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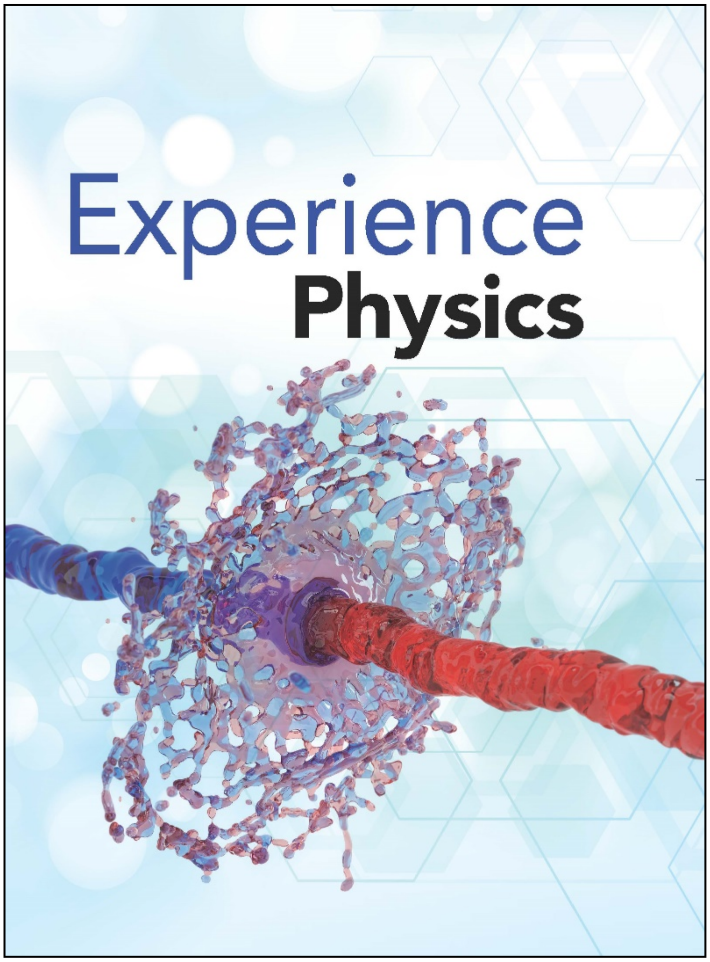

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To the

Arkansas
Science Standards 2016
High School Physics

Prepared by Savvas Learning Company, formerly Pearson K12 Learning

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Introduction

This document demonstrates how ***Experience Physics* ©2022** supports the Arkansas Science Standards 2016 for High School Physics. Correlation references include the 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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Developing and Using Models	
Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.	
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Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.	
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Science and Engineering Practices	
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Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.	
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Performance Expectation P-ESS1-2 Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.	**Experience Notebook:** Gravitational Force, 118-119 **Teacher Guide:** **Inquiry Labs:** Model the Orbital Motion of Planets; Kepler's Laws of Planetary Motion **Digital Activities:** Orbital Motion; Eccentric Orbits; Kepler's Laws **Performance-Based Assessments:** Gravitational Forces on Satellites
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Newton's second law accurately predicts changes in the motion of macroscopic objects. (Performance Expectation P-PS2-1, Performance Expectation P-PS2-2, P-PS-1-1AR, P-ESS1-2, P-ESS1-4, P1-ETS1-2)	**Experience Notebook:** Force Causes an Acceleration, 54 Weight, 66
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Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.	
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Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (P1-ETS1-2)	**Teacher Guide:** **Engineering Workbenches:** Landslide Prevention; Defy Gravity
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Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (P1-ETS1-2)	**Student Experience Notebook:** SEP Design a Solution, 45 SEP Design a Solution, 84 SEP Design a Solution, 94 SEP Design a Solution, 124 **Teacher Guide:** **Engineering Workbenches:** Design an Airdrop System; Landslide Prevention; Defy Gravity
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Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s).	
Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (Performance Expectation P-PS2-1AR)	**Experience Notebook:** SEP Develop a Model, 284 Sample Problem: Work Done on a Book, 290 SEP Develop a Model, 312 SEP Develop a Model, 313 SEP Use Mathematics (60), 318 **Teacher Guide:** **Inquiry Labs:** Gas Particles and Work; The Impact of Position on Energy **Digital Activities:** Hooke's Law and Elastic Potential Energy; Energy in a Moving Cart
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Science assumes the universe is a vast single system in which basic laws are consistent. (Performance Expectation P-PS2-1AR, Performance Expectation P-PS2-2AR, Performance Expectation P-PS2-3AR)	**Experience Notebook:** Energy - A Conserved Quantity, 309 SEP Evaluate Information, 318 **Teacher Guide:** **Inquiry Labs:** Pendulums and the Conservation of Energy **Performance-Based Assessments:** Rocket Launch

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Performance Expectation P-PS2-2AR Plan and conduct an investigation to provide evidence that work done equals energy stored in a conservative system. [Clarification Statement: An example of an investigation could include Hooke's law where energy is stored in a spring.]	**Experience Notebook:** Work Done by a Gas, 285-286 Kinetic Energy and the Work-Energy Theorem, 288 Energy Bar Charts, 289 SEP Use Mathematics (20), 293 CCC Cause and Effect, 293 Elastic Potential Energy, 296-297 Sample Problem: Cart on a Spring, 298-299 **Teacher Guide:** **Inquiry Labs:** Gas Particles and Work **Digital Activities:** Hooke's Law and Elastic Potential Energy; Conservation of Energy
Disciplinary Core Ideas	
PS3.A: Definitions of Energy	
Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. (Performance Expectation P-PS2-2AR)	**Experience Notebook:** Defining Energy of Motion, 287 Kinetic Energy and the Work-Energy Theorem, 288 SEP Use Mathematics (19), 293 Potential Energy, 294 Gravitational Potential Energy, 295 SEP Use Mathematics, 295 Elastic Potential Energy, 296-297 Sample Problem: Cart on a Spring, 298-299 Electromagnetic Potential Energy, 300-301 Mechanical Energy and Work, 302-303 CCC Energy and Matter, 308 Energy - A Conserved Quantity, 309 SEP Construct an Explanation, 309 Energy Transformed Within a System, 313 SEP Use Mathematics (60), 318 CCC Energy and Matter, 318 **Teacher Guide:** **Inquiry Labs:** The Impact of Position on Energy; Pendulums and the Conservation of Energy **Digital Activities:** Mechanical Energy; Asteroid Impact Models **Performance-Based Assessments:** Energy Conversion; Rocket Launch

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Arkansas Science Standards 2016 High School Physics	Experience Physics ©2022
PS3.B: Conservation of Energy and Energy Transfer	
Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (Performance Expectation P-PS2-2AR)	**Experience Notebook:** Energy - A Conserved Quantity, 309 SEP Construct an Explanation, 309 Defining Systems, 310 Expanded Work-Energy Theorem, 312 Energy Transformed Within a System, 313 SEP Evaluate Information, 318 SEP Use Mathematics (60), 318 CCC Energy and Matter, 318 **Teacher Guide:** **Inquiry Labs:** Pendulums and the Conservation of Energy **Digital Activities:** Conservation of Energy; Pendulum Decay **Performance-Based Assessments:** Rocket Launch
Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. (Performance Expectation P-PS2-2AR)	**Experience Notebook:** Defining Energy of Motion, 287 SEP Use Mathematics, 287 SEP Use Mathematics (19), 293 Gravitational Potential Energy, 295 SEP Use Mathematics, 295 Elastic Potential Energy, 296-297 SEP CCC Cause and Effect, 297 Electromagnetic Potential Energy, 300-301 Energy - A Conserved Quantity, 309 Defining Systems, 310 SEP Use Math, 311 Expanded Work-Energy Theorem, 312 SEP Use Mathematics, 313 Sample Problem: Roller Coaster Energy, 314-315 **Teacher Guide:** **Inquiry Labs:** The Impact of Position on Energy; Pendulums and the Conservation of Energy

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Science and Engineering Practices	
Planning and Carrying Out Investigations	
Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.	
Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.	**Teacher Guide:** **Inquiry Labs:** Gas Particles and Work; The Impact of Position on Energy; Pendulums and the Conservation of Energy **Digital Activities:** Conservation of Energy
Connections to Nature of Science	
Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena	
A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence.	**Experience Notebook:** Kinetic Energy and the Work-Energy Theorem, 288 Expanded Work-Energy Theorem, 312
Models, mechanisms, and explanations collectively serve as tools in the development of a scientific theory. (Performance Expectation P-PS2-2AR, Performance Expectation P-PS2-3AR)	**Experience Notebook:** Kinetic Energy and the Work-Energy Theorem, 288 Energy Bar Charts, 289 Sample Problem: Cart on a Spring, 298-299 Expanded Work-Energy Theorem, 312 SEP Develop a Model, 312 SEP Develop a Model, 313 Sample Problem: Roller Coaster Energy, 314-315
Crosscutting Concepts	
Systems and System Models	
When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. (Performance Expectation P-PS2-1AR, Performance Expectation P-PS2-2AR, Performance Expectation P-PS2-3AR)	**Experience Notebook:** SEP Develop a Model, 284 Energy Bar Charts, 289 Modeling Systems, 311 SEP Develop a Model, 312 SEP Develop a Model, 313 **Teacher Guide:** **Inquiry Labs:** Pendulums and the Conservation of Energy **Digital Activities:** Conservation of Energy **Performance-Based Assessments:** Rocket Launch

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Arkansas Science Standards 2016 High School Physics	**Experience Physics ©2022**
Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. (Performance Expectation P-PS2-1AR, Performance Expectation P-PS2-2AR, Performance Expectation P-PS2-3AR)	**Experience Notebook:** SEP Use Math, 311 **Teacher Guide:** **Inquiry Labs:** Gas Particles and Work **Digital Activities:** Energy in a Moving Cart; Asteroid Impact Models
Connections to Nature of Science	
Scientific Knowledge Assumes an Order and Consistency in Natural Systems	
Science assumes the universe is a vast single system in which basic laws are consistent. (Performance Expectation P-PS2-1AR, Performance Expectation P-PS2-2AR, Performance Expectation P-PS2-3AR)	**Experience Notebook:** Energy - A Conserved Quantity, 309 SEP Construct an Explanation, 309 Defining Systems, 310 Expanded Work-Energy Theorem, 312 Energy Transformed Within a System, 313 SEP Evaluate Information, 318 **Teacher Guide:** **Inquiry Labs:** Pendulums and the Conservation of Energy **Digital Activities:** Conservation of Energy; Pendulum Decay **Performance-Based Assessments:** Rocket Launch
Performance Expectation P-PS2-3AR Plan and conduct an investigation to rate the power used in performing work on a system. [Clarification Statement: Emphasis is on the quantitative determination of power in interactions. Examples could include use of pulleys and electric motors.]	**Experience Notebook:** Power, 292 Power - the Rate of Energy Transfer, 316-317 SEP Analyze Data, 317 SEP Use Mathematics (59), 318 **Teacher Guide:** **Performance-Based Assessments:** Energy Conversion
Disciplinary Core Ideas	
PS3.C: Relationship Between Energy and Forces	
When two objects interacting through a force field change relative position, the energy stored in the force field is changed. (Performance Expectation P-PS2-1AR, Performance Expectation P-PS2-3AR, Performance Expectation P-PS2-5AR)	**Experience Notebook:** Potential Energy, 294 Gravitational Potential Energy, 295 Elastic Potential Energy, 296-297 Electromagnetic Potential Energy, 300-301 Power and Work, 316 **Teacher Guide:** **Inquiry Labs:** The Impact of Position on Energy

