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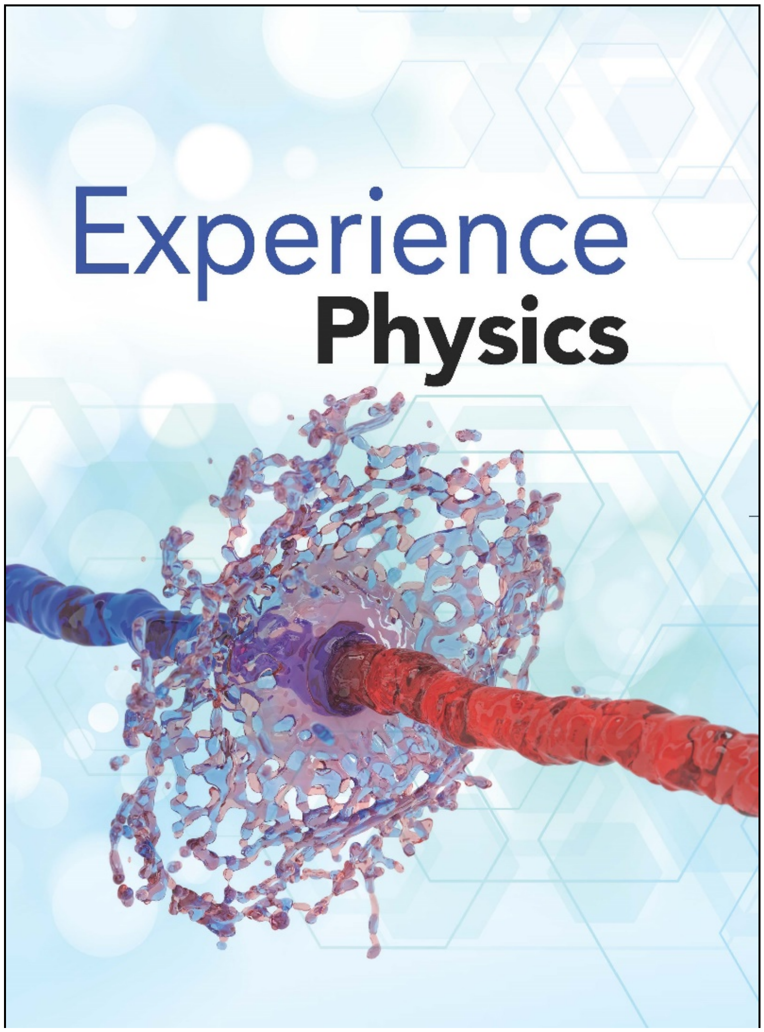

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To the

Maryland
Next Generation Science Standards
for High School

Prepared by Savvas Learning Company, formerly Pearson K12 Learning

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Introduction

This document demonstrates how ***Experience Physics*** **©2022** supports the Maryland Next Generation Science Standards for High School. 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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Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.	**Student Experience Notebook:** Potential Energy, 294 Gravitational Potential Energy, 295 Elastic Potential Energy, 296–297 Cart on a Spring, 298–299 Mechanical Energy and Work, 302 Mechanical Energy Bar Charts, 303 Bowling Ball Bounce, 304–305 Friction as a Change in Energy, 306 Car Skidding to a Stop, 307–308 Expanded Work-Energy Theorem, 312 CCC Energy and Matter, 318 **Digital Activity:** 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.	**Student Experience Notebook:** Gravitational Potential Energy, 295 Elastic Potential Energy, 296–297 Cart on a Spring, 298–299 Electromagnetic Potential Energy, 300–301 Mechanical Energy Bar Charts, 303 Bowling Ball Bounce, 304–305 Friction as a Change in Energy, 306
The availability of energy limits what can occur in any system.	**Student Experience Notebook:** Defining Energy of Motion, 287 Kinetic Energy and the Work-Energy Theorem, 288 Potential Energy, 294 Cart on a Spring, 298–299 Mechanical Energy Bar Charts, 303 Bowling Ball Bounce, 304–305 Friction as a Change in Energy, 306 Car Skidding to a Stop, 307–308 Roller Coaster Energy, 314–315 CCC Energy and Matter, 318

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Science and Engineering Practices	
Using Mathematics and Computational Thinking	
Create a computational model or simulation of a phenomenon, designed device, process, or system.	**Student Experience Notebook:** SEP Use Mathematics, 286 SEP Use Mathematics, 287 SEP Use Mathematics, 288 Work Done on a Book, 290–291 SEP Use Mathematics, 292 Elastic Potential Energy, 296–297 Cart on a Spring, 298–299 SEP Use Mathematics, 301 Mechanical Energy Bar Charts, 303 Bowling Ball Bounce, 304–305 Car Skidding to a Stop, 307–308 SEP Use Mathematical Thinking, 308 SEP Use Mathematics, 313 Roller Coaster Energy, 314–315 SEP Use Mathematics, 318 **Teacher Guide:** **Inquiry Labs:** Gas Particles and Work, The Impact of Position on Energy, Pendulums and the Conservation of Energy **Digital Activities:** Classifying Energy and Work, Hooke's Law and Elastic Potential Energy **Performance-Based Assessment:** Energy Conversion
Crosscutting Concepts	
Systems and System Models	
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.	**Student Experience Notebook:** Force and Displacement, 283 Work and Pressure, 285 Positive and Negative Work, 286 Work and Energy, 288 Energy From Gravity, 295 Comparing Universal Gravitation and Electrostatic Energy, 300 Mechanical Energy Bar Charts, 303 Bowling Ball Bounce, 304–305 Friction and Tires, 306 Rocket Systems, 310 Modeling Systems, 311 **Teacher Guide:** **Inquiry Lab:** Gas Particles and Work **Digital Activities:** Energy in a Moving Cart, Mechanical Energy, Asteroid Impact Models, Conservation of Energy, Rocket Launch **Performance-Based Assessment:** Energy Conversion

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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.	**Student Experience Notebook:** Free-Body Diagrams, 59 Mechanical Energy, 294 Gravitational Potential Energy, 295 Electromagnetic Potential Energy, 300 Mechanical Energy and Work, 302 Friction as a Change in Energy, 306 Car Skidding to a Stop, 307–308 Blackbody Radiation, 532 Four Fundamental Forces, 581 Comparing Energy Transformations, 605 **Teacher Guide:** **Inquiry Lab:** The Impact of Position on Energy **Digital Activities:** Energy, Energy in a Moving Cart, Mechanical Energy, Asteroid Impact Models
Performance Expectation HS-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).	**Student Experience Notebook:** SEP Define Problems, 5 SEP Develop a Model, 7 SEP Develop a Model, 12 SEP Develop a Model, 16 SEP Develop a Model, 26 SEP Develop a Model, 31 SEP Develop and Use a Model, 39 SEP Develop a Model, 47 **Teacher Guide:** **Inquiry Lab:** Kinetic Energy **Digital Activity:** Temperature **Performance-Based Assessment:** Heating Curve of Water

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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.	**Student Experience Notebook:** Potential Energy, 294 Gravitational Potential Energy, 295 Elastic Potential Energy, 296–297 Cart on a Spring, 298–299 Electromagnetic Potential Energy, 300–301 Mechanical Energy and Work, 302 Mechanical Energy Bar Charts, 303 Bowling Ball Bounce, 304–305 Friction as a Change in Energy, 306 Car Skidding to a Stop, 307–308 Energy–A Conserved Quantity Defining Systems, 310–311 Expanded Work-Energy Theorem, 312 Energy Transformed Within a System, 313 Thermodynamic Processes, 377 Expansion of an Ideal Gas, 378–379 **Teacher Guide:** **Digital Activity:** Temperature
At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.	**Student Experience Notebook:** Defining Systems, 310 Modeling Systems, 311 Transferring Energy Through Heating, 374–375 The First Las of Thermodynamics, 376 Evidence for the Big Bang, 679 **Teacher Guide:** **Inquiry Lab:** Kinetic Energy
These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space.	**Student Experience Notebook:** Friction As a Change in Energy, 306 Structure of Matter, 367 Average Kinetic Energy of Gas Particles, 369 Temperature and Energy, 371 Absolute Zero, 372 Thermodynamic Processes, 377 **Teacher Guide:** **Inquiry Lab:** Kinetic Energy **Digital Activity:** Temperature

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Science and Engineering Practices	
Developing and Using Models	
Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.	**Student Experience Notebook:** CCC Systems and System Models, 380 **Teacher Guide:** **Inquiry Labs:** Gas Particles and Work, The Impact of Position on Energy, Pendulums and the Conservation of Energy, Kinetic Energy **Digital Activities:** Energy in a Moving Cart, Conservation of Energy, Simple Harmonic Motion, Pendulum Decay, Gasoline Expansion
Crosscutting Concepts	
Energy and Matter	
Energy cannot be created or destroyed; it only moves between one place and another place, between objects and/or fields, or between systems.	**Student Experience Notebook:** Friction as a Change in Energy, 306 Defining Systems, 310 Thermal Energy, 365 Temperature and Energy, 371 CCC Energy and Matter, 380 **Teacher Guide:** **Inquiry Labs:** Pendulums and the Conservation of Energy, Kinetic Energy **Digital Activities:** Energy, Conservation of Energy, Thermal Energy, Rocket Launch, Meltdown at the Pool, Temperature, Gasoline Expansion **Performance-Based Assessment:** Heating Curve of Water

