• Light incident on a smooth plane surface is reflected such that the angle of incidence equals the angle of reflection (PH.6 a).	**Student Experience Notebook:** Reflection, 496-497 **Teacher Guide:** **Inquiry Labs:** Reflection and Refraction

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• The index of refraction is the ratio of the speed of light in a vacuum to the speed of light in the medium (PH.6 a).	**Student Experience Notebook:** Refraction, 498-499 **Teacher Guide:** **Digital Activities:** Wave Optics
• This relationship between the angles of incidence and refraction and the indices of refraction of the two media is known as Snell's law. Snell's law applies to the refraction of light in any situation, regardless of what the two media are (PH.6 a).	**Student Experience Notebook:** Refraction, 498-499 **Teacher Guide:** **Digital Activities:** Refraction - Snell's Law
• For a converging lens, the focal point is the point at which a beam of light parallel to the principal axis converges (PH.6 b).	**Student Experience Notebook:** Lenses, 501
• For a diverging lens, the focal point is the point from which a beam of light parallel to the principal axis appears to originate (PH.6 b).	**Student Experience Notebook:** Lenses, 501
• A virtual image can be seen by an observer but cannot be projected on a screen because the light does not actually emanate from the image (PH.6 b).	**Student Experience Notebook:** Formation of Images, 502-503
• The focal point is the point at which rays converge or from which they appear to diverge in a lens or mirror (PH.6 b).	**Student Experience Notebook:** Lenses, 501
Essential Knowledge and Practices	
In order to meet this standard, it is expected that students will	
• conduct an experiment utilizing Snell's law to determine the index of refraction for a given material (PH.6 a)	For supporting content, please see: **Student Experience Notebook:** Refraction, 498-499 **Teacher Guide:** **Digital Activities:** Refraction - Snell's Law
• investigate propagation, refraction, and reflection, using the ray model of light (PH.6 a)	**Student Experience Notebook:** Reflection, 496-497 Refraction, 498-499 **Teacher Guide:** **Inquiry Labs:** Reflection and Refraction

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• construct ray diagrams to determine the location and type of image of an object using the laws of reflection and refraction (PH.6 b)	**Student Experience Notebook:** Ray Tracing, 502 SEP Develop a Model, 502 SEP Use a Model, 503 Sample Problem: Image of a Rubber Duck, 505 Practice Problems, #57, #58, 505 Practice Problems, #59-#61, #64, 507
• conduct an experiment to find the location of an image using an optical system (PH.6 b).	For supporting content, please see: **Student Experience Notebook:** Formation of Images, 502-503 Practice Problem, #64, 507
PH.7 The student will investigate and understand, through mathematical and experimental processes, that fields provide a unifying description of force at a distance. Key ideas include	
a) gravitational, electric, and magnetic forces can be described using the field concept; and	**Student Experience Notebook:** Gravitational Fields, 121-123 What Is a Field?, 171 Electric Field, 172 Magnetic Fields, 203-204 **Teacher Guide:** **Inquiry Labs:** Electric Fields **Digital Activities:** Charges and Fields; Modeling Electric Fields; Magnetism; Combining Magnetic Fields
b) field strength diminishes with increased distance from the source.	**Student Experience Notebook:** Inverse Square Laws, 123 Representing Electric Fields, 174 **Teacher Guide:** **Inquiry Labs:** Electric Charges and Coulomb's Law; Magnetic Force and Separation Distance
Enduring Understandings	
Fields existing in space can be used to explain interactions.	
• A field is a region in which each point is affected by a force. Objects fall to the ground because they are affected by the force of the Earth's gravitational field. A paper clip, placed in a magnetic field, is pulled toward the magnet, and the two like magnetic poles repel each other when one is placed in the other's magnetic field (PH.7 a).	**Student Experience Notebook:** Gravitational Force, 118-119 Gravitational Fields, 121-123 What Is a Field?, 171 Electric Field, 172 Magnetism, 198-199 Magnetic Fields, 203-204 **Teacher Guide:** **Inquiry Labs:** Electric Fields **Digital Activities:** Modeling Electric Fields

