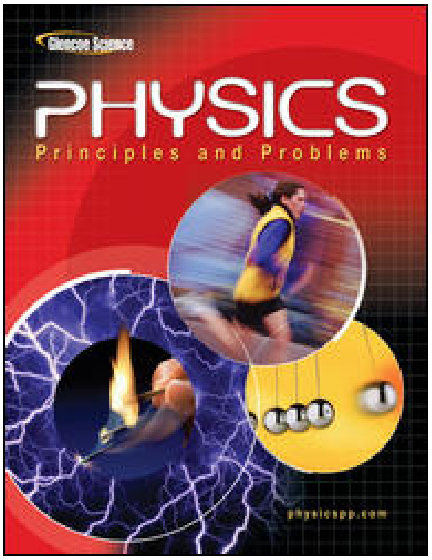

High School Science Content Expectations/Physics Essential Skills

PHYSICS

Principles and Problems

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STANDARDS	PAGE REFERENCES
STANDARD P1: INQUIRY, REFLECTION, AND SOCIAL IMPLICATIONS *Students will understand the nature of science and demonstrate an ability to practice scientific reasoning by applying it to the design, execution, and evaluation of scientific investigations. Students will demonstrate their understanding that scientific knowledge is gathered through various forms of direct and indirect observations and the testing of this information by methods including, but not limited to, experimentation. They will be able to distinguish between types of scientific knowledge (e.g., hypotheses, laws, theories) and become aware of areas of active research in contrast to conclusions that are part of established scientific consensus. They will use their scientific knowledge to assess the costs, risks, and benefits of technological systems as they make personal choices and participate in public policy decisions. These insights will help them analyze the role science plays in society, technology, and potential career opportunities.*	
P1.1 Scientific Inquiry Science is a way of understanding nature. Scientific research may begin by generating new scientific questions that can be answered through replicable scientific investigations that are logically developed and conducted systematically. Scientific conclusions and explanations result from careful analysis of empirical evidence and the use of logical reasoning. Some questions in science are addressed through indirect rather than direct observation, evaluating the consistency of new evidence with results predicted by models of natural processes. Results from investigations are communicated in reports that are scrutinized through a peer review process.	

STANDARDS		PAGE REFERENCES
P1.1A	Generate new questions that can be investigated in the laboratory or field.	**Student Edition:** 8-10 *Design Your Own Physics Lab* 160-161, 392-393, 532-533, 824-825 *Launch Lab* 3, 197, 431, 591 *Technology and Society* 220, 394 **Teacher Wraparound Edition:** AIL 161, 393; HSS 8
P1.1B	Evaluate the uncertainties or validity of scientific conclusions using an understanding of sources of measurement error, the challenges of controlling variables, accuracy of data analysis, logic of argument, logic of experimental design, and/or the dependence on underlying assumptions.	**Student Edition:** 3-10, 11-14, 212-213, 748-759 *Applying Physics* 180, 467 *Extreme Physics* 366, 506 *Future Technology* 556, 826 *Physics Lab* 420-421, 580-581, 766-767, 790-791 **Teacher Wraparound Edition:** CU 14; HSS 8
P1.1C	Conduct scientific investigations using appropriate tools and techniques (e.g., selecting an instrument that measures the desired quantity–length, volume, weight, time interval, temperature–with the appropriate level of precision).	**Student Edition:** 11-14, 15-19 *Design Your Own Physics Lab* 392-393 *Internet Physics Lab* 20-21 *MiniLAB* 8 *Physics Lab* 332-333, 448-449, 606-607, 790-791 *Problem-Solving Strategies* 466, 629 **Teacher Wraparound Edition:** CB 9; CU 14; TPK 11
P1.1D	Identify patterns in data and relate them to theoretical models.	**Student Edition:** 9, 33, 748-756, 760-761 *Extreme Physics* 78, 506 *Launch Lab* 747 *MiniLAB* 702, 813 *Physics Lab* 186-187, 392-393, 738-739 **Teacher Wraparound Edition:** R 33