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Arkansas Science Standards 2016 High School Physics	Experience Physics ©2022
Science and Engineering Practices	
Planning and Carrying Out Investigations	
Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.	
Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.	**Teacher Guide:** **Performance-Based Assessments:** Energy Conversion
Connections to Nature of Science	
Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena	
A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence.	**Experience Notebook:** Kinetic Energy and the Work-Energy Theorem, 288 Expanded Work-Energy Theorem, 312 Power - The Rate of Energy Transfer, 316-317
Models, mechanisms, and explanations collectively serve as tools in the development of a scientific theory. (Performance Expectation P-PS2-2AR, Performance Expectation P-PS2-3AR)	**Experience Notebook:** Kinetic Energy and the Work-Energy Theorem, 288 Expanded Work-Energy Theorem, 312 SEP Develop a Model, 312 Power - The Rate of Energy Transfer, 316-317 SEP Construct an Explanation, 316
Crosscutting Concepts	
Connections to Nature of Science	
Scientific Knowledge Assumes an Order and Consistency in Natural Systems	
Science assumes the universe is a vast single system in which basic laws are consistent. (Performance Expectation P-PS2-1AR, Performance Expectation P-PS2-2AR, Performance Expectation P-PS2-3AR)	**Experience Notebook:** Energy - A Conserved Quantity, 309 SEP Construct an Explanation, 309 Defining Systems, 310 Expanded Work-Energy Theorem, 312 Energy Transformed Within a System, 313 SEP Evaluate Information, 318 **Teacher Guide:** **Inquiry Labs:** Pendulums and the Conservation of Energy **Digital Activities:** Conservation of Energy; Pendulum Decay **Performance-Based Assessments:** Rocket Launch

Arkansas Science Standards 2016 High School Physics	Experience Physics ©2022
Performance Expectation P-PS2-4AR Analyze data to demonstrate the relationship between rotational and linear motion, energy, and momentum. [Clarification Statement: Emphasis is on linear motion and angular motion, force and torque, linear momentum and angular momentum, and linear kinetic energy and rotational kinetic energy, mass and moment of inertia.]	**Experience Notebook:** Defining Energy of Motion, 287 Introduction to Linear Momentum, 322 The Moment of Inertia, 325 Angular Momentum, 326 Impulse, 327 SEP Use Mathematics, 327 Angular Impulse, 328 SEP Construct an Explanation, 328 SEP Use Mathematics (9), 329 Impulse and Momentum in Collisions, 338-339 Types of Collisions, 342-343 SEP Use Mathematics, 343 Sample Problem: A Ballistic Pendulum, 344-345 Sample Problem: Inelastic Collision, 346 SEP Use Mathematics, 347 **Teacher Guide:** **Inquiry Labs:** Momentum and Impulse During Collisions; Elastic and Inelastic Collisions **Performance-Based Assessments:** Minimizing Car Crash Injuries
Science and Engineering Practices	
Analyzing and Interpreting Data	
Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.	
Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. (Performance Expectation P-PS2-4AR)	**Experience Notebook:** SEP Use Mathematics, 323 SEP Use Mathematics, 324 SEP Use Mathematics, 327 SEP Construct an Explanation, 328 SEP Use Mathematics (9), 329 SEP Argue from Evidence, 338 Sample Problem: What a Racket, 340 Sample Problem: High-Speed Collision, 341 SEP Argue from Evidence, 343 SEP Use Mathematics, 343 Sample Problem: A Ballistic Pendulum, 344-345 Sample Problem: Inelastic Collision, 346 SEP Use Mathematics, 347 **Teacher Guide:** **Inquiry Labs:** Momentum and Impulse During Collisions; Elastic and Inelastic Collisions **Performance-Based Assessments:** Minimizing Car Crash Injuries

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Arkansas Science Standards 2016 High School Physics	Experience Physics ©2022
Crosscutting Concepts	
Energy and Matter	
The total amount of energy and matter in closed systems is conserved. (Performance Expectation P-PS2-4AR, Performance Expectation P-PS2-5AR)	**Experience Notebook:** Conserving Mass, 330 Types of Collisions, 342-343 **Teacher Guide:** **Inquiry Labs:** Elastic and Inelastic Collisions **Digital Activities:** Kinetic Energy and Collisions
Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (Performance Expectation P-PS2-4AR, Performance Expectation P-PS2-5AR)	**Experience Notebook:** SEP Argue from Evidence, 343 SEP Use Mathematics, 343 Sample Problem: Inelastic Collision, 346 SEP Use Mathematics, 347 **Teacher Guide:** **Inquiry Labs:** Elastic and Inelastic Collisions **Digital Activities:** Kinetic Energy and Collisions
Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. (Performance Expectation P-PS2-4AR, Performance Expectation P-PS2-5AR)	**Experience Notebook:** Types of Collisions, 342-343 SEP Argue from Evidence, 343 SEP Use Mathematics, 343 Sample Problem: Inelastic Collision, 346 SEP Use Mathematics, 347 **Teacher Guide:** **Inquiry Labs:** Elastic and Inelastic Collisions **Digital Activities:** Kinetic Energy and Collisions

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Arkansas Science Standards 2016 High School Physics	Experience Physics ©2022
Performance Expectation P-PS2-5AR Use mathematical representations to support the claim that the change in kinetic energy of a system is equal to the net work performed upon the system. [Clarification Statement: Emphasis is on quantitative kinetic energy in interactions.]	**Experience Notebook:** Kinetic Energy and the Work-Energy Theorem, 288 SEP Use Mathematics, 288 Energy Bar Charts, 289 Sample Problem: Work Done on a Book, 290-291 SEP Use Mathematics (20), 293 Mechanical Energy Bar Charts, 303 Modeling Systems, 311 Sample Problem: Roller Coaster Energy, 314-315 **Teacher Guide:** **Inquiry Labs:** Gas Particles and Work
Disciplinary Core Ideas	
PS3.C: Relationship Between Energy and Forces	
When two objects interacting through a force field change relative position, the energy stored in the force field is changed. (Performance Expectation P-PS2-1AR, Performance Expectation P-PS2-3AR, Performance Expectation P-PS2-5AR)	**Experience Notebook:** Potential Energy, 294 Mechanical Energy Bar Charts, 303 Sample Problem: Bowling Ball Bounce, 304-305 **Teacher Guide:** **Inquiry Labs:** The Impact of Position on Energy
Science and Engineering Practices	
Using Mathematics and Computational Thinking	
Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.	
Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. (Performance Expectation P-PS2-5AR, Performance Expectation P-PS2-6AR)	**Experience Notebook:** SEP Use Mathematics, 288 Sample Problem: Work Done on a Book, 290-291 SEP Use Mathematics (20), 293 Sample Problem: Roller Coaster Energy, 314-315 **Teacher Guide:** **Inquiry Labs:** Gas Particles and Work **Performance-Based Assessments:** Rocket Launch

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Arkansas Science Standards 2016 High School Physics	Experience Physics ©2022
Crosscutting Concepts	
Energy and Matter	
The total amount of energy and matter in closed systems is conserved. (Performance Expectation P-PS2-4AR, Performance Expectation P-PS2-5AR)	**Experience Notebook:** Energy - A Conserved Quantity, 309 SEP Construct an Explanation, 309 Modeling Systems, 311 Expanded-Work Energy Theorem, 312 **Teacher Guide:** **Inquiry Labs:** Pendulums and the Conservation of Energy **Digital Activities:** Conservation of Energy; Pendulum Decay **Performance-Based Assessments:** Rocket Launch
Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (Performance Expectation P-PS2-4AR, Performance Expectation P-PS2-5AR)	**Experience Notebook:** Modeling Systems, 311 Energy Transformed Within a System, 313 SEP Use Mathematics (60), 318 CCC Energy and Matter, 318 **Teacher Guide:** **Inquiry Labs:** Pendulums and the Conservation of Energy **Digital Activities:** Pendulum Decay **Performance-Based Assessments:** Rocket Launch
Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. (Performance Expectation P-PS2-4AR, Performance Expectation P-PS2-5AR)	**Experience Notebook:** Energy - A Conserved Quantity, 309 SEP Construct an Explanation, 309 Defining Systems, 310 Modeling Systems, 311 Energy Transformed Within a System, 313 SEP Evaluate Information, 318 SEP Use Mathematics (60), 318 CCC Energy and Matter, 318 **Teacher Guide:** **Inquiry Labs:** Pendulums and the Conservation of Energy **Digital Activities:** Pendulum Decay **Performance-Based Assessments:** Rocket Launch

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Performance Expectation P-PS2-6AR Use mathematical representations to support the claim that the total impulse on a system of objects is equal to the change in momentum of the system. [Clarification Statement: Emphasis is on quantitative conservation of momentum in interactions.]	**Experience Notebook:** Impulse, 327 SEP Use Mathematics, 327 SEP Use Mathematics (9), 329 Impulse-Momentum Theorem, 336-337 SEP Use Mathematics, 336 SEP Develop a Model, 337 SEP Argue from Evidence, 338 Comparing Momenta in Systems, 339 Sample Problem: What a Racket, 340 Sample Problem: High-Speed Collision, 341 **Teacher Guide:** **Inquiry Labs:** Momentum and Impulse During Collisions **Digital Activities:** Momentum and Impulse **Performance-Based Assessments:** Minimizing Car Crash Injuries
Disciplinary Core Ideas	
PS2.A: Forces and Motion	
Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. (Performance Expectation P-PS2-6AR)	**Experience Notebook:** Introduction to Linear Momentum, 322 Momentum - a Vector Quantity, 323 SEP Use Mathematics, 323 Net Momentum, 324 SEP Use Mathematics, 324 **Teacher Guide:** **Inquiry Labs:** Momentum and Impulse During Collisions **Digital Activities:** Momentum and Baseball
In any system, total momentum is always conserved. If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system. (Performance Expectation P-PS2-6AR)	**Experience Notebook:** Conserving Momentum, 331 Sample Problem: Conserving Momentum in Space, 332 Comparing Momenta in Collisions, 339 Types of Collisions, 342-343 **Teacher Guide:** **Inquiry Labs:** Elastic and Inelastic Collisions **Digital Activities:** Conservation of Momentum; Kinetic Energy and Collisions **Performance-Based Assessments:** Minimizing Car Crash Injuries

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Arkansas Science Standards 2016 High School Physics	Experience Physics ©2022
Science and Engineering Practices	
Using Mathematics and Computational Thinking	
Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.	
Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. (Performance Expectation P-PS2-5AR, Performance Expectation P-PS2-6AR)	**Experience Notebook:** SEP Use Mathematics, 327 SEP Use Mathematics (9), 329 SEP Use Mathematics, 336 SEP Develop a Model, 337 SEP Argue from Evidence, 338 Comparing Momenta in Systems, 339 Sample Problem: What a Racket, 340 Sample Problem: High-Speed Collision, 341 **Teacher Guide:** **Inquiry Labs:** Momentum and Impulse During Collisions **Digital Activities:** Momentum and Impulse **Performance-Based Assessments:** Minimizing Car Crash Injuries
Crosscutting Concepts	
Cause and Effect	
Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (Performance Expectation P-PS2-6AR)	**Experience Notebook:** CCC Cause and Effect, 321 **Teacher Guide:** **Inquiry Labs:** Momentum and Impulse During Collisions
Systems can be designed to cause a desired effect. (Performance Expectation P-PS2-6AR)	**Teacher Guide:** **Performance-Based Assessments:** Build Your Own Egg-Transport Vehicle; Minimizing Car Crash Injuries **Engineering Workbenches:** Egg Supply Drop

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Performance Expectation P2-ETS1-3 Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts. [AR Clarification Statement: Examples could include analysis of nuclear, coal, and hydro-electric power plants.]	**Experience Notebook:** SEP Design a Solution, 409 SEP Design a Solution, 434 Impacts on the Biosphere, 447 Costs and Benefits, 452-453 Costs and Benefits: Oil, Gas, and Coal, 454 Costs and Benefits: Wind, Solar, and Biomass, 455 Costs and Benefits: Hydroelectric, Geothermal, Tides, and Waves, 456 Costs and Benefits: Nuclear Power, 457 Sustainable Energy Future, 458-459 **Teacher Guide:** **Inquiry Labs:** Natural Resource Management **Digital Activities:** Resource Use and Biodiversity Trade-Offs; Energy Resources and Conservation; Energy Choices **Performance-Based Assessments:** Rocket Launch; Build Your Own Egg-Transport Vehicle; Minimizing Car Crash Injuries; Design, Build, and Refine a Wind-Turbine Motor; Junkyard Electromagnet **Engineering Workbenches:** Design a Roller Coaster; Egg Supply Drop; Energy Sources: Costs and Benefits
Disciplinary Core Ideas	
PS3.D: Energy in Chemical Processes	
Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. Machines are judged as efficient or inefficient based on the amount of energy input needed to perform a particular useful task. Inefficient machines are those that produce more waste heat while performing a task and thus require more energy input. It is therefore important to design for high efficiency so as to reduce costs, waste materials, and many environmental impacts. (Performance Expectation P2-ETS1-3)	**Experience Notebook:** Energy - A Conserved Quantity, 309 Energy Forms and Sectors, 449 SEP Analyze Data, 449 Energy Storage Technologies, 451 SEP Argue from Evidence, 460
ETS1.A: Defining and Delimiting Engineering Problems	
Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (Performance Expectation P2-ETS1-3)	**Student Experience Notebook:** Costs and Benefits, 452-453 Costs and Benefits: Oil, Gas, and Coal, 454 Costs and Benefits: Wind, Solar, and Biomass, 455 Costs and Benefits: Hydroelectric, Geothermal, Tides, and Waves, 456 Costs and Benefits: Nuclear Power, 457