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• An electric field surrounds an electric charge; when another charged particle is placed in that region, it experiences an electric force that either attracts or repels it (PH.7 a).	**Student Experience Notebook:** Electric Field, 172 Representing Electric Fields, 174 Field Lines for Multiple Charges, 175 **Teacher Guide:** **Inquiry Labs:** Electric Fields **Digital Activities:** Charges and Fields; Modeling Electric Fields
• The strength of a field, or the forces in a particular region, could be represented by field lines; the closer the lines, the stronger the forces in that part of the field (PH.7 a).	**Student Experience Notebook:** Field Lines, 122 Uniform Fields, 124 Representing Electric Fields, 174 Field Lines for Multiple Charges, 175 Uniform Electric Fields, 177 Field Lines, 203 **Teacher Guide:** **Inquiry Labs:** Electric Fields **Digital Activities:** Magnetism
• 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 (PH.7 b).	**Student Experience Notebook:** Gravitational Force, 118-119 Inverse Square Laws, 123 Electric Force, 158-159 **Teacher Guide:** **Inquiry Labs:** Electric Charges and Coulomb's Law **Digital Activities:** Coulomb's Law **Performance Based Assessments:** Build and Test an Electroscope
• The interaction of two particles at a distance can be described as a two-step process that occurs simultaneously: the creation of a field by one of the particles and the interaction of the field with the second particle (PH.7 a, b).	**Student Experience Notebook:** Gravitational Force Vectors, 119 Electric Force, 158-159 Electric Field, 172 Field Lines for Multiple Charges, 175 **Teacher Guide:** **Inquiry Labs:** Electric Fields **Digital Activities:** Electric Fields; Modeling Electric Fields

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• 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 (PH.7 a).	**Student Experience Notebook:** Magnetism, 198-199 Magnetic Fields from Moving Charges, 206 Force on a Moving Charge, 207 Charged Particles in Magnetic Fields, 209-211 Magnetic Force on a Wire, 213-214 Torque on Loops, 216-217 **Teacher Guide:** **Inquiry Labs:** Electromagnets and Magnetism **Digital Activities:** Magnetic Fields
Essential Knowledge and Practices	
In order to meet this standard, it is expected that students will	
• describe the vector nature of the forces on an object in the presence of a field (PH.7 a)	**Student Experience Notebook:** Gravitational Force Vectors, 119 SEP Develop a Model, 119 Gravitational Fields, 121-123 Uniform Fields, 124 Electric Force and Vectors, 160 SEP Argue from Evidence, 160 What Is a Field?, 171 SEP Develop a Model, 171 Electric Field, 172 Representing Electric Fields, 174 Field Lines for Multiple Charges, 175 Uniform Electric Fields, 177 Magnetic Fields, 203 SEP Develop and Use a Model, 216 **Teacher Guide:** **Inquiry Labs:** Electric Fields **Digital Activities:** Electric Fields; Modeling Electric Fields; Magnetism
• compare Newton's law of universal gravitation and Coulomb's law of electrostatics (PH.7 a)	**Student Experience Notebook:** Gravitational Force, 118-119 Electric Force, 158-159 Comparing Electric and Gravitational Forces, 162

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• describe the effect of a uniform magnetic field on a moving electrical charge (PH.7 a)	**Student Experience Notebook:** Magnetic Fields from Moving Charges, 206 Force on a Moving Charge, 207 Charged Particles in Magnetic Fields, 209-211 SEP Apply Mathematical Concepts, 209 SEP Construct an Explanation, 211 Magnetic Force on a Wire, 213-214 Torque on Loops, 216-217 **Teacher Guide:** **Digital Activities:** Magnetic Fields
• plan and conduct an experiment utilizing sensors to explore and explain the nature of fields (PH.7 a, b)	**Student Experience Notebook:** SEP Plan an Investigation, 214 **Teacher Guide:** **Inquiry Labs:** Electric Fields
• develop and use of model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction (PH.7 a)	**Student Experience Notebook:** SEP Systems and System Models, 160 Sample Problem: Electric Force Between Particles, 161 SEP Use Models, 172 Sample Problem: Electric Field Due to Two Charges, 173 SEP Use a Model, 175 SEP Develop a Model, 182 SEP Develop a Model, 205 SEP Develop a Model, 212 SEP Develop and Use a Model, 213 SEP Develop and Use a Model, 220 **Teacher Guide:** **Inquiry Labs:** Electric Fields; Magnetic Force and Separation Distance **Digital Activities:** Electric Fields; Modeling Electric Fields; Magnetic Fields; Combining Magnetic Fields
• plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current (PH.7 a)	**Teacher Guide:** **Inquiry Labs:** Electromagnets and Magnetism; Induction of Electrical Current **Performance Based Assessments:** Build a DC Motor