STANDARDS		PAGE REFERENCES
P1.1E	Describe a reason for a given conclusion using evidence from an investigation.	**Student Edition:** 8-10 *Design Your Own Physics Lab* 392-393, 532-533 *Extreme Physics* 50, 188, 422 *Internet Physics Lab* 20-21, 76-77 *Physics Lab* 218-219, 332-333 *Technology and Society* 220, 608 **Teacher Wraparound Edition:** CB 9, 92; PP 99, 213
	P1.2 Scientific Reflection and Social Implications The integrity of the scientific process depends on scientists and citizens understanding and respecting the "Nature of Science." Openness to new ideas, skepticism, and honesty are attributes required for good scientific practice. Scientists must use logical reasoning during investigation design, analysis, conclusion, and communication. Science can produce critical insights on societal problems from a personal and local scale to a global scale. Science both aids in the development of technology and provides tools for assessing the costs, risks, and benefits of technological systems. Scientific conclusions and arguments play a role in personal choice and public policy decisions. New technology and scientific discoveries have had a major influence in shaping human history. Science and technology continue to offer diverse and significant career opportunities.	
P1.2A	Critique whether or not specific questions can be answered through scientific investigations.	**Student Edition:** 10, 415-417, 419, 441-442, 737 *Extreme Physics* 78, 792 *MiniLAB* 418 *Technology and Society* 138, 220 **Teacher Wraparound Edition:** CB 7; CT 123; D 78; E 419; IM 9, 736
P1.2B	Identify and critique arguments about personal or societal issues based on scientific evidence.	**Student Edition:** 500-501, 764-765, 811-814 *Extreme Physics* 50, 792 *Future Technology* 22, 826 *Technology and Society* 394, 608, 716 **Teacher Wraparound Edition:** CU 814; IM 9; PP 6; RLP 5, 501

STANDARDS	PAGE REFERENCES
P1.2C Develop an understanding of a scientific concept by accessing information from multiple sources. Evaluate the scientific accuracy and significance of the information.	**Student Edition:** 3-10, 179-185, 747-759, 760-761, 818-823 *Applying Physics* 154 *Design Your Own Physics Lab* 392-393, 532-533, 554-555, 824-825 *Extreme Physics* 50, 188, 422, 506 *Future Technology* 556, 826 *Physics Lab* 186-187 **Teacher Wraparound Edition:** CB 9, 39; HSS 8; IM 172; PP 6, 16, 762; RLP 173, 175; TPK 760
P1.2D Evaluate scientific explanations in a peer review process or discussion format.	**Student Edition:** 8-10, 12, 15-18 *Connecting Math to Physics* 47, 295 *Internet Physics Lab* 108-109 *Physics Lab* 186-187, 274-275, 580-581, 790-791 *Problem-Solving Strategies* 16, 728 *Share Your Data* 21, 77, 247 **Teacher Wraparound Edition:** CB 12; CD 7; D 13
P1.2E Evaluate the future career and occupational prospects of science fields.	**Student Edition:** 3, 415-419 *Chemistry Connection* 442 *Extreme Physics* 792 *Future Technology* 826 *Technology and Society* 304, 394, 450, 608 **Teacher Wraparound Edition:** RLC 68, 180, 214, 241, 289, 319, 345, 360, 433, 461, 496, 522, 657, 702, 708, 751, 763, 777, 780, 811, 820

STANDARDS		PAGE REFERENCES
	STANDARD P2: MOTION OF OBJECTS *The universe is in a state of constant change. From small particles (electrons) to the large systems (galaxies) all things are in motion. Therefore, for students to understand the universe they must describe and represent various types of motion. Kinematics, the description of motion, always involves measurements of position and time. Students must describe the relationships between these quantities using mathematical statements, graphs, and motion maps. They use these representations as powerful tools to not only describe past motions but also predict future events.*	
	P2.1 Position – Time An object's position can be measured and graphed as a function of time. An object's speed can be calculated and graphed as a function of time.	
P2.1A	Calculate the average speed of an object using the change of position and elapsed time.	**Student Edition:** 38-42, 43-47 *Internet Physics Lab* 20-21 *Launch Lab* 31 *Physics Lab* 48-49 **Teacher Wraparound Edition:** A 47; BA 31; CD 43; CU 33, 42; D 34; ICE 45; IM 46
P2.1B	Represent the velocities for linear and circular motion using motion diagrams (arrows on strobe pictures).	**Student Edition:** 34-37, 46-47, 148-151, 153-155 *Physics Lab* 48-49 **Teacher Wraparound Edition:** CU 156; D 34
P2.1C	Create line graphs using measured values of position and elapsed time.	**Student Edition:** 38-42, 45, 58-64, 66-67, 72-73 *Internet Physics Lab* 76-77 *Launch Lab* 57 **Teacher Wraparound Edition:** CD 38; CT 68; ICE 45, 60, 67; IM 39; TPK 57
P2.1D	Describe and analyze the motion that a position-time graph represents, given the graph.	**Student Edition:** 38-42, 43-45, 66 **Teacher Wraparound Edition:** CD 38; IM 39