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Performance Expectation HS-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 Engineering Performance-Based Assessment, 363 **Teacher Guide:** **Inquiry Labs:** Build a Battery, Electric Motors and Generators **Engineering Workbench:** Design a Roller Coaster **Performance-Based Assessment:** Design, Build, and Refine a Wind-Turbine Rotor
Disciplinary Core Ideas	
PS3.A Definitions of Energy	
At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.	**Student Experience Notebook:** Energy Transformation, 411 Energy changes in Systems with Electric Charges, 412 Ohm's Law, 422 Induction Devices, 442
PS3.D Energy in Chemical Processes and Everyday Life	
Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.	**Student Experience Notebook:** Ohm's Law, 422 Ohmic Materials, 423 Joule's Law, 427 Kirchhoff's Loop Rule, 428–429 Induction Devices, 442 **Teacher Guide:** **Digital Activity:** Junkyard Electromagnet
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.	**Student Experience Notebook:** SEP Design a Solution, 94 SEP Design a Solution, 393 SEP Design a Solution, 492 SEP Identify Criteria, 528 **Teacher Guide:** **Inquiry Lab:** Build a Battery **Digital Activity:** Junkyard Electromagnet **Engineering Workbench:** Energy Sources: Costs and Benefits **Performance-Based Assessment:** Design, Build, and Refine a Wind-Turbine Rotor

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Science and Engineering Practices	
Constructing Explanations and Designing Solutions	
Design, evaluate, and/or refine a solution to a complex real-world problem based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.	**Student Experience Notebook:** SEP Design a Solution, 409 SEP Plan an Investigation, 426 SEP Design a Solution, 434 SEP Construct an Explanation, 436 SEP Use Models, 439 SEP Develop and Use a Model, 444 SEP Construct an Explanation, 486 SEP Design a Solution, 492 **Teacher Guide:** **Inquiry Labs:** Build a Battery, Energy Transmission in Circuits, Electric Motors and Generators **Digital Activities:** Electromagnetic Energy, Junkyard Electromagnet, Potential Difference in a Battery, Series and Parallel Circuits, Properties of Electric Motors **Engineering Workbench:** Energy Sources: Costs and Benefits **Performance-Based Assessment:** Design, Build, and Refine a Wind-Turbine Rotor
Crosscutting Concepts	
Energy and Matter	
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.	**Student Experience Notebook:** CCC Matter and Energy, 411 Ohm's Law, 422 Ohmic Materials, 423 Kirchhoff's Junction Rule, 430 CCC Energy and Matter, 434 Direct Current Generators, 437 CCC Energy and Matter, 479 Standing Waves, 485 Waves on a String, 486 Standing Waves on a Rope, 487 Transfer of Wave Energy, 488 Energy in Waves, 490–491 **Teacher Guide:** **Inquiry Lab:** Build a Battery **Digital Activity:** Power Generation

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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.	**Student Experience Notebook:** What Causes Current, 421 Ohm's Law, 422 Ohmic Materials, 423 Circuit Elements and Diagrams, 424–425 Measurements for Circuits, 426 Joule's Law, 427 Kirchhoff's Loop Rule, 428 Kirchhoff's Junction Rule, 430 Analyzing a Circuit, 431 CCC Energy and Matter, 434 Electric Generators, 435 Alternating Current Generators, 436 Direct Current Generators, 437 Motors, 439 Starting a Motor, 440–441 Induction Devices, 442–443 CCC Energy and Matter, 444 Standing Waves, 485 Waves on a String, 486 Standing Waves on a Rope, 487 Transfer of Wave Energy, 488–489 **Teacher Guide:** **Inquiry Labs:** Build a Battery, Energy Transmission in Circuits, Electric Motors and Generators **Digital Activities:** Electromagnetic Energy, Junkyard Electromagnet, Electric Potential, Potential Difference in a Battery, Energy in Electric Circuits, Electric Circuits, Series and Parallel Circuits, Power Generation **Engineering Workbench:** Energy Sources: Costs and Benefits **Performance-Based Assessment:** Design a Roller Coaster; Design, Build, and Refine a Wind-Turbine Rotor

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Performance Expectation HS-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 SEP Design a Solution, 393 SEP Construct an Explanation, 393 **Teacher Guide:** **Inquiry Lab:** Heat Transfer **Digital Activity:** Thermal Equilibrium and Heat Flow **Engineering Workbench:** Build an Efficient Travel Mug
Disciplinary Core Ideas	
PS3.B Conservation of Energy and Energy Transfer	
Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.	**Student Experience Notebook:** Transferring Energy Through Heating, 374–375 The First Law of Thermodynamics, 376 Thermodynamic Processes, 377 Expansion of an Ideal Gas, 378–379 CCC Systems and System Models, 380 The Second Law of Thermodynamics, 384–385 Thermodynamic Heat Engines, 386–387 Heat Pumps, 390–391 Heat Engine Efficiency, 392–393
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).	**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
PS3.D Energy in Chemical Processes and Everyday Life	
Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.	**Student Experience Notebook:** Thermodynamic Heat Engines, 386–387 Thermodynamic Cycles, 388–389 Heat Pumps, 390–391 Heat Engine Efficiency, 392–393
Science and Engineering Practices	
Planning and Carrying Out Investigations	
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.	**Student Experience Notebook:** SEP Plan an Investigation, 365 **Teacher Guide:** **Inquiry Labs:** Kinetic Energy, Heat Transfer **Digital Activity:** Thermal Equilibrium and Heat Flow **Engineering Workbench:** Build an Efficient Travel Mug

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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.	**Student Experience Notebook:** Heat Flow, 385 Understanding Heat Engines, 386–387 Thermodynamic Cycles, 388–389 Heat Pumps, 390–391 Heat Engine Efficiency, 392–393 **Teacher Guide:** **Inquiry Lab:** Kinetic Energy **Digital Activities:** Thermal Equilibrium and Heat Flow, Why Metals Feel Cool **Engineering Workbench:** Build an Efficient Travel Mug
Performance Expectation HS-PS3-5 Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.	**Student Experience Notebook:** SEP Construct an Explanation, 393 SEP Design a Solution, 393 **Teacher Guide:** **Inquiry Lab:** Magnetic Force and Separation Distance **Digital Activity:** Junkyard Electromagnet **Performance-Based Assessment:** Build and Test an Electroscope

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Disciplinary Core Ideas	
PS3.C: Relationship Between Energy and Forces	
When two objects interacting through a field change relative position, the energy stored in the field is changed.	**Student Experience Notebook:** What is a Field? 171 Parallel Plates, 178 Magnetic Fields, 203 Modeling Multiple Magnets, 205 Magnetic Fields From Moving Charges, 206 Force on a Moving Charge, 207 Magnetic Force on a Wire, 213–214 Modeling Earth's Magnetic Field, 224 Pole Reversals, 225 Electrostatic Potential Energy, 410 Energy Transformation, 411 Energy Changes in Systems with Electric Charges, 412–413 Electric Potential Field, 414 Point Charges, 415 Superposition, 416 Potential Due to Pint Charges, 417 Equipotential Surfaces, 418 Potential Difference, 419 Alternating Current Generators, 436 Direct Current Generators, 437 Motors, 439 Induction Devices, 442–443

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Science and Engineering Practices	
Developing and Using Models	
Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.	**Student Experience Notebook:** SEP Develop and Use a Model, 202 SEP Develop a Model, 203 SEP Develop a Model, 204 SEP Develop a Model, 205 SEP Develop a Model, 212 SEP Develop and Use a Model, 213 SEP Develop and Use a Model, 216 SEP Develop a Model, 217 SEP Develop and Use a Model, 220 SEP Develop and Use a Model, 222 CCC Systems and System Models, 224 SEP Develop a Model, 226 SEP Use Models, 411 SEP Use Models, 416 SEP Use a Model, 418 SEP Develop a Model, 420 SEP Develop Models, 424 SEP Develop Models, 425 SEP Develop a Model, 437 SEP Use Models, 439 SEP Develop and Use a Model, 444 **Teacher Guide:** **Inquiry Labs:** Electric Motors and Generators, Magnetic Force and Separation Distance, **Digital Activities:** Electromagnetic Energy, Energy in Electric Circuits, Series and Parallel Circuits, Power Generation, Properties of Electric Motors, Magnetic Forces, Magnetism, Geomagnetic Polarity Reversal, Breaking Magnets, Magnetic Fields, Combining Magnetic Fields **Engineering Workbench:** Energy Sources: Costs and Benefits, Build a Flashlight Without Batteries **Performance-Based Assessment:** Build a DC Motor