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• describe the relationship between electric charges and magnetic fields (PH.7 a).	**Student Experience Notebook:** Magnetism, 198-199 Magnetic Fields from Moving Charges, 206 CCC Energy and Matter, 206 Magnetic Force on a Wire, 213-214 Current and Magnetic Field, 220-222 SEP Develop and Use a Model, 220 **Teacher Guide:** **Inquiry Labs:** Electromagnets and Magnetism; Induction of Electrical Current **Digital Activities:** Magnetic Fields; Inducing Current **Performance Based Assessments:** Generator Testing
PH.8 The student will investigate and understand, through mathematical and experimental processes, that electrical circuits are a system used to transfer energy. Key ideas include	
a) circuit components have different functions within the system;	**Student Experience Notebook:** Circuit Elements and Diagrams, 424-425 **Teacher Guide:** **Inquiry Labs:** Energy Transmission in Circuits
b) Ohm's law relates voltage, current, and resistance;	**Student Experience Notebook:** Current and Resistivity, 189 Ohm's Law, 422 **Teacher Guide:** **Inquiry Labs:** Energy Transmission in Circuits
c) different types of circuits have different characteristics and are used for different purposes;	**Student Experience Notebook:** Series and Parallel Resistance, 190-191 Circuit Elements and Diagrams, 424-425 **Teacher Guide:** **Inquiry Labs:** Energy Transmission in Circuits **Digital Activities:** Electric Current; Series and Parallel Circuits (Video); Electric Circuits; Energy in Electric Circuits; Series and Parallel Circuits

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d) electrical power is related to the elements in a circuit; and	**Student Experience Notebook:** Circuit Elements and Diagrams, 424-425 Joule's Law, 427 Analyzing a Circuit, 431 Alternating Current Generators, 436 Direct Current Generators, 437 **Teacher Guide:** **Inquiry Labs:** Build a Battery; Electric Motors and Generators
e) electrical circuits have everyday applications.	**Student Experience Notebook:** Electromagnetic Energy, 409 Joule's Law, 427 Electrical Generators, 435 Alternating Current Generators, 436 Direct Current Generators, 437 Motors, 439 **Teacher Guide:** **Inquiry Labs:** Build a Battery; Electric Motors and Generators **Performance Based Assessments:** Junkyard Electromagnet
Enduring Understandings	
Electric charge is a property of an object or system that affects its interactions with other objects or systems containing charge.	
• Current is the rate at which charge moves through a circuit element (PH.8 b).	**Student Experience Notebook:** Current, 187 **Teacher Guide:** **Digital Activities:** Modeling Currents
• Electric potential difference (voltage) in a circuit provides the energy that drives the current (PH.8 b).	**Student Experience Notebook:** Potential Difference, 419 What Causes Current?, 421 **Teacher Guide:** **Digital Activities:** Electric Potential; Potential Difference in a Battery

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• Elements in a circuit are positioned relative to other elements either in series or parallel (PH.8 a, c).	**Student Experience Notebook:** Series and Parallel Resistance, 190-191 Circuit Elements and Diagrams, 424-425 **Teacher Guide:** **Inquiry Labs:** Energy Transmission in Circuits **Digital Activities:** Electric Current; Series and Parallel Circuits (Video); Electric Circuits; Energy in Electric Circuits; Series and Parallel Circuits
• According to Ohm's law, the resistance of an element equals the voltage across the element divided by the current through the element (PH.8 b).	**Student Experience Notebook:** Current and Resistivity, 189 Ohm's Law, 422 **Teacher Guide:** **Inquiry Labs:** Energy Transmission in Circuits
• Potential difference (voltage) is the change in electrical potential energy per unit charge across that element (PH.8 b).	**Student Experience Notebook:** Potential Difference, 419 **Teacher Guide:** **Digital Activities:** Electric Potential; Potential Difference in a Battery
• The dissipated power of a circuit element equals the product of the voltage across that element and the current through that element (PH.8 d).	**Student Experience Notebook:** Joule's Law, 427 **Teacher Guide:** **Inquiry Labs:** Electric Motors and Generators **Performance Based Assessments:** Design, Build, and Refine a Wind-Turbine Rotor
• 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 (PH.8 e).	**Student Experience Notebook:** Alternating Current Generators, 436 Direct Current Generators, 437 **Teacher Guide:** **Inquiry Labs:** Electric Motors and Generators **Digital Activities:** How Power Gets to Your House **Performance Based Assessments:** Build a DC Motor