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Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (Performance Expectation P2-ETS1-3)	**Experience Notebook:** Human Use of Energy, 445-446 Human Power Needs, 449-450 Energy Storage Technologies, 451 Sustainable Energy Future, 458-459 **Teacher Guide:** **Inquiry Labs:** Natural Resource Management **Digital Activities:** Resource Use and Biodiversity Trade-Offs; Energy Choices **Performance-Based Assessments:** Design, Build, and Refine a Wind-Turbine Motor **Engineering Workbenches:** Energy Sources: Costs and Benefits
ETS1.B: Developing Possible Solutions	
When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (Performance Expectation P2-ETS1-3)	**Student Experience Notebook:** Costs and Benefits, 452-453 Costs and Benefits: Oil, Gas, and Coal, 454 Costs and Benefits: Wind, Solar, and Biomass, 455 Costs and Benefits: Hydroelectric, Geothermal, Tides, and Waves, 456 Costs and Benefits: Nuclear Power, 457 **Teacher Guide:** **Inquiry Labs:** Natural Resource Management **Digital Activities:** Resource Use and Biodiversity Trade-Offs; Energy Resources and Conservation; Energy Choices **Performance-Based Assessments:** Design, Build, and Refine a Wind-Turbine Motor; Junkyard Electromagnet **Engineering Workbenches:** Energy Sources: Costs and Benefits
Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (Performance Expectation P2-ETS1-3)	**Teacher Guide:** **Inquiry Labs:** Natural Resource Management **Digital Activities:** Energy Resources and Conservation **Performance-Based Assessments:** Build Your Own Egg-Transport Vehicle; Design, Build, and Refine a Wind-Turbine Motor **Engineering Workbenches:** Design a Roller Coaster; Egg Supply Drop; Energy Sources: Costs and Benefits

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ETS1.C: Optimizing the Design Solution	
Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (Performance Expectation P2-ETS1-3)	**Teacher Guide:** **Performance-Based Assessments:** Build Your Own Egg-Transport Vehicle **Engineering Workbenches:** Design a Roller Coaster; Egg Supply Drop; Energy Sources: Costs and Benefits
Science and Engineering Practices	
Constructing Explanations and Designing Solutions	
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.	
Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. (Performance Expectation P2-ETS1-3)	**Experience Notebook:** SEP Argue from Evidence, 455 SEP Construct an Argument, 459 SEP Argue from Evidence, 460 **Teacher Guide:** **Digital Activities:** Resource Use and Biodiversity Trade-Offs
Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (Performance Expectation P2-ETS1-3)	**Experience Notebook:** SEP Design a Solution, 409 SEP Design a Solution, 434 **Teacher Guide:** **Performance-Based Assessments:** Rocket Launch; Build Your Own Egg-Transport Vehicle; Minimizing Car Crash Injuries; Design, Build, and Refine a Wind-Turbine Motor; Junkyard Electromagnet **Engineering Workbenches:** Design a Roller Coaster; Egg Supply Drop; Energy Sources: Costs and Benefits

Arkansas Science Standards 2016 High School Physics	Experience Physics ©2022
Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (Performance Expectation P2-ETS1-3)	**Experience Notebook:** Impacts on the Biosphere, 447 Costs and Benefits, 452-453 Costs and Benefits: Oil, Gas, and Coal, 454 Costs and Benefits: Wind, Solar, and Biomass, 455 Costs and Benefits: Hydroelectric, Geothermal, Tides, and Waves, 456 Costs and Benefits: Nuclear Power, 457 Sustainable Energy Future, 458-459 **Teacher Guide:** **Digital Activities:** Resource Use and Biodiversity Trade-Offs; Energy Resources and Conservation; Energy Choices **Performance-Based Assessments:** Rocket Launch; Build Your Own Egg-Transport Vehicle; Minimizing Car Crash Injuries; Design, Build, and Refine a Wind-Turbine Motor; Junkyard Electromagnet **Engineering Workbenches:** Design a Roller Coaster; Egg Supply Drop; Energy Sources: Costs and Benefits
Crosscutting Concepts	
Connections to Engineering, Technology, and Applications of Science	
Influence of Science, Engineering, and Technology on Society and the Natural World	
Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (Performance Expectation P2-ETS1-3)	**Experience Notebook:** Human Use of Energy, 445-446 Human Power Needs, 449-450 Energy Storage Technologies, 451 Costs and Benefits, 452-453 Sustainable Energy Future, 458-459 **Teacher Guide:** **Performance-Based Assessments:** Minimizing Car Crash Injuries; Design, Build, and Refine a Wind-Turbine Motor; Junkyard Electromagnet **Engineering Workbenches:** Energy Sources: Costs and Benefits

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New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (Performance Expectation P2-ETS1-3)	**Experience Notebook:** Costs and Benefits, 452-453 Costs and Benefits: Wind, Solar, and Biomass, 455 Costs and Benefits: Hydroelectric, Geothermal, Tides, and Waves, 456 Costs and Benefits: Nuclear Power, 457 **Teacher Guide:** **Digital Activities:** Energy Choices **Performance-Based Assessments:** Design, Build, and Refine a Wind-Turbine Motor; Junkyard Electromagnet **Engineering Workbenches:** Energy Sources: Costs and Benefits

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Topic 3: Heat and Thermodynamics	
Students who demonstrate understanding can:	
Performance Expectation P-PS3-1 Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.	**Experience Notebook:** Transferring Energy Through Heating, 374-375 SEP Analyze Data, 375 SEP Use Mathematics, 376 SEP Use Mathematics (22), 380 SEP Use Mathematics (23), 380 **Teacher Guide:** **Inquiry Labs:** Kinetic Energy; Heat Transfer **Digital Activities:** Thermal Equilibrium and Heat Flow **Performance-Based Assessments:** Heating Curve of Water
Disciplinary Core Ideas	
PS3.A: Definitions of Energy	
Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. (Performance Expectation P-PS3-1)	**Experience Notebook:** Average Kinetic Energy of Gas Particles, 369 SEP Use Mathematics, 369 Transferring Energy Through Heating, 374-375 SEP Analyze Data, 375 SEP Use Mathematics (22), 380 SEP Use Mathematics (23), 380 CCC Systems and System Models, 380 Thermal Equilibrium, 381 Energy Transfer Through Heating, 382-383 **Teacher Guide:** **Inquiry Labs:** Kinetic Energy; Heat Transfer **Digital Activities:** Thermal Equilibrium and Heat Flow **Performance-Based Assessments:** Heating Curve of Water; Meltdown at the Pool
Developing and Using Models	
Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s).	
Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (Performance Expectation P-PS3-1, Performance Expectation P3-ETS1-4)	**Experience Notebook:** CCC Systems and System Models, 380 **Teacher Guide:** **Inquiry Labs:** Kinetic Energy **Digital Activities:** Thermal Equilibrium and Heat Flow **Performance-Based Assessments:** Heating Curve of Water

*An asterisk indicates an engineering connection to a practice or disciplinary core idea.

Arkansas Science Standards 2016 High School Physics	Experience Physics ©2022
Crosscutting Concepts	
Cause and Effect	
Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (Performance Expectation P-PS3-1, Performance Expectation P-PS3-1AR, Performance Expectation P-PS3-2AR)	**Experience Notebook:** CCC Matter and Energy, 365 **Teacher Guide:** **Inquiry Labs:** Kinetic Energy **Performance-Based Assessments:** Meltdown at the Pool
Systems can be designed to cause a desired effect. (Performance Expectation P-PS3-1, Performance Expectation P-PS3-1AR, Performance Expectation P-PS3-2AR)	**Experience Notebook:** Thermodynamic Heat Engines, 386-387 Heat Pumps, 390-391 SEP Design a Solution, 393 **Teacher Guide:** **Engineering Workbenches:** Build an Efficient Travel Mug

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Arkansas Science Standards 2016 High School Physics	**Experience Physics ©2022**
Performance Expectation P-PS3-1AR Construct an explanation based on evidence of the relationships between heat, temperature, and the Kinetic Molecular Theory.	**Experience Notebook:** Average Kinetic Energy of Gas Particles, 369 Understanding Temperature, 370-372 CCC Energy and Matter, 371 SEP Use Models, 372 **Teacher Guide:** **Inquiry Labs:** Kinetic Energy **Digital Activities:** Temperature
Disciplinary Core Ideas	
PS2.C: Stability and Instability in Physical Systems	
When a system has a great number of component pieces, one may not be able to predict much about its precise future. For such systems (e.g., with very many colliding molecules), one can often predict average but not detailed properties and behaviors (e.g., average temperature, motion, and rates of chemical change but not the trajectories or other changes of particular molecules). (Performance Expectation P-PS3-4, Performance Expectation P-PS3-1AR, Performance Expectation P-PS3-2)	**Experience Notebook:** Average Kinetic Energy of Gas Particles, 369 SEP Use Mathematics, 369 SEP Use Mathematics, 371 **Teacher Guide:** **Inquiry Labs:** Kinetic Energy **Digital Activities:** Gasoline Expansion
PS3.B: Conservation of Energy and Energy Transfer	
Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (Performance Expectation P-PS3-1AR, Performance Expectation P-PS3-3)	**Experience Notebook:** Energy - A Conserved Quantity, 309 Transferring Energy Through Heating, 374-375 SEP Analyze Data, 375 Thermal Equilibrium, 381 SEP Construct an Explanation, 381 **Teacher Guide:** **Inquiry Labs:** Heat Transfer **Digital Activities:** Thermal Equilibrium and Heat Flow **Performance-Based Assessments:** Heating Curve of Water; Meltdown at the Pool
Science and Engineering Practices	
Constructing Explanations and Designing Solutions	
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.	
Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. (Performance Expectation P-PS3-1AR, Performance Expectation P-PS3-3, Performance Expectation P3-ETS1-2)	**Experience Notebook:** CCC Energy and Matter, 371 **Teacher Guide:** **Digital Activities:** Temperature

Arkansas Science Standards 2016 High School Physics	Experience Physics ©2022
Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (Performance Expectation P-PS3-1AR, Performance Expectation P-PS3-3, Performance Expectation P3-ETS1-2)	**Experience Notebook:** SEP Design a Solution, 393 **Teacher Guide:** **Engineering Workbenches:** Build an Efficient Travel Mug
Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (Performance Expectation P-PS3-1AR, Performance Expectation P-PS3-3, Performance Expectation P3-ETS1-2)	**Teacher Guide:** **Engineering Workbenches:** Build an Efficient Travel Mug
Crosscutting Concepts	
Cause and Effect	
Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (Performance Expectation P-PS3-1, Performance Expectation P-PS3-1AR, Performance Expectation P-PS3-2AR)	**Experience Notebook:** CCC Cause and Effect, 368 **Teacher Guide:** **Digital Activities:** Gasoline Expansion
Systems can be designed to cause a desired effect. (Performance Expectation P-PS3-1, Performance Expectation P-PS3-1AR, Performance Expectation P-PS3-2AR)	**Experience Notebook:** Thermodynamic Heat Engines, 386-387 Heat Pumps, 390-391 SEP Design a Solution, 393 **Teacher Guide:** **Engineering Workbenches:** Build an Efficient Travel Mug
Connections to Nature of Science	
Scientific Knowledge Assumes an Order and Consistency in Natural Systems	
Science assumes the universe is a vast single system in which basic laws are consistent. (Performance Expectation P-PS3-1AR, Performance Expectation P-PS3-2AR, Performance Expectation P-PS3-4)	**Experience Notebook:** Energy - A Conserved Quantity, 309
Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. (Performance Expectation P-PS3-1AR, Performance Expectation P-PS3-2AR, Performance Expectation P-PS3-4)	**Experience Notebook:** Energy - A Conserved Quantity, 309