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Crosscutting Concepts	
Cause and Effect	
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.	**Student Experience Notebook:** Electromotive Force, 229 Electromagnetic Energy, 409 What Causes Current? 421 Electric Generators, 435 Induction Devices, 442 **Teacher Guide:** **Digital Activities:** Junkyard Electromagnet, Electric Potential, Potential Difference in a Battery, Energy in Electric Circuits, Electric Circuits, Magnetic Forces, Combining Magnetic Fields
Performance Expectation HS-PS4-1 Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.	**Student Experience Notebook:** SEP Analyze Data, 467 SEP Use Mathematics, 467 SEP Analyze and Interpret Data, 469 SEP Argue F\from Evidence, 471 **Teacher Guide:** **Inquiry Lab:** Mechanical Waves **Digital Activities:** Making Waves, Properties of Waves, Waves and Shallow Water
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.	**Student Experience Notebook:** Properties of Waves, 467 Transverse Waves, 468–470 Wave Speed at an Interface, 471 Longitudinal Waves, 472–474 Modeling Waves, 475 Moving Wave Source, 480–481 Standing Waves, 485–487 Energy in Waves, 490–492 **Teacher Guide:** **Inquiry Lab:** Mechanical Waves **Digital Activity:** Properties of Waves

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Science and Engineering Practices	
Using Mathematics and Computational Thinking	
Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations.	**Student Experience Notebook:** SEP Analyze Data, 467 SEP Use Mathematics, 467 SEP Analyze and Interpret Data, 469 Wave on a Rope, 470 Properties of Sound Waves, 474 Modeling a Sound Wave, 476–477 SEP Use Mathematics, 478 SEP Analyze and Interpret Data, 478 A Passing Ambulance, 481 SEP Develop a Model, 482 SEP Develop a Model, 483 SEP Use Mathematics, 484 Standing Waves on a Rope, 487 SEP Analyze and Interpret Data, 489 SEP Use Mathematics, 490 SEP Use Mathematics, 492 SEP Use Mathematics, 499 SEP Use Computational Thinking, 504 Image of a Rubber Duck, 505 Reading with a Magnifying Glass, 506–507 **Teacher Guide:** **Inquiry Labs:** Mechanical Waves, Interference of Sound Waves **Digital Activities:** Making Waves, Properties of Waves, Waves and Shallow Water **Performance-Based Assessment:** The Speed of Sound in Open Air
Crosscutting Concepts	
Cause and Effect	
Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.	**Student Experience Notebook:** SEP Analyze and Interpret Data, 469 CCC Cause and Effect, 475 SEP Construct an Explanation, 491 SEP Develop and Use a Model, 498 **Teacher Guide:** **Inquiry Labs:** Mechanical Waves, Interference of Sound Waves, Reflection and Refraction **Digital Activities:** Waves, Making Waves, Properties of Waves, Wave Speed, Wave Behavior and Energy, Interference, Wave Optics, Refraction **Engineering Workbench:** Waves

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Performance Expectation HS-PS4-2 Evaluate questions about the advantages of using a digital transmission and storage of information.	**Student Experience Notebook:** Storing Pictures in Digital Code, 543 Storing Sounds in Digital Code, 544 Computer Memory, 545 Advantages and Disadvantages of Digital Information, 547 Investigating Phenomenon, 548 **Teacher Guide:** **Inquiry Lab:** Binary Logic **Digital Activity:** Music Storage for Home Recording **Performance-Based Assessment:** Send Messages with a Telegraph
Disciplinary Core Ideas	
PS4.A: Wave Properties	
Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses.	**Student Experience Notebook:** Representing Information Digitally, 542 Storing Pictures in Digital Code, 543 Storing Sounds in Digital Code, 544 Computer Memory, 545 Advantages and Disadvantages of Digital Information, 547 Audio Information, 549 Visual Information, 550–551 Medical Imaging, 552–553 Antennas, 554–555 **Teacher Guide:** **Digital Activity:** Music Storage for Home Recording **Engineering Workbench:** Rover
Science and Engineering Practices	
Asking Questions and Defining Problems	
Evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set or the suitability of a design.	**Student Experience Notebook:** SEP Ask Questions, 547 **Teacher Guide:** **Inquiry Lab:** Binary Logic **Digital Activity:** Music Storage for Home Recording **Engineering Workbench:** Rover

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Crosscutting Concepts	
Stability and Change	
Systems can be designed for greater or lesser stability.	**Student Experience Notebook:** Storing Pictures in Digital Code, 543 Computer Memory, 545 Advantages and Disadvantages of Digital Information, 547 **Teacher Guide:** **Digital Activity:** Music Storage for Home Recording **Performance-Based Assessment:** Send Messages with a Telegraph
Connections to Engineering, Technology, and Applications of Science: Influence of Engineering, Technology, and Science 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.	**Student Experience Notebook:** Computer Memory, 545 Audio Information, 549 Visual Information, 550–551 Medical Imaging, 552–553 Antennas, 554–555 **Teacher Guide:** **Digital Activities:** Music Storage for Home Recording, Transistors and Integrated Circuits **Performance-Based Assessment:** Send Messages with a Telegraph
Performance Expectation HS-PS4-3 Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.	**Student Experience Notebook:** SEP Evaluate Claims, 521 SEP Argue from Evidence, 523 **Teacher Guide:** **Inquiry Lab:** Particle Nature of Light **Digital Activities:** Particle-Wave Duality of Light, Particle-Wave Duality
Disciplinary Core Ideas	
PS4.A: Wave Properties	
Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other.	**Student Experience Notebook:** Modeling Wave Interactions, 482–483 Beats, 484 Standing Waves, 485 Waves on a String, 486–487 Diffraction, 494–495 Lenses, 501 Formation of Images, 502–503 **Teacher Guide:** **Digital Activity:** Electromagnetic Waves and Their Properties

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PS4.B: Electromagnetic Radiation	
Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features.	**Student Experience Notebook:** Diffraction, 494–495 Reflection, 496–497 Refraction, 498–500 Lenses, 501 Formation of Images, 502–503 The Lens Equation, 504 Image of a Rubber Duck, 505 Reading with a Magnifying Glass, 506–507 **Teacher Guide:** **Inquiry Lab:** Particle Nature of Light
Science and Engineering Practices	
Engaging in Argument from Evidence	
Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.	**Student Experience Notebook:** SEP Analyze and Interpret Data, 489 SEP Argue from Evidence, 489 SEP Argue from Evidence, 502 SEP Argue from Evidence, 508 SEP Analyze and Interpret Data, 509 SEP Engage in Argument from Evidence, 509 SEP Argue from Evidence, 513 SEP Argue from Evidence, 515 SEP Construct an Argument, 516 SEP Use Evidence, 528 **Teacher Guide:** **Inquiry Labs:** Diffraction, Particle Nature of Light **Digital Activities:** Electromagnetic Radiation, Particle-Wave Duality of Light, Laser Interference, Particle-Wave Duality, Light Intensity and 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. 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.	**Student Experience Notebook:** Energy in Waves, 490–492 Diffraction, 494–495 Refraction, 498–500 Formation of Images, 502–503 Intensity of Polarized Light, 518–519 Shortcomings of the Wave Theory, 520–521 Photoelectric Effect, 522 **Teacher Guide:** **Digital Activities:** Electromagnetic Waves and Their Properties, Laser Interference, Particle-Wave Duality, Light Intensity and Energy

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Crosscutting Concepts	
Systems and System Models	
Models (e.g., physical, mathematical, and computer models) can be used to simulate systems and interactions — including energy, matter and information flows — within and between systems at different scales.	**Student Experience Notebook:** SEP Develop a Model, 482 SEP Develop a Model, 483 SEP Use a Model, 491 SEP Develop a Model, 508 CCC Systems and System Models, 511 SEP Develop a Model, 519 SEP Develop a Model, 521 SEP Use a Model, 522 SEP Develop a Model, 528 **Teacher Guide:** **Digital Activities:** Electromagnetic Waves and Their Properties, Particle-Wave Duality
Performance Expectation HS-PS4-4 Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.	**Student Experience Notebook:** SEP Evaluate Claims, 521 **Teacher Guide:** **Inquiry Lab:** Electromagnetic Radiation and Matter **Digital Activity:** Sunscreen and UV Protection **Performance-Based Assessment:** Clothing and Sun Protection
Disciplinary Core Ideas	
PS4.B: Electromagnetic Radiation	
When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells.	**Student Experience Notebook:** Photon-Electron Interactions, 529 Photon Energy Absorption by Matter, 530–531 Blackbody Radiation, 532–533 Damage to Living Cells, 534–536 **Teacher Guide:** **Inquiry Lab:** Electromagnetic Radiation and Matter **Digital Activity:** EM Radiation and Matter
Science and Engineering Practices	
Obtaining, Evaluating, and Communicating Information	
Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or media reports, verifying the data when possible.	**Student Experience Notebook:** SEP Evaluate Claims, 535 SEP Evaluate Claims, 536 **Teacher Guide:** **Inquiry Lab:** Electromagnetic Radiation and Matter **Digital Activity:** Sunscreen and UV Protection **Performance-Based Assessment:** Clothing and Sun Protection