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Essential Knowledge and Practices	
In order to meet this standard, it is expected that students will	
• describe the function of components in an electrical system (PH.8 a)	**Student Experience Notebook:** Circuit Elements and Diagrams, 424-425 SEP Communicate Technical Information, 425
• recognize a series and a parallel circuit (PH.8 b)	**Student Experience Notebook:** Series and Parallel Resistance, 190-191 Sample Problem: Combining Series and parallel Resistors, 192 **Teacher Guide:** **Inquiry Labs:** Energy Transmission in Circuits **Digital Activities:** Electric Current; Series and Parallel Circuits (Video); Electric Circuits; Energy in Electric Circuits; Series and Parallel Circuits
• apply Ohm's law to a series and a parallel circuit (PH.8 b)	**Student Experience Notebook:** Ohm's Law, 422 **Teacher Guide:** **Inquiry Labs:** Energy Transmission in Circuits
assemble and analyze simple circuits composed of voltage sources and loads in series and in parallel (PH.8 c)	**Student Experience Notebook:** Series and Parallel Resistance, 190-191 Circuit Elements and Diagrams, 424-425 SEP Develop Models, 425 Analyzing a Circuit, 431 **Teacher Guide:** **Inquiry Labs:** Energy Transmission in Circuits **Digital Activities:** Energy in Electric Circuits; Series and Parallel Circuits
• solve simple circuits using Ohm's law (PH.8 b, c)	**Student Experience Notebook:** Ohm's Law, 422 SEP Use Mathematics, 422 **Teacher Guide:** **Inquiry Labs:** Energy Transmission in Circuits
• calculate the dissipated power of a circuit element (PH.8 d)	**Student Experience Notebook:** Joule's Law, 427 **Teacher Guide:** **Inquiry Labs:** Electric Motors and Generators **Performance Based Assessments:** Design, Build, and Refine a Wind-Turbine Rotor

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• recognize that DC power is supplied by batteries and that AC power is supplied by electrical wall sockets (PH.8 e).	**Student Experience Notebook:** Alternating Current Generators, 436 Direct Current Generators, 437 **Teacher Guide:** **Inquiry Labs:** Electric Motors and Generators **Digital Activities:** How Power Gets to Your House **Performance Based Assessments:** Build a DC Motor
PH.9 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. Topics, such as these listed, may be included.	
a) wave/particle duality;	**Student Experience Notebook:** Shortcomings of the Wave Theory, 520-521 Photoelectric Effect, 522 Particles of Light, 523 The Dual Nature of Light, 524-525 **Teacher Guide:** **Inquiry Labs:** Particles Nature of Light **Digital Activities:** Particle-Wave Duality **Performance Based Assessments:** Particle-Wave Duality of Light
b) quantum mechanics and uncertainty;	**Student Experience Notebook:** Modeling Electric and Contact Forces, 166 Anchoring Phenomenon, 463 Revisit Anchoring Phenomenon, 509 Particles of Light, 523 The Dual Nature of Light, 524-525 Revisit Anchoring Phenomenon, 537 Revisit Anchoring Phenomenon, 565
c) relativity;	**Student Experience Notebook:** Gravitational Lens, 501 **Teacher Guide:** **Engage Everyday Phenomenon:** Why do time measurements on a GPS have to be calibrated to match the same time measurements on Earth?, 420-421

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d) nuclear physics;	**Student Experience Notebook:** The Nucleus, 570-571 Size and Mass of the Nucleus, 572-573 Nuclear Mass and Energy, 575 Strong Force, 582-583 Binding Energy, 584-585 Nuclear Stability, 587-588 Weak Nuclear Force, 591-592 Converting Mass to Energy, 594-595 Curve of Binding Energy, 596 Nuclear Fission, 597 Fusion, 603-604 Radioactivity, 610-611 Alpha Decay and Cluster Decay, 614 Beta Decay and Electron Capture, 615 Gamma Decay, 616 **Teacher Guide:** **Inquiry Labs:** Subatomic Particles; Forces and Atomic Nuclei; Nuclear Reactions and Critical Mass **Digital Activities:** Nuclear Particles; Valley of Stability; Nuclear Forces; Strong Nuclear Force; Fission and Fusion; Generating Fission; Nuclear Reactions; Radioactive Decay **Performance Based Assessments:** Model Nuclear Forces; Operate a Nuclear Fission Reactor **Engineering Workbenches:** Energy Production
e) solid state physics;	**Student Experience Notebook:** Metals, 184-185 Forces in Materials, 241 Coulomb Forces Between Atoms, 251 Covalent Bonds, 252-253 Metallic Bonds, 254 States of Matter, 256-257 Conductivity of Materials, 259 Stress and Strain, 260-261 Bulk Modulus, 262 Metallic Properties in Alloys, 264 Ceramics and Glass, 266-268 **Teacher Guide:** **Inquiry Labs:** Physical Properties of Solid Materials **Digital Activities:** Forces Between Atoms; Attractive and Repulsive Forces; Material Properties **Performance Based Assessments:** Structure-Property Relationships; Forces in Materials