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Arkansas Science Standards 2016 High School Physics	Experience Physics ©2022
Performance Expectation P-PS3-2AR Plan and conduct an investigation of the relationships between pressure, volume, temperature, and amount of gas.	For supporting content, please see: **Experience Notebook:** Ideal Gases: A Microscopic Approach, 368 CCC Cause and Effect, 368 Ideal Gases: A Macroscopic Approach, 373 SEP Use Mathematics, 373 Sample Problem: Expansion of an Ideal Gas, 378
Disciplinary Core Ideas	
PS2.C: Stability and Instability in Physical Systems	
When a system has a great number of component pieces, one may not be able to predict much about its precise future. For such systems (e.g., with very many colliding molecules), one can often predict average but not detailed properties and behaviors (e.g., average temperature, motion, and rates of chemical change but not the trajectories or other changes of particular molecules). (Performance Expectation P-PS3-4, Performance Expectation P-PS3-1AR, Performance Expectation P-PS3-2)	**Experience Notebook:** Average Kinetic Energy of Gas Particles, 369 SEP Use Mathematics, 369 Understanding Temperature, 370-371 SEP Use Mathematics, 373
Science and Engineering Practices	
Planning and Carrying Out Investigations	
Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.	
Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (Performance Expectation P-PS3-2AR, Performance Expectation P-PS3-4)	For supporting content, please see: **Experience Notebook:** Ideal Gases: A Microscopic Approach, 368 CCC Cause and Effect, 368 Ideal Gases: A Macroscopic Approach, 373 SEP Use Mathematics, 373 Sample Problem: Expansion of an Ideal Gas, 378
Crosscutting Concepts	
Cause and Effect	
Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (Performance Expectation P-PS3-1, Performance Expectation P-PS3-1AR, Performance Expectation P-PS3-2AR)	**Experience Notebook:** CCC Cause and Effect, 368
Systems can be designed to cause a desired effect. (Performance Expectation P-PS3-1, Performance Expectation P-PS3-1AR, Performance Expectation P-PS3-2AR)	**Experience Notebook:** Pressure and Volume, 368

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Arkansas Science Standards 2016 High School Physics	Experience Physics ©2022
Connections to Nature of Science	
Scientific Knowledge Assumes an Order and Consistency in Natural Systems	
Science assumes the universe is a vast single system in which basic laws are consistent. (Performance Expectation P-PS3-1AR, Performance Expectation P-PS3-2AR, Performance Expectation P-PS3-4)	**Experience Notebook:** Ideal Gases: A Macroscopic Approach, 373 Sample Problem: Expansion of an Ideal Gas, 378
Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. (Performance Expectation P-PS3-1AR, Performance Expectation P-PS3-2AR, Performance Expectation P-PS3-4)	**Experience Notebook:** Ideal Gases: A Macroscopic Approach, 373 Sample Problem: Expansion of an Ideal Gas, 378
Performance Expectation P-PS3-3AR Use mathematical representations to model the conservation of energy in fluids.	For supporting content, please see: **Experience Notebook:** Energy - A Conserved Quantity, 309 Convection, 383 **Teacher Guide:** **Digital Activities:** Gasoline Expansion
Science and Engineering Practices	
Using Mathematics and Computational Thinking	
Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.	
Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. (Performance Expectation P-PS3-3AR)	For supporting content, please see: **Teacher Guide:** **Digital Activities:** Gasoline Expansion
Crosscutting Concepts	
Energy and Matter	
The total amount of energy and matter in closed systems is conserved. (Performance Expectation P-PS3-3, Performance Expectation P-PS3-4, Performance Expectation P-PS3-3AR)	**Experience Notebook:** Energy - A Conserved Quantity, 309
Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (Performance Expectation P-PS3-3, Performance Expectation P-PS3-4, Performance Expectation P-PS3-3AR)	**Experience Notebook:** Convection, 383

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Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. (Performance Expectation P-PS3-3, Performance Expectation P-PS3-4, Performance Expectation P-PS3-3AR)	**Experience Notebook:** Energy - A Conserved Quantity, 309 Convection, 383
Performance Expectation P-PS3-3 Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.*	**Student Experience Notebook:** SEP Design a Solution, 206 SEP Design a Solution, 212 SEP Design a Solution, 238 **Teacher Guide:** **Inquiry Labs:** Build a Battery; Electric Motors and Generators **Performance-Based Assessments:** Design, Build, and Refine a Wind-Turbine Rotor **Engineering Workbenches:** Design a Roller Coaster
Disciplinary Core Ideas	
PS3.B: Conservation of Energy and Energy Transfer	
Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (Performance Expectation P-PS3-1AR, Performance Expectation P-PS3-3)	**Experience Notebook:** Energy - A Conserved Quantity, 309 Transferring Heat Through Heating, 374-375 The First Law of Thermodynamics, 376 Thermal Equilibrium, 381 Energy Transfer Through Heating, 382-383 **Teacher Guide:** **Inquiry Labs:** Heat Transfer; Convection, Conduction, and Radiation **Performance-Based Assessments:** Meltdown at the Pool **Engineering Workbenches:** Build an Efficient Travel Mug
PS3.D: Energy in Chemical Processes	
Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. Machines are judged as efficient or inefficient based on the amount of energy input needed to perform a particular useful task. Inefficient machines are those that produce more waste heat while performing a task and thus require more energy input. It is therefore important to design for high efficiency so as to reduce costs, waste materials, and many environmental impacts (Performance Expectation P-PS3-3, Performance Expectation P3-ETS1-1)	**Student Experience Notebook:** The First Law of Thermodynamics, 376 Thermodynamic Heat Engines, 386-387 Thermodynamic Cycles, 388-389 Heat Pumps, 390-391 Sample Problem: Heat Engine Efficiency, 392

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Arkansas Science Standards 2016 High School Physics	Experience Physics ©2022
Science and Engineering Practices	
Constructing Explanations and Designing Solutions	
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.	
Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. (Performance Expectation P-PS3-1AR, Performance Expectation P-PS3-3, Performance Expectation P3-ETS1-2)	**Experience Notebook:** SEP Construct an Explanation, 387
Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (Performance Expectation P-PS3-1AR, Performance Expectation P-PS3-3, Performance Expectation P3-ETS1-2)	**Student Experience Notebook:** SEP Design a Solution, 206 SEP Design a Solution, 212 SEP Design a Solution, 238 **Teacher Guide:** **Inquiry Labs:** Build a Battery; Electric Motors and Generators **Performance-Based Assessments:** Design, Build, and Refine a Wind-Turbine Rotor **Engineering Workbenches:** Design a Roller Coaster
Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (Performance Expectation P-PS3-1AR, Performance Expectation P-PS3-3, Performance Expectation P3-ETS1-2)	**Teacher Guide:** **Performance-Based Assessments:** Design, Build, and Refine a Wind-Turbine Rotor **Engineering Workbenches:** Design a Roller Coaster
Crosscutting Concepts	
Energy and Matter	
The total amount of energy and matter in closed systems is conserved. (Performance Expectation P-PS3-3, Performance Expectation P-PS3-4, Performance Expectation P-PS3-3AR)	**Experience Notebook:** Energy - A Conserved Quantity, 309 Transferring Energy Through Heating, 374-375 The First Law of Thermodynamics, 376

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Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (Performance Expectation P-PS3-3, Performance Expectation P-PS3-4, Performance Expectation P-PS3-3AR)	**Student Experience Notebook:** Transferring Energy Through Heating, 374-375 The First Law of Thermodynamics, 376 Energy Transfer Through Heating, 382-383 Thermodynamic Heat Engines, 386-387 SEP Construct an Explanation, 387 Thermodynamic Cycles, 388-389 SEP Develop Models, 388 Heat Pumps, 390-391 CCC Energy and Matter, 390 **Teacher Guide:** **Inquiry Labs:** Heat Transfer; Convection, Conduction, and Radiation **Digital Activities:** Thermal Equilibrium and Heat Flow **Performance-Based Assessments:** Meltdown at the Pool **Engineering Workbenches:** Build an Efficient Travel Mug
Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. (Performance Expectation P-PS3-3, Performance Expectation P-PS3-4, Performance Expectation P-PS3-3AR)	**Experience Notebook:** Energy - A Conserved Quantity, 309 Transferring Energy Through Heating, 374-375 The First Law of Thermodynamics, 376 Energy Transfer Through Heating, 382-383 The Second Law of Thermodynamics, 384-385 Thermodynamic Heat Engines, 386-387 SEP Construct an Explanation, 387 Thermodynamic Cycles, 388-389 SEP Develop Models, 388 Heat Pumps, 390-391 **Teacher Guide:** **Inquiry Labs:** Heat Transfer; Convection, Conduction, and Radiation **Digital Activities:** Thermal Equilibrium and Heat Flow **Performance-Based Assessments:** Meltdown at the Pool **Engineering Workbenches:** Build an Efficient Travel Mug

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Arkansas Science Standards 2016 High School Physics	**Experience Physics ©2022**
Performance Expectation P-PS3-4 Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).	**Student Experience Notebook:** SEP Plan an Investigation, 365 The Second Law of Thermodynamics, 384-385 SEP Construct an Explanation, 393 **Teacher Guide:** **Inquiry Labs:** Heat Transfer **Digital Activities:** Thermal Equilibrium and Heat Flow **Engineering Workbenches:** Build an Efficient Travel Mug
Disciplinary Core Ideas	
PS2.C: Stability and Instability in Physical Systems	
Systems often change in predictable ways; understanding the forces that drive the transformations and cycles within a system, as well as the forces imposed on the system from the outside, helps predict its behavior under a variety of conditions. (Performance Expectation P-PS3-4)	**Experience Notebook:** The Second Law of Thermodynamics, 384-385 CCC Energy and Matter, 385 SEP Construct an Explanation, 393 **Teacher Guide:** **Inquiry Labs:** Heat Transfer **Digital Activities:** Thermal Equilibrium and Heat Flow
When a system has a great number of component pieces, one may not be able to predict much about its precise future. For such systems (e.g., with very many colliding molecules), one can often predict average but not detailed properties and behaviors (e.g., average temperature, motion, and rates of chemical change but not the trajectories or other changes of particular molecules). (Performance Expectation P-PS3-4, Performance Expectation P-PS3-1AR, Performance Expectation P-PS3-2)	**Experience Notebook:** Average Kinetic Energy of Gas Particles, 369 The Second Law of Thermodynamics, 384-385 SEP Develop a Model, 385 **Teacher Guide:** **Inquiry Labs:** Heat Transfer **Digital Activities:** Thermal Equilibrium and Heat Flow
PS3.B: Conservation of Energy and Energy Transfer	
Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). Any object or system that can degrade with no added energy is unstable. Eventually it will do so, but if the energy releases throughout the transition are small, the process duration can be very long (e.g., long-lived radioactive isotopes). (Performance Expectation P-PS3-4)	**Student Experience Notebook:** Thermal Equilibrium and Heat Flow, 381 Energy Transfer Through Heating, 382–383 The Second Law of Thermodynamics, 384–385 Thermodynamic Heat Engines, 386–387 Heat Engine Efficiency, 392–393 **Teacher Guide:** **Inquiry Labs:** Heat Transfer **Digital Activities:** Thermal Equilibrium and Heat Flow