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Crosscutting Concepts	
Cause and Effect	
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.	**Student Experience Notebook:** Effects of UV Exposure, 534–536 **Teacher Guide:** **Performance-Based Assessment:** Clothing and Sun Protection
Performance Expectation HS-PS4-5 Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.	**Student Experience Notebook:** CCC Energy and Matter, 549 SEP Construct Explanations, 552 SEP Construct Explanations (21), 556 SEP Construct Explanations (23), 556 **Teacher Guide:** **Inquiry Labs:** Converting Electrical Signals to Sounds, Converting Sunlight to Electricity **Digital Activities:** Antennas, Solar Panels on a Cloudy Day **Performance-Based Assessment:** Send Messages with a Telegraph
Disciplinary Core Ideas	
PS3.D: Energy in Chemical Processes	
Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy.	**Student Experience Notebook:** Capturing an EM Wave Energy, 557 EnergyfFrom the Sun, 558 Solar Panels, 559 Efficiency of Solar Power, 560 **Teacher Guide:** **Inquiry Lab:** Converting Sunlight to Electricity
PS4.A: Wave Properties	
Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses.	**Student Experience Notebook:** Representing Information Digitally, 542 Storing Pictures in Digital Code, 543 Storing Sounds in Digital Code, 544 Computer Memory, 545 Advantages and Disadvantages of Digital Information, 547 Audio Information, 549 Visual Information, 550–551 Medical Imaging, 552–553 Antennas, 554–555 **Teacher Guide:** **Performance-Based Assessment:** Send Messages with a Telegraph

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PS4.B: Electromagnetic Radiation	
Photoelectric materials emit electrons when they absorb light of a high-enough frequency.	**Student Experience Notebook:** Photoelectric Effect, 522 Particles of Light, 523 Energy from the Sun, 558 Solar Panels, 559 Gamma Decay, 616 **Teacher Guide:** **Inquiry Lab:** Converting Sunlight to Electricity
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, 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.	**Student Experience Notebook:** Waves on a String, 486–487 Transfer of Wave Energy, 488–489 Energy in Waves, 490–492 Audio Information, 549 Visual Information, 550–551 Medical Imaging, 552–553 Antennas, 554–555 **Teacher Guide:** **Inquiry Lab:** Converting Electrical Signals to Sounds **Performance-Based Assessment:** Send Messages with a Telegraph
Science and Engineering Practices	
Obtaining, Evaluating, and Communicating Information	
Communicate technical information or 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).	**Student Experience Notebook:** SEP Argue From Evidence, 489 SEP Construct an Explanation, 492 SEP Argue From Evidence, 513 SEP Argue From Evidence, 515 SEP Construct an Explanation, 531 SEP Obtain Information, 555 SEP Construct Explanations, 559 SEP Construct an Argument, 561 **Teacher Guide:** **Inquiry Labs:** Reflection and Refraction, Converting Electrical Signals to Sounds, Converting Sunlight to Electricity **Engineering Workbench:** Rover

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Crosscutting Concepts	
Cause and Effect	
Systems can be designed to cause a desired effect.	**Student Experience Notebook:** Solar Panels, 559 SEP Construct Explanations, 559 **Teacher Guide:** **Inquiry Lab:** Converting Sunlight to Electricity **Digital Activity:** Solar Panels on a Cloudy Day
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).	**Student Experience Notebook:** SEP Reason Quantitatively, 556 SEP Obtain Information, 561 Radiotherapy, 563 CCC Matter and Energy, 564 SEP Design Solutions, 564 **Teacher Guide:** **Inquiry Lab:** Converting Electrical Signals to Sounds **Digital Activities:** Refraction - Snell's Law, Storage for Home Recording, Antennas, Capturing and Transmitting Energy **Engineering Workbench:** Waves
Connections to Engineering, Technology, and Applications of Science: Influence of Engineering, Technology, and Science on Society and the Natural World	
Modern civilization depends on major technological systems.	**Student Experience Notebook:** SEP Reason Quantitatively, 556 SEP Obtain Information, 561 CCC Matter and Energy, 564 SEP Design Solutions, 564 **Teacher Guide:** **Inquiry Lab:** Converting Sunlight to Electricity **Digital Activities:** Information and Instrumentation, Capturing and Transmitting Information **Engineering Workbench:** Waves

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Earth & Space Science	
Performance Expectation HS-ESS1-1 Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy in the form of radiation.	**Student Experience Notebook:** CCC Scale, Proportion, and Quantity, 656 Energy in the Sun's Fusion Processes, 657 SEP Develop and Use a Model, 659 SEP Develop and Use a Model, 661 SEP Use Mathematics, 662 **Teacher Guide:** **Inquiry Lab:** Sunlight Intensity and Solar Flares **Digital Activities:** The Universe, Build a Star! **Performance-Based Assessment:** Life Cycle of Stars
Disciplinary Core Ideas	
ESS1.A: The Universe and Its Stars	
The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years.	**Student Experience Notebook:** Fusion and Sunlight, 655 The Sun's Fusion, 656 Energy in the Sun's Fusion Processes, 657 Transfer of Fusion Energy, 658–659 Color and Temperature of Stars, 669 Different Types of Stars, 670–671 Life Cycle of Stars, 672 Nuclear Fusion Within Stars, 674–675 The Death of Stars, 676 **Teacher Guide:** **Digital Activity:** Build a Star!
PS3.D: Energy in Chemical Processes and Everyday Life	
Nuclear fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation.	**Student Experience Notebook:** Fusion, 603 Fusion and Sunlight, 655 The Sun's Fusion, 656 Energy in the Sun's Fusion Processes, 657 Transfer of Fusion Energy, 658–659 Color and Temperature of Stars, 669 Different Types of Stars, 670–671 Life Cycle of Stars, 672 Nuclear Fusion Within Stars, 674–675 The Death of Stars, 676 **Teacher Guide:** **Inquiry Labs:** Sunlight Intensity and Solar Flares, Elemental Composition of Stars **Digital Activities:** The Universe, Build a Star!

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Science and Engineering Practices	
Developing and Using Models	
Develop a model based on evidence to illustrate the relationships between systems or between components of a system.	**Student Experience Notebook:** Experience It!, 655 Fusion Processes in the Sun, 656 Energy in the Sun's Fusion Processes, 657 Layer of the Sun, 659 SEP Develop and Use Models, 659 Sunspot Structure, 661 SEP Develop and Use Model, 661 **Teacher Guide:** **Inquiry Lab:** Sunlight Intensity and Solar Flares **Digital Activity:** Build a Star!
Crosscutting Concepts	
Scale, Proportion, and Quantity	
The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.	**Student Experience Notebook:** The Sun, 654 Energy from the Sun, 655 CCC Scale, Proportion, and Quantity, 655 CCC Scale, Proportion, and Quantity, 663 Apparent Magnitude of Selected Celestial Objects, 666 CCC Scale, Proportion, and Quantity, 666 Structure of the Milky Way Galaxy, 668 Main Sequence Stars, 670 CCC Scale, Proportion, and Quantity, 670 **Teacher Guide:** **Digital Activity:** Build a Star!
Performance Expectation HS-ESS1-2 Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.	**Student Experience Notebook:** Experience It!, 681 SEP Use Mathematics, 681 SEP Construct an Explanation, 682 SEP Evaluate Scientific Information, 683 CCC Energy and Matter, 684 CCC Energy and Matter (41), 685 CCC Energy and Matter (42), 685 SEP Apply Scientific Reasoning, 687 **Teacher Guide:** **Inquiry Lab:** The Expansion of the Universe **Digital Activity:** Origins of the Universe

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Disciplinary Core Ideas	
ESS1.A: The Universe and Its Stars	
The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.	**Student Experience Notebook:** Luminosity, Apparent Brightness, and Magnitude, 666 Alpha Centauri, 667 Color and Temperature of Stars, 669 Evidence for the Big Bang, 679 Big Bang Nucleosynthesis, 685 **Teacher Guide:** **Engineering Workbench:** The Colors of Light
The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non- stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe.	**Student Experience Notebook:** Evidence for the Big Bang, 679 Expansion and the Age of the Universe, 680–681 A Model of the Big Bang, 682 Cosmic Microwave Background, 683 Recombination and Light, 684 Big Bang Nucleosynthesis, 685 **Teacher Guide:** **Inquiry Labs:** Elemental Composition of Stars, The Expansion of the Universe
Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode.	**Student Experience Notebook:** Nuclear Fusion Within Stars, 674–675 The Death of Stars, 676–677 Big Bang Nucleosynthesis, 685 History of the Universe, 686–687 **Teacher Guide:** **Inquiry Lab:** Elemental Composition of Stars **Engineering Workbench:** The Colors of Light
PS4.B: Electromagnetic Radiation	
Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities.	**Student Experience Notebook:** Photon Energy Absorption by Matter, 530 Big Bang Nucleosynthesis, 685 **Teacher Guide:** **Inquiry Lab:** Elemental Composition of Stars **Engineering Workbench:** The Colors of Light

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Science and Engineering Practices	
Constructing Explanations and Designing Solutions	
Construct 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.	**Student Experience Notebook:** SEP Evaluate Scientific Information, 683 CCC Energy and Matter, 684 CCC Energy and Matter (41), 685 CCC Energy and Matter (42), 685 SEP Apply Scientific Reasoning, 687 **Teacher Guide:** **Inquiry Labs:** Elemental Composition of Stars, The Expansion of the Universe **Digital Activities:** Origins of the Universe, Elemental Composition of the Solar System
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.	**Student Experience Notebook:** Wave Behavior of EM Radiation, 516 Shortcoming of the Wave Theory, 520–521 Photoelectric Effect, 522 The Dual Nature of Light, 524–525 Evidence for the Big Bang, 679 Expansion and the Age of the Universe, 680–681 A Model of the Big Bang, 682 Cosmic Microwave Background, 683 Recombination and Light, 684 Big Bang Nucleosynthesis, 685 **Teacher Guide:** **Digital Activity:** Origins of the Universe
Crosscutting Concepts	
Energy and Matter	
Energy cannot be created or destroyed– only moved between one place and another place, between objects and/or fields, or between systems.	**Student Experience Notebook:** Evidence for the Big Bang, 679 Expansion and the Age of the Universe, 680–681 A Model of the Big Bang, 682 Cosmic Microwave Background, 683 Recombination and Light, 684 Big Bang Nucleosynthesis, 685 History of the Universe, 686–687 Dark Energy, 688