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f) nanotechnology;	For supporting content, please see: **Student Experience Notebook:** Information and Instrumentation, 539
g) superconductivity;	**Student Experience Notebook:** SEP Obtain Information, 186
h) the standard model; and	**Student Experience Notebook:** Elementary Particles, 576 Leptons and Quarks, 578-579
i) dark matter and dark energy.	**Student Experience Notebook:** Star Distribution in the Galaxy, 668 Dark Energy, 688
Enduring Understandings	
The study of modern and non-Newtonian physics can be applied in varied technological applications. The intent of this standard is not that each area be taught; instead, the teacher should select areas based on student interest and their own understandings of physics concepts.	
• 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) (PH.9 a, b).	**Student Experience Notebook:** Wave Behavior of EM Radiation, 516 Polarization, 517 Shortcomings of the Wave Theory, 520-521 Photoelectric Effect, 522 Particles of Light, 523 The Dual Nature of Light, 524-525 **Teacher Guide:** **Inquiry Labs:** Diffraction; Particles Nature of Light **Digital Activities:** Particle-Wave Duality **Performance Based Assessments:** Particle-Wave Duality of Light
• 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 (PH.9 a, b).	**Student Experience Notebook:** Modeling Electric and Contact Forces, 166 Anchoring Phenomenon, 463 Revisit Anchoring Phenomenon, 509 Particles of Light, 523 The Dual Nature of Light, 524-525 Revisit Anchoring Phenomenon, 537 Revisit Anchoring Phenomenon, 565

Virginia Standards of Learning for Science Curriculum Framework 2018: High School Physics	Experience Physics ©2022
• The special theory of relativity states that the laws of physics are the same for all inertial reference frames and the speed of light in a vacuum is constant and independent of the motion of all observers (PH.9 c).	**Student Experience Notebook:** Gravitational Lens, 501 **Teacher Guide:** **Engage Everyday Phenomenon:** Why do time measurements on a GPS have to be calibrated to match the same time measurements on Earth?, 420-421
• The general theory of relativity is a theory of space and time. The central idea is that space and time are two aspects of spacetime. Spacetime is curved in the presence of mass (PH.9 c).	**Student Experience Notebook:** Gravitational Lens, 501
• The strong nuclear force binds protons and neutrons in the nucleus. Fission is the breakup of heavier nuclei into lighter nuclei. Fusion is the combination of lighter nuclei into heavier nuclei. The study of these topics is called nuclear physics (PH.9 d).	**Student Experience Notebook:** Strong Force, 582-583 Nuclear Fission, 597 Chain Reactions, 598 Power From Nuclear Fission, 599 Fission Products, 601-602 Fusion, 603-604 The Sun's Fusion, 656 **Teacher Guide:** **Inquiry Labs:** Forces and Atomic Nuclei; Nuclear Reactions and Critical Mass **Digital Activities:** Nuclear Forces; Strong Nuclear Force; Fission and Fusion; Generating Fission; Nuclear Reactions **Performance Based Assessments:** Operate a Nuclear Fission Reactor
• Natural radioactivity is the spontaneous disintegration of unstable nuclei. Alpha, beta, and gamma rays are different emissions associated with radioactive decay (PH.9 d).	**Student Experience Notebook:** Radioactivity, 610-611 Exponential Decay, 612-613 Alpha Decay and Cluster Decay, 614 Beta Decay and Electron Capture, 615 Gamma Decay, 616 **Teacher Guide:** **Digital Activities:** Radioactive Decay; Penetrating Particles