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Science and Engineering Practices	
Planning and Carrying Out Investigations	
Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.	
Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (Performance Expectation P-PS3-2AR, Performance Expectation P-PS3-4)	**Student Experience Notebook:** SEP Plan an Investigation, 365 **Teacher Guide:** **Inquiry Labs:** Heat Transfer **Engineering Workbenches:** Build an Efficient Travel Mug
Crosscutting Concepts	
Energy and Matter	
The total amount of energy and matter in closed systems is conserved. (Performance Expectation P-PS3-3, Performance Expectation P-PS3-4, Performance Expectation P-PS3-3AR)	**Experience Notebook:** Energy - A Conserved Quantity, 309 Heat Flow and Entropy, 385 Understanding Heat Engines, 386
Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (Performance Expectation P-PS3-3, Performance Expectation P-PS3-4, Performance Expectation P-PS3-3AR)	**Student Experience Notebook:** The Second Law of Thermodynamics, 384-385 CCC Energy and Matter, 385 Thermodynamic Heat Engines, 386-387 SEP Develop Models, 388 Heat Pumps, 390-391 **Teacher Guide:** **Inquiry Labs:** Heat Transfer **Digital Activities:** Thermal Equilibrium and Heat Flow **Engineering Workbenches:** Build an Efficient Travel Mug

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Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. (Performance Expectation P-PS3-3, Performance Expectation P-PS3-4, Performance Expectation P-PS3-3AR)	**Student Experience Notebook:** Transferring Energy Through Heating, 374-375 Thermal Equilibrium, 381 Energy Transfer Through Heating, 382-383 The Second Law of Thermodynamics, 384-385 CCC Energy and Matter, 385 Thermodynamic Heat Engines, 386-387 Heat Pumps, 390-391 SEP Construct an Explanation, 393 **Teacher Guide:** **Inquiry Labs:** Heat Transfer **Digital Activities:** Thermal Equilibrium and Heat Flow **Engineering Workbenches:** Build an Efficient Travel Mug
Connections to Nature of Science	
Scientific Knowledge Assumes an Order and Consistency in Natural Systems	
Science assumes the universe is a vast single system in which basic laws are consistent. (Performance Expectation P-PS3-1AR, Performance Expectation P-PS3-2AR, Performance Expectation P-PS3-4)	**Experience Notebook:** The Second Law of Thermodynamics, 384-385 CCC Energy and Matter, 385 SEP Construct an Explanation, 393
Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. (Performance Expectation P-PS3-1AR, Performance Expectation P-PS3-2AR, Performance Expectation P-PS3-4)	**Experience Notebook:** The Second Law of Thermodynamics, 384-385 CCC Energy and Matter, 385 Thermodynamic Heat Engines, 386-387 SEP Construct an Explanation, 393

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Arkansas Science Standards 2016 High School Physics	Experience Physics ©2022
Performance Expectation P3-ETS1-1 Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.	**Student Experience Notebook:** CCC Cause and Effect, 447 SEP Argue from Evidence, 455 **Teacher Guide:** **Inquiry Labs:** Natural Resource Management; Converting Sunlight to Electricity **Digital Activities:** Resource Use and Biodiversity Trade-Offs; Operate a Nuclear Fission Reactor **Performance-Based Assessments:** Minimizing Car Crash Injuries **Engineering Workbenches:** Earthquake-Resistant Structures; Energy Sources: Costs and Benefits **Problem-Based Learning:** Staying Fit to Mars and Back; Ultraviolet Radiation
Disciplinary Core Ideas	
PS3.D: Energy in Chemical Processes	
Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. Machines are judged as efficient or inefficient based on the amount of energy input needed to perform a particular useful task. Inefficient machines are those that produce more waste heat while performing a task and thus require more energy input. It is therefore important to design for high efficiency so as to reduce costs, waste materials, and many environmental impacts (Performance Expectation P-PS3-3, Performance Expectation P3-ETS1-1)	**Experience Notebook:** Thermodynamic Heat Engines, 386-387 Thermodynamic Cycles, 388-389 Heat Pumps, 390-391 **Teacher Guide:** **Inquiry Labs:** Converting Sunlight to Electricity

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Arkansas Science Standards 2016 High School Physics	Experience Physics ©2022
ETS1.A: Defining and Delimiting Engineering Problems	
Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (Performance Expectation P3-ETS1-1, Performance Expectation P3-ETS1-3)	**Student Experience Notebook:** SEP Design a Solution, 409 SEP Design a Solution, 492 SEP Identify Criteria, 528 **Teacher Guide:** **Digital Activities:** Resource Use and Biodiversity Trade-Offs; Operate a Nuclear Fission Reactor **Performance-Based Assessments:** Build Your Own Egg-Transport Vehicle; Minimizing Car Crash Injuries; Junkyard Electromagnet **Engineering Workbenches:** Egg Supply Drop; Landslide Prevention; Earthquake-Resistant Structures; Energy Sources: Costs and Benefits; Waves and Erosion **Problem-Based Learning:** Energy in Complex Machines; Staying Fit to Mars and Back; Ultraviolet Radiation
Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (Performance Expectation P3-ETS1-1, Performance Expectation P3-ETS1-3)	**Student Experience Notebook:** SEP Design a Solution, 109 SEP Design a Solution, 409 CCC Cause and Effect, 453 CCC Stability and Change, 458 SEP Construct an Argument, 459 CCC Energy and Matter, 535 SEP Defend Your Claim, 599 **Teacher Guide:** **Inquiry Labs:** Natural Resource Management; Converting Sunlight to Electricity **Digital Activities:** Resource Use and Biodiversity Trade-Offs; Operate a Nuclear Fission Reactor **Performance-Based Assessments:** Design, Build and Refine a Wind-Turbine Rotor **Engineering Workbenches:** Energy Sources: Costs and Benefits **Problem-Based Learning:** Staying Fit to Mars and Back; Ultraviolet Radiation
Science and Engineering Practices	
Asking Questions and Defining Problems	
Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations.	
Analyze complex real-world problems by specifying criteria and constraints for successful solutions. (Performance Expectation P3-ETS1-1, Performance Expectation P3-ETS1-3)	**Teacher Guide:** **Engineering Workbenches:** Build an Efficient Travel Mug

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Arkansas Science Standards 2016 High School Physics	Experience Physics ©2022
Crosscutting Concepts	
Connections to Engineering, Technology, and Applications of Science	
Interdependence of Science, Engineering, and Technology	
Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (Performance Expectation P3-ETS1-1, Performance Expectation P3-ETS1-2, Performance Expectation P3-ETS1-3, Performance Expectation P3-ETS1-4)	For supporting content, please see: **Teacher Guide:** **Engineering Workbenches:** Build an Efficient Travel Mug
Influence of Engineering, Technology, and Science on Society and the Natural World	
Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (Performance Expectation P3-ETS1-1, Performance Expectation P3-ETS1-2, Performance Expectation P3-ETS1-3, Performance Expectation P3-ETS1-4)	**Teacher Guide:** **Engineering Workbenches:** Build an Efficient Travel Mug
New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (Performance Expectation P3-ETS1-1, Performance Expectation P3-ETS1-2, Performance Expectation P3-ETS1-3, Performance Expectation P3-ETS1-4)	For supporting content, please see: **Experience Notebook:** Thermodynamic Heat Engines, 386-387 Heat Pumps, 390-391 **Teacher Guide:** **Engineering Workbenches:** Build an Efficient Travel Mug

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Arkansas Science Standards 2016 High School Physics	Experience Physics ©2022
Performance Expectation P3-ETS1-2 Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.	**Experience Notebook:** SEP Design a Solution, 393 **Teacher Guide:** **Engineering Workbenches:** Build an Efficient Travel Mug
Disciplinary Core Ideas	
ETS1.B: Developing Possible Solutions	
When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (Performance Expectation P3-ETS1-2, Performance Expectation P3-ETS1-4)	**Teacher Guide:** **Engineering Workbenches:** Build an Efficient Travel Mug
Science and Engineering Practices	
Constructing Explanations and Designing Solutions	
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.	
Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. (Performance Expectation P-PS3-1AR, Performance Expectation P-PS3-3, Performance Expectation P3-ETS1-2)	For supporting content, please see: **Experience Notebook:** SEP Construct an Explanation, 387
Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (Performance Expectation P-PS3-1AR, Performance Expectation P-PS3-3, Performance Expectation P3-ETS1-2)	**Experience Notebook:** SEP Design a Solution, 393 **Teacher Guide:** **Engineering Workbenches:** Build an Efficient Travel Mug
Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (Performance Expectation P-PS3-1AR, Performance Expectation P-PS3-3, Performance Expectation P3-ETS1-2)	**Teacher Guide:** **Engineering Workbenches:** Build an Efficient Travel Mug

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Arkansas Science Standards 2016 High School Physics	Experience Physics ©2022
Crosscutting Concepts	
Connections to Engineering, Technology, and Applications of Science	
Interdependence of Science, Engineering, and Technology	
Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (Performance Expectation P3-ETS1-1, Performance Expectation P3-ETS1-2, Performance Expectation P3-ETS1-3, Performance Expectation P3-ETS1-4)	For supporting content, please see: **Teacher Guide:** **Engineering Workbenches:** Build an Efficient Travel Mug
Influence of Engineering, Technology, and Science on Society and the Natural World	
Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (Performance Expectation P3-ETS1-1, Performance Expectation P3-ETS1-2, Performance Expectation P3-ETS1-3, Performance Expectation P3-ETS1-4)	**Experience Notebook:** SEP Design a Solution, 393 **Teacher Guide:** **Engineering Workbenches:** Build an Efficient Travel Mug
New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (Performance Expectation P3-ETS1-1, Performance Expectation P3-ETS1-2, Performance Expectation P3-ETS1-3, Performance Expectation P3-ETS1-4)	For supporting content, please see: **Experience Notebook:** Thermodynamic Heat Engines, 386-387 Heat Pumps, 390-391 **Teacher Guide:** **Engineering Workbenches:** Build an Efficient Travel Mug

Arkansas Science Standards 2016 High School Physics	Experience Physics ©2022
Performance Expectation P3-ETS1-3 Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.	**Experience Notebook:** SEP Design a Solution, 393 **Teacher Guide:** **Engineering Workbenches:** Build an Efficient Travel Mug
Disciplinary Core Ideas	
ETS1.A: Defining and Delimiting Engineering Problems	
Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (Performance Expectation P3-ETS1-1, Performance Expectation P3-ETS1-3)	**Teacher Guide:** **Engineering Workbenches:** Build an Efficient Travel Mug
Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (Performance Expectation P3-ETS1-1, Performance Expectation P3-ETS1-3)	For supporting content, please see: **Teacher Guide:** **Engineering Workbenches:** Build an Efficient Travel Mug
Science and Engineering Practices	
Asking Questions and Defining Problems	
Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations.	
Analyze complex real-world problems by specifying criteria and constraints for successful solutions. (Performance Expectation P3-ETS1-1, Performance Expectation P3-ETS1-3)	**Experience Notebook:** SEP Design a Solution, 393 **Teacher Guide:** **Engineering Workbenches:** Build an Efficient Travel Mug
Crosscutting Concepts	
Connections to Engineering, Technology, and Applications of Science	
Interdependence of Science, Engineering, and Technology	
Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (Performance Expectation P3-ETS1-1, Performance Expectation P3-ETS1-2, Performance Expectation P3-ETS1-3, Performance Expectation P3-ETS1-4)	For supporting content, please see: **Teacher Guide:** **Engineering Workbenches:** Build an Efficient Travel Mug

Arkansas Science Standards 2016 High School Physics	**Experience Physics ©2022**
Influence of Engineering, Technology, and Science on Society and the Natural World	
Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (Performance Expectation P3-ETS1-1, Performance Expectation P3-ETS1-2, Performance Expectation P3-ETS1-3, Performance Expectation P3-ETS1-4)	**Experience Notebook:** SEP Design a Solution, 393 **Teacher Guide:** **Engineering Workbenches:** Build an Efficient Travel Mug
New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (Performance Expectation P3-ETS1-1, Performance Expectation P3-ETS1-2, Performance Expectation P3-ETS1-3, Performance Expectation P3-ETS1-4)	For supporting content, please see: **Experience Notebook:** Thermodynamic Heat Engines, 386-387 Heat Pumps, 390-391 **Teacher Guide:** **Engineering Workbenches:** Build an Efficient Travel Mug
Performance Expectation P3-ETS1-4 Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.	**Student Experience Notebook:** Seismic Tomography, 403 The Formation of the Solar System, 632 Formation of Earth and the Moon, 633 **Teacher Guide:** **Inquiry Labs:** Natural Resource Management **Performance-Based Assessments:** Generator Testing; Junkyard Electromagnet **Engineering Workbenches:** Energy Sources: Costs and Benefits
Disciplinary Core Ideas	
ETS1.B: Developing Possible Solutions	
When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (Performance Expectation P3-ETS1-2, Performance Expectation P3-ETS1-4)	**Teacher Guide:** **Inquiry Labs:** Natural Resource Management **Performance-Based Assessments:** Junkyard Electromagnet **Engineering Workbenches:** Energy Sources: Costs and Benefits