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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.	**Student Experience Notebook:** Expansion and the Age of the Universe, 680–681 Cosmic Microwave Background, 683 Big Bang Nucleosynthesis, 685
Connections to Nature of Science: Scientific Knowledge Assumes an Order and Consistency in Natural Systems	
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. Science assumes the universe is a vast single system in which basic laws are consistent.	**Student Experience Notebook:** Impact Craters and Solar System History, 634 Grand Canyon, 636 Physical and Geologic Time, 636–637 Geologic Time Divisions, 644–645 Ages of Ocean Crust, 646–647 **Teacher Guide:** **Digital Activity:** Origins of the Universe
Performance Expectation HS-ESS1-3 Communicate scientific ideas about the way stars, over their life cycle, produce elements.	**Student Experience Notebook:** Fusion Processes in the Sun, 656 Energy in the Sun's Fusion Processes, 657 SEP Obtain, Evaluate, and Communicate Information, 674 CCC Energy and Matter, 675 CCC Energy and Matter, 676 SEP Develop and Use a Model, 677 CCC Energy and Matter, 678 CCC Energy and Matter, (41), 685 CCC Energy and Matter, (42), 685 **Teacher Guide:** **Digital Activities:** Build a Star!, Stars, The Universe **Performance-Based Assessment:** Life Cycle of Stars

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Disciplinary Core Ideas	
ESS1.A: The Universe and Its Stars	
The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.	**Student Experience Notebook:** Photon Energy Absorption by Matter, 530 SEP Construct an Explanation, 531 Photosphere, Chromosphere, Corona, 660 Distances to Nearby Stars, 665 Luminosity, Apparent Brightness, and Magnitude, 666 Alpha Centauri, 667 Star Distribution in the Galaxy, 668 Color and Temperature of Stars, 669 Different Types of Stars, 670–671 Evidence for the Big Bang, 679 Expansion and the Age of the Universe, 680–681 Big Bang Nucleosynthesis, 685 **Teacher Guide:** **Digital Activity:** Discovering Exoplanets **Inquiry Lab:** Elemental Composition of Stars **Engineering Workbench:** The Colors of Light
Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode.	**Student Experience Notebook:** Fusion Processes in the Sun, 656 Energy in the Sun's Fusion Processes, 657 Different Types of Stars, 670–671 Life Cycle of Start, 672 Star Formation 673 Nuclear Fusion Within Stars, 674–675 The Death of Stars, 676–677 Big Bang Nucleosynthesis, 685 **Teacher Guide:** **Digital Activities:** Build a Star!, Stars

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Science and Engineering Practices	
Obtaining, Evaluating, and Communicating Information	
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).	**Student Experience Notebook:** SEP Obtain and Communicate Information, 672 SEP Construct an Explanation, 673 SEP Obtain, Evaluate, and Communicate Information, 674 CCC Energy and Matter, 675 CCC Energy and Matter, 676 SEP Develop and Use a Model, 677 CCC Energy and Matter, 678 CCC Energy and Matter, (41), 685 CCC Energy and Matter, (42), 685 **Teacher Guide:** **Inquiry Lab:** Elemental Composition of Stars **Digital Activities:** Build a Star!, Stars, The Universe **Performance-Based Assessment:** Life Cycle of Stars
Crosscutting Concepts	
Energy and Matter	
In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.	**Student Experience Notebook:** Conservation of Baryons, 595 Beta Decay and Electron Capture, 615 Fusion Processes in the Sun, 656 The Death of Stars, 676–677 Big Bang Nucleosynthesis, 685 **Teacher Guide:** **Digital Activity:** The Universe

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Performance Expectation HS-ESS1-4 Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.	**Student Experience Notebook:** SEP Argue from Evidence, 129 CCC Scale, Proportion, and Quantity, 130 Satellite in a Circular Orbit, 131 Different Orbits, 132 SEP Use Mathematics (32), 133 SEP Use Mathematics (33), 133 Geosynchronous Orbits, 134 SEP Use Mathematics, 135 The Earth-Moon-Sun System, 137 Eclipses and the Lunar Orbit, 138 Investigative Phenomenon, 141 SEP Use Mathematics, 142 SEP Use Mathematics, 144 SEP Use Mathematics, 146 SEP Analyze and Interpret Data, 147 Jupiter's Distance from the Sun, 148 **Teacher Guide:** **Inquiry Labs:** Model the Orbital Motion of Planets, Kepler's Laws of Planetary Motion **Digital Activities:** Gravitational Forces on Satellites, Eccentric Orbits, Kepler's Law of Planetary Periods
Disciplinary Core Ideas	
ESS1.B: Earth and the Solar System	
Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system.	**SE:** 1 Kepler's First Law, 142–143 Kepler's Second Law, 144 Kepler's Third Law, 146–148 **Teacher Guide:** **Inquiry Labs:** Model the Orbital Motion of Planets, Kepler's Laws of Planetary Motion **Digital Activity:** Kepler's Law of Planetary Periods **Performance-Based Assessment:** What Causes the Seasons?

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Science and Engineering Practices	
Using Mathematical and Computational Thinking	
Use mathematical or computational representations of phenomena to describe explanations.	**Student Experience Notebook:** SEP Use Mathematics, 131 SEP Use Mathematics, 133 Geosynchronous Orbits, 134 SEP Use Mathematics, 135 CCC Patterns, 137 SEP Use Mathematics, 139 SEP Use Mathematics, 140 SEP Use Mathematics, 141 SEP Use Mathematics, 142 SEP Use Mathematics, 143 SEP Use Mathematics, 144 SEP Use Mathematics, 146 SEP Analyze and Interpret Data, 147 Jupiter’s Distance from the Sun, 148 SEP Use Mathematics, 152 **Teacher Guide:** **Inquiry Labs:** Model the Orbital Motion of Planets, Kepler's Laws of Planetary Motion **Digital Activities:** Evidence for a non-circular Earth, Eccentric Orbits, Kepler's Law of Planetary Periods **Engineering Workbench:** Defy Gravity
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).	**Student Experience Notebook:** CCC Scale, Proportion, and Quantity, 130 SEP Use Mathematics, 131 CCC Scale, Proportion, and Quantity, 132 SEP Use Mathematics, 133 Geosynchronous Orbits, 134 SEP Use Mathematics, 135 SEP Develop a Model, 149 CCC Scale, Proportion, and Quantity, 151 **Teacher Guide:** **Inquiry Labs:** Model the Orbital Motion of Planets, Kepler's Laws of Planetary Motion **Digital Activities:** Gravity and Orbits - Model, Eccentric Orbits, Kepler's Law of Planetary Periods, Mercury’s Resonant Orbit **Engineering Workbench:** Defy Gravity **Performance-Based Assessment:** What Causes the Seasons?

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Performance Expectation HS-ESS1-5 Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks.	**Student Experience Notebook:** SEP Construct an Explanation, 360 CCC Patterns, 640 SEP Analyze Data, 641 SEP Develop and Use a Model, 642 CCC Stability and Change, 644 **Teacher Guide:** **Inquiry Lab:** Plate Tectonics and Seafloor Spreading **Digital Activities:** Rock Clocks, Ages of Rocks, Seafloor Spreading **Performance-Based Assessment:** Uranium-Lead Dating
Disciplinary Core Ideas	
ESS1.C: The History of Planet Earth	
Continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are less than 200 million years old.	**Student Experience Notebook:** Pole Reversals, 225 Plate Tectonics, 349 Heat Flow and Plate Tectonics, 395 The Oldest Rocks on Earth, 629 Ages of Ocean Crust, 646–647 Ages of Continental Crust, 648–649
ESS2.B: Plate Tectonics and Large-Scale System Interactions	
Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history.	**Student Experience Notebook:** Pole Reversals, 225 Plate Tectonics, 349 Physical and Geologic Time, 636–637 Seal Level Changes, 641 Geologic Time Scales, 643–644 Ages of Ocean Crust, 646–647
PS1.C: Nuclear Processes	
Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials.	**Student Experience Notebook:** Radioactive Decay, 610–611 Exponential Decay, 612–613 Radioactivity and the Valley of Stability, 618–619 Radiometric Dating, 622 Carbon-14 Dating, 623 Calibrating C-14, 624–625 Radiometric Dating of Charcoal, 626 Age Dating Older Rocks, 627 Uranium-Lead Dating, 628 **Teacher Guide:** **Inquiry Lab:** Radiometric Dating of Rocks **Digital Activity:** Rock Clocks