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• Solid state physics is the study of rigid matter or solids through methods such as quantum mechanics, crystallography, electromagnetism, and metallurgy. It is the largest branch of condensed matter physics (PH.9 e).	**Student Experience Notebook:** Metals, 184-185 Forces in Materials, 241 Coulomb Forces Between Atoms, 251 Covalent Bonds, 252-253 Metallic Bonds, 254 States of Matter, 256-257 Conductivity of Materials, 259 Stress and Strain, 260-261 Bulk Modulus, 262 Metallic Properties in Alloys, 264 Ceramics and Glass, 266-268 **Teacher Guide:** **Inquiry Labs:** Physical Properties of Solid Materials **Digital Activities:** Forces Between Atoms; Attractive and Repulsive Forces; Material Properties **Performance Based Assessments:** Structure-Property Relationships; Forces in Materials
• Matter behaves differently at nanometer scale (size and distance) than at macroscopic scale (PH.9 f).	For supporting content, please see: **Student Experience Notebook:** Conductivity and Resistivity, 188
• Certain materials at very low temperatures exhibit the property of zero resistance called superconductivity (PH.9 g).	**Student Experience Notebook:** SEP Obtain Information, 186
• Nuclear physics is the study of the nature of atomic nuclei, including the interactions among protons, neutrons, and the quarks that comprise them (PH.9 d).	**Student Experience Notebook:** The Nucleus, 570-571 Size and Mass of the Nucleus, 572-573 Elementary Particles, 576 Leptons and Quarks, 578-579 **Teacher Guide:** **Inquiry Labs:** Subatomic Particles **Digital Activities:** Nuclear Particles; The Nucleus

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• The Standard Model of particle physics is a theory concerning the electromagnetic, weak, and strong nuclear interactions, as well as classifying all the known subatomic particles (PH.9 h).	**Student Experience Notebook:** Elementary Particles, 576 Leptons and Quarks, 578-579 Four Fundamental Forces, 581 Strong Force, 582-583 Weak Nuclear Force, 591-592 **Teacher Guide:** **Inquiry Labs:** Subatomic Particles; Forces and Atomic Nuclei **Digital Activities:** The Nucleus; Nuclear Forces; Strong Nuclear Force
• The fundamental particles (quarks, protons, and neutrons) that emerged in the early universe soon after the big bang are the same types of particles that are studied today in particle physics experiments at laboratories such as the Large Hadron Collider (LHC) in Switzerland and the Thomas Jefferson National Accelerator Facility (JLab) in Newport News, Virginia (PH.9 h).	**Student Experience Notebook:** Elementary Particles, 576 Leptons and Quarks, 578-579 History of the Universe, 686-687
Essential Knowledge and Practices	
In order to meet this standard, it is expected that students will	
• evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described by either a wave model or a particle model, and that for some situations one model is more useful than another (PH.9 a, b)	**Student Experience Notebook:** Shortcomings of the Wave Theory, 520-521 SEP Evaluate Claims, 521 Photoelectric Effect, 522 Particles of Light, 523 SEP Argue from Evidence, 523 The Dual Nature of Light, 524-525 CCC Patterns, 525 SEP Use Evidence, 528 **Teacher Guide:** **Inquiry Labs:** Particle Nature of Light **Digital Activities:** Particle-Wave Duality

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• communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy (PH.9 a, b)	**Student Experience Notebook:** Audio Information, 549 Medical Imaging, 552-553 SEP Construct Explanations, 552 Antennas, 554-555 SEP Construct Explanations, 556 Capturing an EM Wace's Energy, 557-559 Cooking, 562 Radiotherapy, 563 CCC Matter and Energy, 564 SEP Argue from Evidence, 564 **Teacher Guide:** **Inquiry Labs:** Converting Electrical Signals to Sounds; Converting Sunlight to Electricity **Digital Activities:** Antennas; Solar Panels on a Cloudy Day
• provide examples of technologies used to explore topics in modern physics (PH.9, b, c, d, e, f, g, h, i)	**Student Experience Notebook:** Polarization, 517 SEP Form a Hypothesis, 537 **Teacher Guide:** **Engineering Workbenches:** The Colors of Light **Related Phenomena:** Particle Accelerators, 366
• compare classical physics and modern physics at the extremes of speed and size (PH.9 a, b, c, d, e, f, g, h, i)	For supporting content, please see: **Student Experience Notebook:** Nuclear Physics, 569
• explore the connections between and the benefits of the pursuit of pure science and subsequent applications (PH.9 a, b, c, d, e, f, g, h, i).	**Student Experience Notebook:** CCC Structure and Function, 267 Ceramics and Glass in Everyday Life, 268 Metal Detectors and Their Applications, 443 Understanding the Photoelectric Effect, 522 Applications of Nuclear Fission, 599 **Teacher Guide:** **Performance Based Assessments:** Operate a Nuclear Fission Reactor **Engineering Workbenches:** Earthquake-Resistant Structures