Arkansas Science Standards 2016 High School Physics	Experience Physics ©2022
Science and Engineering Practices	
Developing and Using Models	
Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s).	
Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (Performance Expectation P-PS3-1, Performance Expectation P3-ETS1-4)	**Teacher Guide:** **Inquiry Labs:** Natural Resource Management **Performance-Based Assessments:** Junkyard Electromagnet **Engineering Workbenches:** Energy Sources: Costs and Benefits
Crosscutting Concepts	
Connections to Engineering, Technology, and Applications of Science	
Interdependence of Science, Engineering, and Technology	
Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (Performance Expectation P3-ETS1-1, Performance Expectation P3-ETS1-2, Performance Expectation P3-ETS1-3, Performance Expectation P3-ETS1-4)	For supporting content, please see: **Experience Notebook:** Transition to the Future, 459 **Teacher Guide:** **Performance-Based Assessments:** Generator Testing; Junkyard Electromagnet **Engineering Workbenches:** Energy Sources: Costs and Benefits
Influence of Engineering, Technology, and Science on Society and the Natural World	
Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (Performance Expectation P3-ETS1-1, Performance Expectation P3-ETS1-2, Performance Expectation P3-ETS1-3, Performance Expectation P3-ETS1-4)	**Teacher Guide:** **Inquiry Labs:** Natural Resource Management **Performance-Based Assessments:** Generator Testing; Junkyard Electromagnet **Engineering Workbenches:** Energy Sources: Costs and Benefits
New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (Performance Expectation P3-ETS1-1, Performance Expectation P3-ETS1-2, Performance Expectation P3-ETS1-3, Performance Expectation P3-ETS1-4)	**Teacher Guide:** **Inquiry Labs:** Natural Resource Management **Performance-Based Assessments:** Junkyard Electromagnet **Engineering Workbenches:** Energy Sources: Costs and Benefits

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Arkansas Science Standards 2016 High School Physics	Experience Physics ©2022
Topic 4: Waves, Sound, and Simple Harmonic Motion	
Students who demonstrate understanding can:	
Performance Expectation P-PS4-1AR Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, speed, and energy of waves traveling in various media.	**Student Experience Notebook:** SEP Analyze Data, 467 SEP Use Mathematics, 467 SEP Analyze and Interpret Data, 469 Sample Problem: Wave on a Rope, 470 SEP Use Mathematics, 475 Sample Problem: Modeling a Sound Wave, 476 SEP Use Mathematics, 478 SEP Analyze and Interpret Data, 478 **Teacher Guide:** **Inquiry Labs:** Mechanical Waves **Digital Activities:** Waves and Shallow Water; Properties of Waves; Wave Speed **Performance-Based Assessments:** Discovering the Speed of Sound in Open Air; Making Waves
Disciplinary Core Ideas	
PS4.A: Wave Properties	
The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing.(P-PS4-1AR, P-PS4-2AR)	**Student Experience Notebook:** Properties of Waves, 467 Transverse Waves, 468–469 Sample Problem: Wave on a Rope, 470 Wave Speed at an Interface, 471 Longitudinal Waves, 472–473 Sample Problem: Properties of Sound Waves, 474 Modeling Waves, 475 **Teacher Guide:** **Inquiry Lab:** Mechanical Waves **Digital Activity:** Properties of Waves **Performance-Based Assessments:** Discovering the Speed of Sound in Open Air; Making Waves

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Arkansas Science Standards 2016 High School Physics	Experience Physics ©2022
Science and Engineering Practices	
Using Mathematics and Computational Thinking	
Mathematical and computational thinking at the 9-12 level builds on K-8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.	
Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations. (P-PS4-1AR)	**Student Experience Notebook:** SEP Analyze Data, 467 SEP Use Mathematics, 467 SEP Analyze and Interpret Data, 469 Sample Problem: Wave on a Rope, 470 Sample Problem: Properties of Sound Waves, 474 SEP Use Mathematics, 475 Sample Problem: Modeling a Sound Wave, 476 SEP Use Mathematics, 478 SEP Analyze and Interpret Data, 478 **Teacher Guide:** **Inquiry Labs:** Mechanical Waves **Digital Activities:** Waves and Shallow Water; Properties of Waves; Wave Speed **Performance-Based Assessments:** Discovering the Speed of Sound in Open Air; Making Waves
Crosscutting Concepts	
Patterns	
Empirical evidence is needed to identify patterns. (P-PS4-1AR, P-PS4-3AR)	**Experience Notebook:** CCC Patterns, 465 Properties of Waves, 467 **Teacher Guide:** **Inquiry Labs:** Mechanical Waves **Digital Activities:** Waves and Shallow Water **Performance-Based Assessments:** Discovering the Speed of Sound in Open Air; Making Waves
Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (P-PS4-1AR, P-PS4-3AR)	**Experience Notebook:** CCC Cause and Effect, 473 **Teacher Guide:** **Inquiry Labs:** Mechanical Waves **Digital Activities:** Wave Speed **Performance-Based Assessments:** Discovering the Speed of Sound in Open Air; Making Waves

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Arkansas Science Standards 2016 High School Physics	Experience Physics ©2022
Energy and Matter	
The total amount of energy and matter in closed systems is conserved. (P-PS4-1AR, P-PS4-3AR)	**Experience Notebook:** Energy - A Conserved Quantity, 309 Energy at an Interface, 491
Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (P-PS4-1AR, P-PS4-3AR)	**Experience Notebook:** Wave Interactions, 479 CCC Energy and Matter, 479 Transfer of Wave Energy, 488-489 Energy in Waves, 490-491 SEP Use a Model, 491
Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. (P-PS4-1AR, P-PS4-3AR)	**Experience Notebook:** Waves, 465 Mechanical Waves, 466 Wave Interactions, 479 Transfer of Wave Energy, 488-489 Energy in Waves, 490-491 **Teacher Guide:** **Inquiry Labs:** Mechanical Waves

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Performance Expectation P-PS4-2AR Develop and use models to investigate longitudinal and transverse waves in various media.	**Experience Notebook:** SEP Develop a Model, 466 SEP Develop a Model, 468 SEP Develop a Model, 471 SEP Plan an Investigation, 472 Sample Problem: Modeling a Sound Wave, 476 SEP Develop a Model, 478 SEP Develop a Model, 482 SEP Develop a Model, 483 SEP Use a Model, 490 SEP Use a Model, 491 SEP Develop a Model, 492 **Teacher Guide:** **Inquiry Labs:** Mechanical Waves; Interference of Sound Waves **Digital Activities:** Properties of Waves; Wave Behavior and Energy
Disciplinary Core Ideas	
PS4.A: Wave Properties	
The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing.(P-PS4-1AR, P-PS4-2AR)	**Student Experience Notebook:** Properties of Waves, 467 Transverse Waves, 468–469 Sample Problem: Wave on a Rope, 470 Wave Speed at an Interface, 471 Longitudinal Waves, 472–473 Sample Problem: Properties of Sound Waves, 474 Modeling Waves, 475 SEP Use Mathematics, 475 Sample Problem: Modeling a Sound Wave, 476 SEP Develop a Model, 478 **Teacher Guide:** **Inquiry Lab:** Mechanical Waves **Digital Activity:** Properties of Waves **Performance-Based Assessments:** Discovering the Speed of Sound in Open Air; Making Waves

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Arkansas Science Standards 2016 High School Physics	**Experience Physics ©2022**
Science and Engineering Practices	
Developing and Using Models	
Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.	
Use a model to predict the relationships between systems or between components of a system. (P-PS4-2AR, P-PS4-3AR, P4-ETS1-4)	**Experience Notebook:** SEP Develop a Model, 478 SEP Develop a Model, 482 SEP Develop a Model, 483 SEP Use a Model, 490 SEP Use a Model, 491 SEP Develop a Model, 492 **Teacher Guide:** **Inquiry Labs:** Mechanical Waves; Interference of Sound Waves **Digital Activities:** Properties of Waves; Wave Behavior and Energy
Crosscutting Concepts	
Structure and Function	
Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. (P-PS4-2AR)	**Experience Notebook:** SEP Design a Solution, 492 **Teacher Guide:** **Engineering Workbenches:** Waves and Erosion
P-PS4-3AR Develop and use models to describe the interaction of light with matter.	**Experience Notebook:** SEP Use Models, 493 SEP Evaluate and Communicate Information, 496 SEP Design a Solution, 497 SEP Develop a Model, 498 SEP Develop a Model, 502 SEP Use a Model, 503 **Teacher Guide:** **Inquiry Labs:** Reflection and Refraction **Digital Activities:** Wave Optics
Disciplinary Core Ideas	
PS4.A: Wave Properties	
The reflection, refraction, and transmission of waves at an interface between two media can be modeled on the basis of these properties. (P-PS4-3)	**Experience Notebook:** Reflection, 496-497 Refraction, 498-499 **Teacher Guide:** **Inquiry Labs:** Reflection and Refraction **Digital Activities:** Refraction - Snell's Law; Wave Optics; Refraction

Arkansas Science Standards 2016 High School Physics	Experience Physics ©2022
Science and Engineering Practices	
Developing and Using Models	
Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.	
Use a model to predict the relationships between systems or between components of a system. (P-PS4-2AR, P-PS4-3AR, P4-ETS1-4)	**Experience Notebook:** SEP Evaluate and Communicate Information, 496 SEP Design a Solution, 497 SEP Develop a Model, 498 SEP Develop a Model, 502 SEP Use a Model, 503 **Teacher Guide:** **Inquiry Labs:** Reflection and Refraction **Digital Activities:** Wave Optics
Crosscutting Concepts	
Patterns	
Empirical evidence is needed to identify patterns. (P-PS4-1AR, P-PS4-3AR)	**Experience Notebook:** Snell's Law, 499 **Teacher Guide:** **Digital Activities:** Refraction - Snell's Law
Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (P-PS4-1AR, P-PS4-3AR)	**Teacher Guide:** **Inquiry Labs:** Reflection and Refraction **Digital Activities:** Wave Optics
Energy and Matter	
The total amount of energy and matter in closed systems is conserved. (P-PS4-1AR, P-PS4-3AR)	**Experience Notebook:** Energy - A Conserved Quantity, 309 Energy at an Interface, 491
Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (P-PS4-1AR, P-PS4-3AR)	**Experience Notebook:** Electromagnetic Waves, 512-513 SEP Argue from Evidence, 513
Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. (P-PS4-1AR, P-PS4-3AR)	**Experience Notebook:** Energy - A Conserved Quantity, 309 Energy at an Interface, 491 Reflection, 496-497 Refraction, 498-499 Electromagnetic Waves, 512-513 SEP Argue from Evidence, 513 **Teacher Guide:** **Inquiry Labs:** Reflection and Refraction **Digital Activities:** Wave Optics

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Arkansas Science Standards 2016 High School Physics	Experience Physics ©2022
Performance Expectation P4-ETS1-4 Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.	**Teacher Guide:** **Performance-Based Assessments:** Making Waves
Disciplinary Core Ideas	
PS4.A: Wave Properties	
Resonance is a phenomenon in which waves add up in phase in a structure, growing in amplitude due to energy input near the natural vibration frequency. Structures have particular frequencies at which they resonate. This phenomenon (e.g., waves in a stretched string, vibrating air in a pipe) is used in speech and in the design of all musical instruments. (P4-ETS1-4)	**Experience Notebook:** Waves on a String, 486 SEP Construct an Explanation, 486 **Teacher Guide:** **Inquiry Labs:** Interference of Sound Waves
ETS1.B: Developing Possible Solutions	
Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (P4-ETS1-4)	**Experience Notebook:** SEP Design a Solution, 492 SEP Design a Solution, 497 **Teacher Guide:** **Performance-Based Assessments:** Making Waves **Engineering Workbenches:** Waves and Erosion
Science and Engineering Practices	
Using Mathematics and Computational Thinking	
Mathematical and computational thinking at the 9-12 level builds on K-8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.	
Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. (P4-ETS1-4)	**Teacher Guide:** **Performance-Based Assessments:** Making Waves
Developing and Using Models	
Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.	