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Science and Engineering Practices	
Engaging in Argument from Evidence	
Evaluate evidence behind currently accepted explanations or solutions to determine the merits of arguments.	**Student Experience Notebook:** SEP Engage in Argument from Evidence, 647 SEP Engage in Argument from Evidence, 650 **Teacher Guide:** **Inquiry Lab:** Plate Tectonics and Seafloor Spreading **Digital Activities:** Rock Clocks, Ages of Rocks, Seafloor Spreading
Crosscutting Concepts	
Patterns	
Empirical evidence is needed to identify patterns.	**Student Experience Notebook:** Impact Craters and Solar System History, 634 CCC Patterns, 640 Ages of Ocean Crust, 646–647 Ages of Continental Crust, 648–649 CCC Patterns, (51), 650 CCC Patterns, (54), 650 **Teacher Guide:** **Inquiry Lab: Plate** Tectonics and Seafloor Spreading **Digital Activity:** Radioactive Decay
Performance Expectation HS-ESS1-6 Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history.	**Student Experience Notebook:** SEP Construct Explanations, 629 CCC Scale, Proportion, and Quantity, 630 SEP Construct Explanations, 633 SEP Analyze and Interpret Data, 634 SEP Construct Explanations, 635 Finding the Relative Ages of Rocks, 640 SEP Analyze Data, 641 Unconformities, 642 CCC Stability and Change, 645 Ages of Ocean Crust, 646–647 SEP Construct Explanations, 649 **Teacher Guide:** **Inquiry Lab:** Plate Tectonics and Seafloor Spreading **Performance-Based Assessment:** Uranium-Lead Dating

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Disciplinary Core Ideas	
ESS1.C: The History of Planet Earth	
Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history.	**Student Experience Notebook:** The Oldest Rocks on Earth, 629 Meteorites and Solar Spectroscopy, 630 Formation of Earth and the Moon, 633 Impact Craters and Solar System History, 634 Physical and Geologic Time, 636–637 Sea Level Changes, 641–642 Geologic Time Divisions, 644 Ages of Ocean Crust, 646–647
PS1.C: Nuclear Processes	
Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials.	**Student Experience Notebook:** Radioactivity, 610 Exponential Decay, 612–613 Radioactivity and the Valley of Stability, 618 Decay Series for Large Nuclei, 619 Radiometric Dating, 622 Carbon-14 Age Dating, 623 Calibrating C-14, 624–625 Radiometric Dating of Charcoal, 626 Age Dating Older Rocks, 627 Uranium-Lead Dating, 628 **Teacher Guide:** **Inquiry Lab:** Radiometric Dating of Rocks
Science and Engineering Practices	
Constructing Explanations and Designing Solutions	
Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.	**Student Experience Notebook:** SEP Defend Your Claim, 609 SEP Construct Explanations, 623 SEP Construct Explanations, 629 CCC Scale, Proportion, and Quantity, 630 SEP Construct Explanations, 633 SEP Construct Explanations, (38), 635 SEP Construct Explanations, (39), 635 SEP Construct Explanations, 638 SEP Develop and Use a Model, 642 CCC Stability and Change, 645 SEP Construct Explanations, 649 SEP Engage in Argument from Evidence, 650 **Teacher Guide:** **Inquiry Labs:** Half-Life Simulation, Radiometric Dating of Rocks **Digital Activity:** Radiometric Dating **Engineering Workbench:** Build a Glove Box

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Connections to Nature of Science: Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena	
Models, mechanisms, and explanations collectively serve as tools in the development of a scientific theory.	**Student Experience Notebook:** True Ages, 625 Formation of the Solar System, 631 Formation of Earth and the Moon, 633 CCC Stability and Change, 644 **Teacher Guide:** **Inquiry Labs:** Radiometric Dating of Rocks, Half-Life Simulation
Crosscutting Concepts	
Stability and Change	
Much of science deals with constructing explanations of how things change and how they remain stable.	**Student Experience Notebook:** CCC Stability and Change, 612 Beta Decay and Electron Capture, 615 CCC Energy and Matter, 616 CCC Energy and Matter, 617 Decay Series for Large Nuclei, 619 CCC Energy and Matter, 622 SEP Construct Explanations, 623 CCC Systems and System Models, 624 Age Dating Older Rocks, 627 Unconformities, 642 CCC Stability and Change, 644 CCC Stability and Change, 645 **Teacher Guide:** **Inquiry Lab:** Half-Life Simulation **Digital Activities:** Radioactive Decay, Radiometric Dating

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Performance Expectation HS-ESS2-1 Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.	**Student Experience Notebook:** SEP Use Models, 357 SEP Develop a Model, 358 SEP Use Models, 361 SEP Use Models, 395 **Teacher Guide:** **Inquiry Labs:** Mechanical Weathering of Rock, Collisions at a Fault Line, Plate Tectonics and Seafloor Spreading **Digital Activities:** Mountain Building, Plate Boundaries, Seafloor Spreading
Disciplinary Core Ideas	
ESS2.A: Earth Materials and Systems	
Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.	**Student Experience Notebook:** Earth Systems, 95-96 Forces at Earth's Surface, 97 Time Scales of Geologic Processes, 98–100 Mass Wasting, 101 Stream Systems, 102–103 Glacial systems, 104–105 Aeolian Systems, 106 Shoreline Systems, 107 Isostasy and Rebound, 108 Homans as a Geologic Force, 109 Physical and Geologic Time, 636–637 Continuous vs. Catastrophic, 638 Relative Time, 639 Finding the Relative Ages of Rocks, 640 Seal Level Changes, 641–642
ESS2.B: Plate Tectonics and Large-Scale System Interactions	
Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust.	**Student Experience Notebook:** Earth Systems, 95 Isostasy and Rebound, 108 Crust Deformation, 348 Plate Tectonics, 349 Current Plate Motions, 350–351 Force, Stress, and Earthquakes, 352–353 Divergent Plate Boundaries, 354–355 Ocean-Continent Collision, 356–357 Ocean-Ocean Collision, 358 Continent-Continent Collision, 359 The Wilson Cycle of Multiple Collisions, 360–361 Relative Time, 639 Finding the Relative Ages of Rocks, 640 Seal Level Changes, 641–642 Geologic Time Scales, 643–645 Ages of Ocean Crust, 646–647 Ages of Continental Crust, 648–649

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Science and Engineering Practices	
Developing and Using Models	
Develop a model based on evidence to illustrate the relationships between systems or between components of a system.	**Student Experience Notebook:** SEP Use Models, 357 SEP Develop a Model, 358 SEP Use Models, 361 SEP Develop and Use a Model, 642 **Teacher Guide:** **Inquiry Labs:** Mechanical Weathering of Rock, Collisions at a Fault Line, Plate Tectonics and Seafloor Spreading **Digital Activities:** Mountain Building, Plate Boundaries
Crosscutting Concepts	
Stability and Change	
Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.	**Student Experience Notebook:** Time Scales of Geologic Processes, 98–99 Weathering, 100 Physical and Geologic Time, 636–637 Continuous vs. Catastrophic, 638 Relative Time, 639 Physical and Geologic Time, 636–637 Continuous vs. Catastrophic, 638 Relative Time, 639 Sea Level Changes, 641–642 **Teacher Guide:** **Inquiry Lab:** Plate Tectonics and Seafloor Spreading **Digital Activity:** Seafloor Spreading

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Performance Expectation HS-ESS2-3 Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.	**Student Experience Notebook:** SEP Use Mathematics, 400 CCC Systems and System Models, 404 **Teacher Guide:** **Inquiry Lab:** Convection, Conduction, and Radiation **Digital Activity:** Convection Currents
Disciplinary Core Ideas	
ESS2.A: Earth Materials and Systems	
Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid mantle and crust. Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and gravitational movement of denser materials toward the interior.	**Student Experience Notebook:** Heat Flow at Earth's Surface, 394–395 Probing Earth's Interior, 396 Earth's Composition, 397 Earth's Temperature and Heat, 398–399 Heat Conduction and Melting, 400–401 Mantle Convection, 402–403 Mantle Convection and Plate Tectonics, 404 Core Convection and Magnetism, 405
ESS2.B: Plate Tectonics and Large-Scale System Interactions	
The radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle, providing the primary source of the heat that drives mantle convection. Plate tectonics can be viewed as the surface expression of mantle convection.	**Student Experience Notebook:** Heat Flow and Plate Tectonics, 395 Sources of Energy, 399 Mantle Convection and Plate Tectonics, 404 Radioactivity, 610
PS4.A: Wave Properties	
Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet.	**Student Experience Notebook:** Probing Earth's Interior, 396 Seismic Tomography, 403 Mantle Convection and Plate Tectonics, 404
Science and Engineering Practices	
Developing and Using Models	
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.	**Student Experience Notebook:** Heat Flow and Plate Tectonics, 395 Probing Earth's Interior, 396 Heat Conduction and Melting, 400–401 Mantle Convection, 402–403 Mantle Convection and Plate Tectonics, 404 Core Convection and Magnetism, 405 **Teacher Guide:** **Inquiry Lab:** Convection, Conduction, and Radiation **Digital Activities:** Convection Currents, Heat Flow Within Earth

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Connections to Nature of Science: Scientific Knowledge is Based on Empirical Evidence	
Science knowledge is based on empirical evidence. Science disciplines share common rules of evidence used to evaluate explanations about natural systems. Science includes the process of coordinating patterns of evidence with current theory.	**Student Experience Notebook:** Probing Earth's Interior, 396 Earth's Composition, 397 Seismic Tomography, 403 Mantle Convection and Plate Tectonics, 404 Core Convection and Magnetism, 405 **Teacher Guide:** **Digital Activity:** Heat Flow on Earth's Surfaces
Crosscutting Concepts	
Energy and Matter	
Energy drives the cycling of matter within and between systems.	**Student Experience Notebook:** Heat Flow at Earth's Surface, 394–395 Earth's Temperature and Heat, 398–399 Mantle Convection and Plate Tectonics, 404 **Teacher Guide:** **Inquiry Lab:** Convection, Conduction, and Radiation **Digital Activity:** Heat Flow Within Earth
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.	**Student Experience Notebook:** Mantle Convection, 402–403 Mantle Convection and Plate Tectonics, 404 Core Convection and Magnetism, 405

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Performance Expectation HS-ESS3-2 Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.	**Student Experience Notebook:** CCC Cause and Effect, 454 SEP Argue from Evidence, 455 SEP Construct an Argument, 459 SEP Argue from Evidence, 460 SEP Construct an Explanation, 460 **Teacher Guide:** **Digital Activities:** Energy Choices, Resource Use and Biodiversity Tradeoffs, Junkyard Electromagnet **Engineering Workbench:** Energy Sources: Costs and Benefits
Disciplinary Core Ideas	
ESS3.A Natural Resources	
All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors.	**Student Experience Notebook:** Energy Use, Population, and Impact, 446 Impacts on the Biosphere, 447 Impact Reduction, 448 Costs and Benefits, 452 Costs and Benefits of Renewable Energy, 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 Energy from the Sun, 558
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.	**Student Experience Notebook:** Human Power Needs, 449-450 Energy Storage Technologies, 451 Costs and Benefits, 452 Costs and Benefits of Renewable Energy, 453 Sustainable Energy Future, 458–459 Energy from the Sun, 558

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Science and Engineering Practices	
Engaging in Argument from Evidence	
Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations).	**Student Experience Notebook:** CCC Cause and Effect, 454 SEP Argue from Evidence, 455 SEP Construct an Explanation (62), 456 SEP Construct an Argument, 459 SEP Argue from Evidence, 460 SEP Construct an Explanation, 460 SEP Communicate Information, 461 **Teacher Guide:** **Digital Activity:** Resource Use and Biodiversity Tradeoffs **Engineering Workbench:** Energy Sources: Costs and Benefits **Performance-Based Assessment:** Design, Build, and Refine A Wind-Turbine Rotor
Crosscutting Concepts	
Connections to Engineering, Technology, and Applications of Science: Influence of Engineering, Technology, and Science on Society and the Natural World	
Engineers continuously modify these systems to increase benefits while decreasing costs and risks. Analysis of costs and benefits is a critical aspect of decisions about technology.	**Student Experience Notebook:** Annual Load Management, 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 **Digital Activity:** Junkyard Electromagnet
Connections to Nature of Science: Science Addresses Questions About the Natural and Material World	
Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions. Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge. Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues.	**Student Experience Notebook:** Human Use of Energy, 445–446 Costs and Benefits, 452–453 Sustainable Energy Future, 458–459 **Teacher Guide:** **Digital Activity:** Resource Use and Biodiversity Tradeoffs

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Performance Expectation HS-ESS3-3 Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.	**Student Experience Notebook:** SEP Use Mathematics, 446 SEP Analyze Data, 446 CCC Cause and Effect, 448 Impact Reduction, 448 **Teacher Guide:** **Inquiry Lab:** Natural Resource Management **Engineering Workbench:** Energy Sources: Costs and Benefits
Disciplinary Core Ideas	
ESS3.C: Human Impacts on Earth Systems	
The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.	**Student Experience Notebook:** Human Use of Energy, 445–446 Impacts on the Biosphere, 447 Sustainable Energy Future, 458–459 **Teacher Guide:** **Digital Activity:** Resource Use and Biodiversity Tradeoffs
Science and Engineering Practices	
Using Mathematics and Computational Thinking	
Create a computational model or simulation of a phenomenon, designed device, process, or system.	**Student Experience Notebook:** SEP Use Mathematics, 446 SEP Analyze Data, 446 CCC Cause and Effect, 448 Impact Reduction, 448 SEP Use Mathematics, 452 SEP Use Mathematics, 457 SEP Use Mathematics, 460 **Teacher Guide:** **Inquiry Lab:** Natural Resource Management **Digital Activity:** Impact Reduction

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Crosscutting Concepts	
Stability and Change	
Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.	**Student Experience Notebook:** Human Energy Consumption, 445 Human Population Growth and Production, 446 How Energy Use Impact Biodiversity, 447 Impact Reduction, 448 Annual Supply and Demand Variations, 450 Daily Variations in Supply and Demand, 450 Changes in U. S. Generating Capacity Since 2009, 454 Levelized Cost of Energy Sources, 455 The Success of U. S. Environmental Regulations, 458 **Teacher Guide:** **Digital Activity:** Resource Use and Biodiversity Tradeoffs
Connections to Engineering, Technology, and Applications of Science: Influence of Engineering, Technology, and Science on Society and the Natural World	
Modern civilization depends on major technological systems New technologies can have deep impacts on society and the environment, including some that were not anticipated.	**Student Experience Notebook:** Human Use of Energy, 445–447 Human Power Needs, 449–450 Energy Storage Technologies, 451 Sustainable Energy Future, 458–459
Connections to Nature of Science: Science is a Human Endeavor	
Scientific knowledge is a result of human endeavors, imagination, and creativity.	**Student Experience Notebook:** Human Use of Energy, 445–446 Energy Storage Technologies, 451 Sustainable Energy Sources, 459 Transition to the Future, 459 \
Engineering, Technology, and Application of Science	
Performance Expectation HS-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 **Teacher Guide:** **Inquiry Labs:** Converting Sunlight to Electricity, Natural Resource Management **Digital Activities:** Resource Use and Biodiversity Trade Offs, Operate a Nuclear Fission Reactor **Engineering Workbench:** Design an Airdrop System, Egg Supply Drop, Earthquake-Resistant Structures **Performance-Based Assessment:** Build Your Own Egg-Transport Vehicle, Minimizing Car Crash Injuries **Problem-Based Learning:** Staying Fit to Mars and Back, Ultraviolet Radiation

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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.	**Student Experience Notebook:** SEP Design a Solution, 409 SEP Design a Solution, 492 SEP Identify Criteria, 528 Engineering Workbench, 537 **Teacher Guide:** **Inquiry Lab:** Natural Resource Management **Digital Activities:** Resource Use and Biodiversity Trade Offs, Junkyard Electromagnet, Operate a Nuclear Fission Reactor **Engineering Workbench:** Design an Airdrop System, Egg Supply Drop, Energy Sources: Costs and Benefits, Earthquake-Resistant Structures, Waves and Erosion, Landslide Prevention **Performance-Based Assessment:** Build Your Own Egg-Transport Vehicle, Minimizing Car Crash Injuries **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.	**Student Experience Notebook:** SEP Construct an Explanation, 100 SEP Construct an Explanation, 103 SEP Design a Solution, 109 SEP Design a Solution, 409 CCC Stability and Change, 458 SEP Construct an Argument, 459 CCC Energy and Matter, 535 SEP Defend Your Claim, 599 **Teacher Guide:** **Inquiry Labs:** Converting Sunlight to Electricity, Natural Resource Management **Digital Activities:** Resource Use and Biodiversity Trade Offs, Operate a Nuclear Fission Reactor **Engineering Workbench:** Energy Sources: Costs and Benefits, Energy Production **Performance-Based Assessment:** Design, Build and Refine a Wind-Turbine Rotor, Design a Roller Coaster **Problem-Based Learning:** Staying Fit to Mars and Back, Ultraviolet Radiation

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Science and Engineering Practices	
Asking Questions and Defining Problems	
Analyze complex real-world problems by specifying criteria and constraints for successful solutions.	**Student Experience Notebook:** SEP Define a Problem, 49 SEP Design a Solution, 49 SEP Define Problems, 123 SEP Design a Solution, 528 **Teacher Guide:** **Digital Activity:** Operate a Nuclear Fission Reactor **Engineering Workbench:** Design an Airdrop System, Landslide Prevention, Defy Gravity, Design an Electronic Quiz Board, Build a Flashlight Without Batteries, Earthquake-Resistant Structures, Design a Roller Coaster, Egg Supply Drop, Build an Efficient Travel Mug, Energy Sources: Costs and Benefits, Waves and Erosion, Solar Panel Art, Rover, Energy Production, Build a Glove Box, The Colors of Light **Performance-Based Assessment:** Send Messages with a Telegraph **Problem-Based Learning:** Energy in Complex Machines, Staying Fit to Mars and Back, Ultraviolet Radiation
Crosscutting Concepts	
Connections to Engineering, Technology, and Applications of Science: Influence of Science, Engineering, and Technology on Society and the Natural World	
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.	**Student Experience Notebook:** Electromagnetic Energy, 409 How Energy Use Impacts Biodiversity, 447 Power from Nuclear Fission, 599 **Teacher Guide:** **Digital Activities:** Resource Use and Biodiversity Trade Offs, Operate a Nuclear Fission Reactor **Engineering Workbench:** Design an Airdrop System, Landslide Prevention, Defy Gravity, Design an Electronic Quiz Board, Build a Flashlight Without Batteries, Earthquake-Resistant Structures, Design a Roller Coaster, Egg Supply Drop, Build an Efficient Travel Mug, Energy Sources: Costs and Benefits, Waves and Erosion, Solar Panel Art, Rover, Energy Production, Build a Glove Box, The Colors of Light **Performance-Based Assessment:** Send Messages with a Telegraph **Problem-Based Learning:** Staying Fit to Mars and Back, Ultraviolet Radiation