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Use a model to predict the relationships between systems or between components of a system. (P-PS4-2AR, P-PS4-3AR, P4-ETS1-4)	**Experience Notebook:** SEP Design a Solution, 492 SEP Design a Solution, 497 **Teacher Guide:** **Performance-Based Assessments:** Making Waves **Engineering Workbenches:** Waves and Erosion
Connections to Nature of Science	
Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena	
A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. (P4-ETS1-4)	**Experience Notebook:** Shortcomings of the Wave Theory, 520-521 Particles of Light, 523 SEP Argue from Evidence, 523 The Dual Nature of Light, 524-525 **Teacher Guide:** **Inquiry Labs:** Particle Nature of Light **Digital Activities:** Particle-Wave Duality
Crosscutting Concepts	
Connections to Engineering, Technology, and Applications of Science	
Interdependence of Science, Engineering, and Technology	
Science and engineering complement each other in the cycle known as research and development (R&D). (P4-ETS1-4)	For supporting content, please see: **Experience Notebook:** SEP Design a Solution, 492 SEP Design a Solution, 497 SEP Design a Solution, 528 **Teacher Guide:** **Performance-Based Assessments:** Making Waves **Engineering Workbenches:** Waves and Erosion

Arkansas Science Standards 2016 High School Physics	**Experience Physics ©2022**
Influence of Engineering, Technology, and Science on Society and the Natural World	
Modern civilization depends on major technological systems. (P4-ETS1-4)	**Experience Notebook:** Waves, 465 SEP Design a Solution, 492 Electromagnetic Radiation, 511 CCC Energy and Matter, 519 SEP Identify Criteria, 528 SEP Argue from Evidence, 536 CCC Energy and Matter, 537 Medical Imaging, 552-553 Antennas, 554 Capturing an EM Wave's Energy, 557-559 **Teacher Guide:** **Inquiry Labs:** Converting Sunlight to Electricity **Performance-Based Assessments:** Making Waves; Clothing and Sun Protection **Engineering Workbenches:** Waves and Erosion
Topic 5: Electricity	
Students who demonstrate understanding can:	
Performance Expectation P-PS2-4 Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.	**Student Experience Notebook:** SEP Use a Model, 119 SEP Develop a Model, 119 Sample Problem: Earth and the Moon, 120 SEP Use Mathematics, 128 SEP Use Mathematics, 159 SEP Systems and System Models, 160 Sample Problem: Electric Force Between Particles, 161 SEP Use Mathematics (12), 162 Sample Problem: Electric Field Due to Two Charges, 173 CCC Systems and System Models, 174 SEP Use Math, 175 **Teacher Guide:** **Inquiry Lab:** Electric Charges and Coulomb's Law **Performance-Based Assessments:** Build and Test an Electroscope

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Disciplinary Core Ideas	
PS2.B: Types of Interactions	
Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. (Performance Expectation P-PS2-4)	**Student Experience Notebook:** Gravitational Force, 118-119 Electric Charge, 156 Electrons, Protons, and Neutrons, 157 Electric Force, 158-159 Electric Force and Vectors, 160 Coulomb Forces Between Atoms, 251 **Teacher Guide:** **Inquiry Labs:** Electric Charges and Coulomb's Law **Performance-Based Assessments:** Build and Test and Electroscope
Science and Engineering Practices	
Using Mathematics and Computational Thinking	
Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.	
Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. (Performance Expectation P-PS2-4, P-PS5-1AR)	**Student Experience Notebook:** SEP Use a Model, 119 SEP Develop a Model, 119 Sample Problem: Earth and the Moon, 120 SEP Use Mathematics, 128 SEP Use Mathematics, 159 SEP Systems and System Models, 160 Sample Problem: Electric Force Between Particles, 161 SEP Use Mathematics (12), 162 Sample Problem: Electric Field Due to Two Charges, 173 CCC Systems and System Models, 174 SEP Use Math, 175 **Teacher Guide:** **Inquiry Lab:** Electric Charges and Coulomb's Law **Performance-Based Assessments:** Build and Test an Electroscope

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Arkansas Science Standards 2016 High School Physics	Experience Physics ©2022
Connections to Nature of Science	
Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena	
Theories and laws provide explanations in science. (Performance Expectation P-PS2-4)	**Experience Notebook:** Gravitational Force, 118-119 Electric Force, 158-159 **Teacher Guide:** **Inquiry Lab:** Electric Charges and Coulomb's Law
Laws are statements or descriptions of the relationships among observable phenomena. (Performance Expectation P-PS2-4, P-PS5-1AR)	**Experience Notebook:** Gravitational Force, 118-119 Electric Force, 158-159 **Teacher Guide:** **Inquiry Lab:** Electric Charges and Coulomb's Law **Performance-Based Assessments:** Build and Test an Electroscope
Crosscutting Concepts	
Cause and Effect	
Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (Performance Expectation P-PS2-4, Performance Expectation P-PS2-5)	**Experience Notebook:** SEP Use a Model, 119 SEP Develop a Model, 119 SEP Use Mathematics, 159 SEP Argue from Evidence, 160 **Teacher Guide:** **Inquiry Labs:** Electric Charges and Coulomb's Law
Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. (Performance Expectation P-PS2-4, Performance Expectation P-PS2-5)	**Experience Notebook:** SEP Use a Model, 119 SEP Develop a Model, 119 SEP Use Mathematics, 159 SEP Argue from Evidence, 160 **Teacher Guide:** **Inquiry Labs:** Electric Charges and Coulomb's Law

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Performance Expectation P-PS2-5 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.	**Student Experience Notebook:** SEP Plan an Investigation, 214 **Teacher Guide:** **Inquiry Labs:** Electromagnets and Magnetism; Induction of Electrical Current; Electric Motors and Generators **Digital Activities:** Magnetic Fields; Inducing Current **Performance-Based Assessments:** Build a DC Motor; Generator Testing **Engineering Workbenches:** Build a Flashlight Without Batteries
Disciplinary Core Ideas	
PS3.B: Conservation of Energy and Energy Transfer	
Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (Performance Expectation P-PS2-5)	**Experience Notebook:** Magnetic Fields from Moving Charges, 206 Charged Particles in Magnetic Fields, 209-211 CCC Energy and Matter, 212 Current and Magnetic Fields, 220-222 Wireless Energy Transfer, 237 CCC Energy and Matter, 238 Energy - A Conserved Quantity, 309 **Teacher Guide:** **Inquiry Labs:** Electromagnets and Magnetism; Induction of Electrical Current **Digital Activities:** Magnetic Fields; Inducing Current **Performance-Based Assessments:** Build a DC Motor; Generator Testing
Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.(Performance Expectation P-PS2-5)	**Experience Notebook:** Sample Problem: Calculating Force on a Wire, 215 Sample Problem: Torque on a Loop, 218 Current and Magnetic Fields, 220-223 SEP Use Mathematics, 221 Sample Problem: Field Inside a Solenoid, 223 Sample Problem: Calculating Magnetic Flux, 228 Sample Problem: Inducing Current by Decreasing Area, 234

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Arkansas Science Standards 2016 High School Physics	Experience Physics ©2022
Science and Engineering Practices	
Planning and Carrying Out Investigations	
Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.	
Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (Performance Expectation P-PS2-5, P-PS5-1AR)	**Student Experience Notebook:** SEP Plan an Investigation, 214 **Teacher Guide:** **Inquiry Labs:** Electromagnets and Magnetism; Induction of Electrical Current; Electric Motors and Generators **Digital Activities:** Magnetic Fields; Inducing Current **Performance-Based Assessments:** Build a DC Motor; Generator Testing **Engineering Workbenches:** Build a Flashlight Without Batteries
Crosscutting Concepts	
Cause and Effect	
Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (Performance Expectation P-PS2-4, Performance Expectation P-PS2-5)	**Student Experience Notebook:** CCC Cause and Effect, 229 **Teacher Guide:** **Inquiry Labs:** Electromagnets and Magnetism; Induction of Electrical Current; Electric Motors and Generators **Digital Activities:** Magnetic Fields; Combining Magnetic Fields; Inducing Current **Performance-Based Assessment:** Build a DC Motor; Generator Testing
Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. (Performance Expectation P-PS2-4, Performance Expectation P-PS2-5)	**Experience Notebook:** CCC Cause and Effect, 229 SEP Argue from Evidence, 231 **Teacher Guide:** **Inquiry Labs:** Electromagnets and Magnetism; Induction of Electrical Current; Electric Motors and Generators **Performance-Based Assessments:** Build a DC Motor; Generator Testing

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Performance Expectation P-PS3-2 Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects).	**Experience Notebook:** Intermolecular Forces, 165 Modeling Electric and Contact Forces, 166-167 SEP Develop a Model, 167 SEP Develop and Use a Model, 178 SEP Develop a Model, 182 SEP Develop and Use a Model, 191 SEP Develop a Model (72), 194 Electrostatic Potential Energy, 410 Energy Changes in Systems with Electric Charges, 412 SEP Develop a Model, 437 SEP Use Models, 439 SEP Develop and Use a Model, 444 **Teacher Guide:** **Digital Activities:** Modeling Currents; Potential Difference in a Battery
Disciplinary Core Ideas	
PS3.C: Relationship Between Energy and Forces	
When two objects interacting through a force field change relative position, the energy stored in the force field is changed.(Performance Expectation P-PS3-2)	**Experience Notebook:** Field Lines for Multiple Charges, 175 Electrostatic Potential Energy, 410 CCC Patterns, 410 Energy Transformation, 411-412 SEP Use Models, 411 Energy Changes in Systems with Electric Charges, 412 What Causes Current?, 421 **Teacher Guide:** **Digital Activities:** Potential Difference in a Battery

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Developing and Using Models	
Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s).	
Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (Performance Expectation P-PS3-2)	**Experience Notebook:** SEP Develop a Model, 167 SEP Develop and use a Model, 178 SEP Develop a Model, 182 SEP Develop and Use a Model, 191 SEP Develop a Model (72), 194 SEP Develop a Model, 411 SEP Develop a Model, 437 SEP Develop and Use a Model, 444 **Teacher Guide:** **Digital Activities:** Modeling Currents; Potential Difference in a Battery
Crosscutting Concepts	
Scale, Proportion, and Quantity	
Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). (Performance Expectation P-PS3-2)	**Experience Notebook:** CCC Scale, Proportion, and Quantity, 170 CCC Scale, Proportion, and Quantity, 414
Performance Expectation P-PS5-1AR Use mathematical representations and conduct investigations to provide evidence of the relationships between power, current, voltage, and resistance.	**Experience Notebook:** SEP Use Mathematics, 422 SEP Plan an Investigation, 423 SEP Plan an Investigation, 426 SEP Use Mathematics, 427 Sample Problem: Applying Kirchhoff's Loop Rule, 429 SEP Use Mathematics, 430 Sample Problem: Applying Kirchhoff's Rules, 432-433 **Teacher Guide:** **Inquiry Labs:** Energy Transmission in Circuits; Electric Motors and Generators **Digital Activities:** Electric Circuits

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Disciplinary Core Ideas	
PS3.A: Definitions of Energy	
Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. (P-PS5-1AR)	**Experience Notebook:** Energy - A Conserved Quantity, 309 What Causes Current?, 421 Ohm's Law, 422 SEP Use Mathematics, 422 Kirchhoff's Junction Rule, 430 Sample Problem: Applying Kirchhoff's Rules, 432-433 CCC Cause and Effect, 442 **Teacher Guide:** **Inquiry Labs:** Energy Transmission in Circuits; Electric Motors and Generators **Digital Activities:** Energy in Electric Circuits; Series and Parallel Circuits
Science and Engineering Practices	
Constructing Explanations and Designing Solutions	
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.	
Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. (P-PS5-1AR, P5-ETS1-1)	**Experience Notebook:** SEP Construct an Explanation, 428 CCC Cause and Effect, 442 **Teacher Guide:** **Inquiry Labs:** Energy Transmission in Circuits; Electric Motors and Generators **Digital Activities:** Electric Circuits
Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (P-PS5-1AR, P5-ETS1-1)	**Experience Notebook:** SEP Design a Solution, 434 **Teacher Guide:** **Inquiry Labs:** Electric Motors and Generators
Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (P-PS5-1AR, P-PS5-2AR, P5-ETS1-1)	**Teacher Guide:** **Inquiry Labs:** Electric Motors and Generators