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Performance Expectation HS-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.	**Student Experience Notebook:** Instantaneous Velocity, 21 Engineering Performance-Based Assessment, 363 Computer Memory, 545 SEP Argue from Evidence, 548 **Teacher Guide:** **Inquiry Labs::** Binary Logic, Converting Electrical Signals to Sound, Build a Battery, Electric Fields, Indirect Observation of the Atom, Cohesive Forces and Surface Tension, Electric Motors and Generators, Interference of Sound Waves **Digital Activity:** Operate a Nuclear Fission Reactor **Engineering Workbench:** Waves and Erosion, Landslide Prevention, Design an Electronic Quiz Board, Build a Flashlight Without Batteries, Earthquake-Resistant Structures, Build an Efficient Travel Mug, The Colors of Light **Performance-Based Assessment:** Build and Test an Electroscope, Build a DC Motor, Design, Build and Refine a Wind-Turbine Rotor
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.	**Student Experience Notebook:** SEP Construct an Argument, 47 SEP Argue from Evidence, 182 SEP Construct an Argument, 561 SEP Defend Your Claim, 599 **Teacher Guide:** **Inquiry Labs:** Build a Battery, Electric Motors and Generators, Natural Resource Management **Digital Activities:** Junkyard Electromagnet, Operate a Nuclear Fission Reactor **Engineering Workbench:** Design an Airdrop System, Egg Supply Drop, Landslide Prevention, Defy Gravity, Design an Electronic Quiz Board, Energy Sources: Costs and Benefits, Build a Flashlight Without Batteries, Design a Roller Coaster, Build an Efficient Travel Mug, The Colors of Light **Performance-Based Assessment:** Build Your Own Egg-Transport Vehicle, Minimizing Car Crash Injuries, Build and Test an Electroscope, Build a DC Motor, Design, Build and Refine a Wind-Turbine Rotor

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Science and Engineering Practices	
Constructing Explanations and Designing Solutions	
Design a solution to a complex real-world problem based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.	**Student Experience Notebook:** SEP Design a Solution, 45 SEP Design a Solution, 84 SEP Design a Solution, 94 SEP Design a Solution, 124 SEP Design Solutions, 164 SEP Design a Solution, 206 SEP Design a Solution, 212 SEP Design a Solution, 219 SEP Design a Solution, 232 SEP Design a Solution, 238 SEP Design a Solution, 393 SEP Design a Solution, 497 SEP Design a Solution, 528 SEP Design Solutions, 551 **Teacher Guide:** **Digital Activities:** Junkyard Electromagnet **Engineering Workbench:** Landslide Prevention, Defy Gravity, Earthquake-Resistant Structures, Design a Roller Coaster, The Colors of Light **Performance-Based Assessment:** Design, Build and Refine a Wind-Turbine Rotor
Performance Expectation HS-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.	**Student Experience Notebook:** SEP Ask Questions, 281 CCC Cause and Effect, 454 SEP Identify Criteria, 528 SEP Communicate Information, 461 **Teacher Guide:** **Inquiry Labs:** Momentum and Impulse, Electric Motors and Generators, Natural Resource Management **Digital Activities:** Vehicle Stopping Distance, Generator Testing, Transistors and Integrated Circuits, Junkyard Electromagnet, Operate a Nuclear Fission Reactor **Engineering Workbench:** Landslide Prevention, Energy Sources: Costs and Benefits, Waves and Erosion, Solar Panel Art, Rover, Earthquake-Resistant Structures **Performance-Based Assessment:** Design, Build and Refine a Wind-Turbine Rotor

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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.	**Student Experience Notebook:** SEP Design a Solution, 109 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 Efficiency of Fuels: Nuclear vs. Hydrocarbon, 600 **Teacher Guide:** **Inquiry Labs:** Momentum and Impulse, Natural Resource Management **Digital Activities:** Vehicle Stopping Distance, Electric Circuits, Generator Testing, Transistors and Integrated Circuits, Junkyard Electromagnet, Operate a Nuclear Fission Reactor **Engineering Workbench:** Waves and Erosion, Energy Sources: Costs and Benefits, Solar Panel Art, Rover, Landslide Prevention, Earthquake-Resistant Structures **Performance-Based Assessment:** Design, Build and Refine a Wind-Turbine Rotor, Send Messages with a Telegraph **Problem-Based Learning:** Electromagnetic Roller Coaster

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Science and Engineering Practices	
Constructing Explanations and Designing Solutions	
Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.	**Student Experience Notebook:** SEP Design a Solution, 45 SEP Design a Solution, 49 SEP Design a Solution, 94 SEP Design a Solution, 109 SEP Design a Solution, 212 SEP Design a Solution, 269 SEP Design a Solution, 409 SEP Design a Solution, 434 SEP Construct an Argument, 459 SEP Design a Solution, 492 SEP Design Solutions, 541 SEP Design Solutions, 564 **Teacher Guide:** **Digital Activities:** Enantiomers, Electric Circuits, Resource Use and Biodiversity Trade Offs **Engineering Workbench:** Design an Airdrop System, Landslide Prevention, Defy Gravity, Design an Electronic Quiz Board, Build a Flashlight Without Batteries, Earthquake-Resistant Structures, Design a Roller Coaster, Egg Supply Drop, Build an Efficient Travel Mug, Energy Sources: Costs and Benefits, Waves and Erosion, Solar Panel Art, Rover, Energy Production, Build a Glove Box, The Colors of Light **Performance-Based Assessment:** Design, Build and Refine a Wind-Turbine Rotor **Problem-Based Learning:** Electromagnetic Roller Coaster, A Mystery on Planet K

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Crosscutting Concepts	
Connections to Engineering, Technology, and Applications of Science: Influence of Science, Engineering, and Technology on Society and the Natural World	
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.	**Student Experience Notebook:** Energy Storage Technologies, 451 Costs and Benefits of Renewable Energy, 453 Levelized Cost of Energy Sources, 455 Computer Memory, 545 Digital Data, 547 Wireless Charging, 561 **Teacher Guide:** **Digital Activities:** Vehicle Stopping Distance, Enantiomers, Electric Circuits, Resource Use and Biodiversity Trade Offs, Transistors and Integrated Circuits, Junkyard Electromagnet **Engineering Workbench:** Design an Airdrop System, Landslide Prevention, Defy Gravity, Design an Electronic Quiz Board, Build a Flashlight Without Batteries, Earthquake-Resistant Structures, Design a Roller Coaster, Egg Supply Drop, Build an Efficient Travel Mug, Energy Sources: Costs and Benefits, Waves and Erosion, Solar Panel Art, Rover, Energy Production, Build a Glove Box, The Colors of Light **Performance-Based Assessment:** Design, Build and Refine a Wind-Turbine Rotor

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Performance Expectation HS-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 Lab:** Natural Resource Management **Digital Activities:** Generator Testing, Junkyard Electromagnet **Engineering Workbench:** Rover, Energy Sources: Costs and Benefits
Disciplinary Core Ideas	
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.	**Student Experience Notebook:** Lumpy Geoid, 121 Twin Satellites, 121 Computer Simulation of Mantle Convection, 402 Seismic Tomography, 403 Forces that Drive Mantle Convection, 404 Earth's External and Internal Magnetic Field, 405 The Formation of the Solar System, 632 Formation of Earth and the Moon, 633 **Teacher Guide:** **Inquiry Lab:** Natural Resource Management **Digital Activities:** Generator Testing, Junkyard Electromagnet **Engineering Workbench:** Rover, Energy Sources: Costs and Benefits

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Science and Engineering Practices	
Using Mathematics and Computational Thinking	
Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems.	**Student Experience Notebook:** SEP Use Computational Thinking, 38 SEP Use Mathematics, 446 Impact Reduction, 448 SEP Use Mathematics, 457 SEP Use Computational Thinking, 504 **Teacher Guide:** **Digital Activities:** Vehicle Stopping Distance, Resource Use and Biodiversity Trade Offs **Engineering Workbench:** Rover, Defy Gravity, Design an Electronic Quiz Board, Design a Roller Coaster, Energy Production **Performance-Based Assessment:** Build and Test an Electroscope, Structure-Property Relationships, Energy Conversion
Crosscutting Concepts	
Systems and System Models	
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.	**Student Experience Notebook:** CCC Systems and System Models, 319 CCC Systems and System Models, 511 Interference Pattern, 524 CCC Systems and System Models, 539 **Teacher Guide:** **Digital Activity:** Electric Circuits **Engineering Workbench:** Rover, Design an Electronic Quiz Board, Energy Sources: Costs and Benefits, Design a Roller Coaster **Performance-Based Assessment:** Build and Test an Electroscope, Structure-Property Relationships