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Using Mathematics and Computational Thinking	
Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.	
Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. (Performance Expectation P-PS2-4, P-PS5-1AR)	**Experience Notebook:** SEP Use Mathematics, 422 SEP Use Mathematics, 427 Sample Problem: Applying Kirchhoff's Loop Rule, 429 SEP Use Mathematics, 430 Sample Problem: Applying Kirchhoff's Rules, 432-433 **Teacher Guide:** **Inquiry Labs:** Energy Transmission in Circuits; Electric Motors and Generators **Digital Activities:** Electric Circuits
Planning and Carrying Out Investigations	
Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.	
Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (Performance Expectation P-PS2-5, P-PS5-1AR)	**Experience Notebook:** SEP Plan an Investigation, 423 SEP Plan an Investigation, 426 **Teacher Guide:** **Inquiry Labs:** Energy Transmission in Circuits; Electric Motors and Generators
Connections to Nature of Science	
Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena	
Laws are statements or descriptions of the relationships among observable phenomena. (Performance Expectation P-PS2-4, P-PS5-1AR)	**Experience Notebook:** Ohm's Law, 422 Joule's Law, 427 **Teacher Guide:** **Inquiry Labs:** Energy Transmission in Circuits

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Crosscutting Concepts	
Systems and System Models	
When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. (P-PS5-1AR, P-PS5-2AR)	**Experience Notebook:** Sample Problem: Applying Kirchhoff's Loop Rule, 429 Analyzing a Circuit, 431 Sample Problem: Applying Kirchhoff's Rules, 432-433 **Teacher Guide:** **Inquiry Labs:** Energy Transmission in Circuits; Electric Motors and Generators **Digital Activities:** Electric Circuits; Energy in Electric Circuits
Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows— within and between systems at different scales. (P-PS5-1AR, P-PS5-2AR)	**Experience Notebook:** SEP Develop Models, 424 SEP Develop Models, 425 **Teacher Guide:** **Digital Activities:** Energy in Electric Circuits; Series and Parallel Circuits
Performance Expectation P-PS5-2AR Evaluate competing design solutions for construction and use of electrical consumer products.*	For supporting content, please see: **Experience Notebook:** Alternating Current Generators, 436 Metal Detectors and Their Applications, 443 Wireless Charging, 561 Cooking, 562 **Teacher Guide:** **Inquiry Labs:** Electric Motors and Generators
Disciplinary Core Ideas	
PS3.D: Energy in Chemical Processes	
All forms of electricity generation and transportation fuels have associated economic, social, and environmental costs and benefits, both short and long term. (P-PS5-2AR, P-PS5-3AR)	**Experience Notebook:** CCC Energy and Matter, 444 Impacts on the Biosphere, 447 Costs and Benefits, 452-453 Costs and Benefits: Oil, Gas, and Coal, 454 Costs and Benefits: Wind, Solar, and Biomass, 455 Costs and Benefits: Hydroelectric, Geothermal, Tides, and Waves, 456 Costs and Benefits: Nuclear Power, 457 **Teacher Guide:** **Digital Activities:** Energy Resources and Conservation; Energy Choices

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Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. Machines are judged as efficient or inefficient based on the amount of energy input needed to perform a particular useful task. Inefficient machines are those that produce more waste heat while performing a task and thus require more energy input. It is therefore important to design for high efficiency so as to reduce costs, waste materials, and many environmental impacts. (P-PS5-2AR, P-PS5-3AR)	**Experience Notebook:** Human Power Needs, 449 SEP Analyze Data, 449 Energy Storage Technologies, 451 SEP Argue from Evidence, 460 **Teacher Guide:** **Digital Activities:** Energy Resources and Conservation **Performance-Based Assessments:** Design, Build, and Refine a Wind-Turbine Motor **Engineering Workbenches:** Energy Sources: Costs and Benefits
Science and Engineering Practices	
Constructing Explanations and Designing Solutions	
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.	
Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (P-PS5-1AR, P-PS5-2AR, P5-ETS1-1)	**Experience Notebook:** Costs and Benefits, 452-453 Costs and Benefits: Oil, Gas, and Coal, 454 Costs and Benefits: Wind, Solar, and Biomass, 455 Costs and Benefits: Hydroelectric, Geothermal, Tides, and Waves, 456 Costs and Benefits: Nuclear Power, 457 **Teacher Guide:** **Inquiry Labs:** Electric Motors and Generators **Performance-Based Assessments:** Design, Build, and Refine a Wind-Turbine Motor **Engineering Workbenches:** Energy Sources: Costs and Benefits
Crosscutting Concepts	
Systems and System Models	
When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. (P-PS5-1AR, P-PS5-2AR)	**Experience Notebook:** SEP Develop and Use a Model, 444 **Teacher Guide:** **Inquiry Labs:** Electric Motors and Generators **Digital Activities:** Energy Resources and Conservation; Energy Choices **Engineering Workbenches:** Energy Sources: Costs and Benefits

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Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows— within and between systems at different scales. (P-PS5-1AR, P-PS5-2AR)	**Experience Notebook:** SEP Develop a Model, 437 SEP Use Models, 439 SEP Develop and Use a Model, 444 **Teacher Guide:** **Digital Activities:** Energy Resources and Conservation; Energy Choices **Engineering Workbenches:** Energy Sources: Costs and Benefits
Connections to Engineering, Technology, and Applications of Science	
Interdependence of Science, Engineering, and Technology	
Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (P-PS5-2AR, P5-ETS1-1)	For supporting content, please see: **Experience Notebook:** Transition to the Future, 459
Performance Expectation P-PS5-3AR Obtain and combine information on alternating and direct current circuits in various applications.	**Experience Notebook:** Modeling a Simple Motor, 219 Wireless Induction, 236 Wireless Energy Transfer, 237 SEP Evaluate Information, 237 Electric Generators, 435 CCC Cause and Effect, 435 Alternating Current Generators, 436 Direct Current Generators, 437 Motors, 439 CCC Energy and Matter, 444 Wireless Wonders, 555 Solar Cells, 559 Wireless Charging, 561 **Teacher Guide:** **Inquiry Labs:** Electric Motors and Generators **Digital Activities:** Properties of Electric Motors **Performance-Based Assessments:** Build a DC Motor; Generator Testing

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Arkansas Science Standards 2016 High School Physics	Experience Physics ©2022
Disciplinary Core Ideas	
PS3.D: Energy in Chemical Processes	
All forms of electricity generation and transportation fuels have associated economic, social, and environmental costs and benefits, both short and long term. (P-PS5-2AR, P-PS5-3AR)	**Experience Notebook:** CCC Energy and Matter, 444 Impacts on the Biosphere, 447 Costs and Benefits, 452-453 Costs and Benefits: Oil, Gas, and Coal, 454 Costs and Benefits: Wind, Solar, and Biomass, 455 Costs and Benefits: Hydroelectric, Geothermal, Tides, and Waves, 456 Costs and Benefits: Nuclear Power, 457 **Teacher Guide:** **Digital Activities:** Energy Resources and Conservation; Energy Choices
Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. Machines are judged as efficient or inefficient based on the amount of energy input needed to perform a particular useful task. Inefficient machines are those that produce more waste heat while performing a task and thus require more energy input. It is therefore important to design for high efficiency so as to reduce costs, waste materials, and many environmental impacts. (P-PS5-2AR, P-PS5-3AR)	**Experience Notebook:** Human Power Needs, 449 SEP Analyze Data, 449 Energy Storage Technologies, 451 SEP Argue from Evidence, 460 **Teacher Guide:** **Digital Activities:** Energy Resources and Conservation **Performance-Based Assessments:** Build a DC Motor; Generator Testing **Engineering Workbenches:** Energy Sources: Costs and Benefits
PS4.C: Information Technologies and Instrumentation	
Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, and scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them. Knowledge of quantum physics enabled the development of semiconductors, computer chips, and lasers, all of which are now essential components of modern imaging, communications, and information technologies. (Boundary: Details of quantum physics are not formally taught at this grade level.) (P-PS5-3AR)	**Experience Notebook:** Medical Imaging, 552-553 Wireless Wonders, 555 Solar Cells, 559 Wireless Charging, 561 **Teacher Guide:** **Inquiry Labs:** Converting Sunlight to Electricity

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Science and Engineering Practices	
Obtaining, Evaluating, and Communicating Information	
Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs.	
Communicate scientific ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (P-PS5-3AR)	**Experience Notebook:** SEP Construct an Explanation, 236 SEP Evaluate Information, 237 CCC Cause and Effect, 435 SEP Construct an Explanation, 436 SEP Use Models, 439 CCC Energy and Matter, 444 **Teacher Guide:** **Inquiry Labs:** Electric Motors and Generators **Digital Activities:** Properties of Electric Motors **Performance-Based Assessments:** Build a DC Motor; Generator Testing
Performance Expectation P5-ETS1-1 Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.	**Experience Notebook:** SEP Design a Solution, 409 Human Use of Energy, 445-446 Human Power Needs, 449-450 Energy Storage Technologies, 451 Costs and Benefits, 452-453 Costs and Benefits: Oil, Gas, and Coal, 454 Costs and Benefits: Wind, Solar, and Biomass, 455 Costs and Benefits: Hydroelectric, Geothermal, Tides, and Waves, 456 Costs and Benefits: Nuclear Power, 457 Sustainable Energy Future, 458-459 **Teacher Guide:** **Inquiry Labs:** Natural Resource Management **Digital Activities:** Energy Resources and Conservation; Energy Choices **Performance-Based Assessments:** Design, Build, and Refine a Wind-Turbine Rotor **Engineering Workbenches:** Energy Sources: Costs and Benefits

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Disciplinary Core Ideas	
ETS1.C: Optimizing the Design Solution	
Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (P5-ETS1-1)	**Experience Notebook:** Costs and Benefits, 452-453 Costs and Benefits: Oil, Gas, and Coal, 454 Costs and Benefits: Wind, Solar, and Biomass, 455 Costs and Benefits: Hydroelectric, Geothermal, Tides, and Waves, 456 Costs and Benefits: Nuclear Power, 457 **Teacher Guide:** **Digital Activities:** Energy Choices **Performance-Based Assessments:** Design, Build, and Refine a Wind-Turbine Rotor **Engineering Workbenches:** Energy Sources: Costs and Benefits
Science and Engineering Practices	
Constructing Explanations and Designing Solutions	
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.	
Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. (P-PS5-1AR, P5-ETS1-1)	**Experience Notebook:** SEP Argue from Evidence, 455 SEP Construct an Argument, 459 **Teacher Guide:** **Digital Activities:** Resource Use and Biodiversity Trade-Offs
Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (P-PS5-1AR, P5-ETS1-1)	**Experience Notebook:** SEP Design a Solution, 409 **Teacher Guide:** **Performance-Based Assessments:** Design, Build, and Refine a Wind-Turbine Rotor **Engineering Workbenches:** Energy Sources: Costs and Benefits

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Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (P-PS5-1AR, P-PS5-2AR, P5-ETS1-1)	**Experience Notebook:** Costs and Benefits, 452-453 Costs and Benefits: Oil, Gas, and Coal, 454 Costs and Benefits: Wind, Solar, and Biomass, 455 Costs and Benefits: Hydroelectric, Geothermal, Tides, and Waves, 456 Costs and Benefits: Nuclear Power, 457 **Teacher Guide:** **Performance-Based Assessments:** Design, Build, and Refine a Wind-Turbine Rotor **Engineering Workbenches:** Energy Sources: Costs and Benefits
Crosscutting Concepts	
Connections to Engineering, Technology, and Applications of Science	
Interdependence of Science, Engineering, and Technology	
Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (P-PS5-2AR, P5-ETS1-1)	For supporting content, please see: **Experience Notebook:** Transition to the Future, 459