STANDARDS		PAGE REFERENCES
P2.1E	Describe and classify various motions in a plane as one dimensional, two dimensional, circular, or periodic.	**Student Edition:** 32-37, 147-151, 153-155, 176, 180, 375-379 *Design Your Own Physics Lab* 160-161, 392-393 *Launch Lab* 147 **Teacher Wraparound Edition:** BA 375; CT 378; D 34
P2.1F	Distinguish between rotation and revolution and describe and contrast the two speeds of an object like the Earth.	**Student Edition:** 171-173, 176, 179-180, 197-199, 208-210, 216-217 *Physics Lab* 186-187 **Teacher Wraparound Edition:** CB 208; CD 172; HSS 206
	P2.2 Velocity — Time The motion of an object can be described by its position and velocity as functions of time and by its average speed and average acceleration during intervals of time.	
P2.2A	Distinguish between the variables of distance, displacement, speed, velocity, and acceleration.	**Student Edition:** 36-37, 43-47, 59-64, 65-71 *Physics Lab* 48-49 **Teacher Wraparound Edition:** CH 66; CU 71; ICE 60, 70; IM 36; QD 69; TPK 43
P2.2B	Use the change of speed and elapsed time to calculate the average acceleration for linear motion.	**Student Edition:** 57-64, 65-68, 90-91 *Internet Physics Lab* 76-77 **Teacher Wraparound Edition:** CH 69; CT 74; IM 61, 90; R 63; UA 62
P2.2C	Describe and analyze the motion that a velocity-time graph represents, given the graph.	**Student Edition:** 58-64, 66-67, 72-73, 90 *Internet Physics Lab* 76-77 **Teacher Wraparound Edition:** CB 59; CT 68; ICE 60, 67; UM 74
P2.2D	State that uniform circular motion involves acceleration without a change in speed.	**Student Edition:** 153-156, 179-181 **Teacher Wraparound Edition:** BA 153; CD 179; CU 156, 178; E 659; ICE 181; IM 154

STANDARDS		PAGE REFERENCES
	P2.3x Frames of Reference All motion is relative to whatever frame of reference is chosen, for there is no motionless frame from which to judge all motion.	
	STANDARD P3: FORCES AND MOTION *Students identify interactions between objects either as being by direct contact (e.g., pushes or pulls, friction) or at a distance (e.g., gravity, electromagnetism), and to use forces to describe interactions between objects. They recognize that non-zero net forces always cause changes in motion (Newton's first law). These changes can be changes in speed, direction, or both. Students use Newton's second law to summarize relationships among and solve problems involving net forces, masses, and changes in motion (using standard metric units). They explain that whenever one object exerts a force on another, a force equal in magnitude and opposite in direction is exerted back on it (Newton's third law).*	
	P3.1 Basic Forces in Nature Objects can interact with each other by "direct contact" (e.g., pushes or pulls, friction) or at a distance (e.g., gravity, electromagnetism, nuclear).	
P3.1A	Identify the force(s) acting between objects in "direct contact" or at a distance.	**Student Edition:** 88-89, 105-107, 175-176, 179-185, 546-553 *Design Your Own Physics Lab* 554-555 *Internet Physics Lab* 108-109 **Teacher Wraparound Edition:** CB 177; CD 176, 542; ICE 181; PP 105; QD 175; TPK 546
	P3.1x Forces There are four basic forces (gravitational, electromagnetic, strong, and weak nuclear) that differ greatly in magnitude and range. Between any two charged particles, electric force is vastly greater than the gravitational force. Most observable forces (e.g., those exerted by a coiled spring or friction) may be traced to electric forces acting between atoms and molecules.	
	P3.2 Net Forces Forces have magnitude and direction. The net force on an object is the sum of all the forces acting on the object. Objects change their speed and/or direction only when a net force is applied. If the net force on an object is zero, there is no change in motion (Newton's First Law).	
P3.2A	Identify the magnitude and direction of everyday forces (e.g., wind, tension in ropes, pushes and pulls, weight).	**Student Edition:** 90-91, 98, 105-107, 126-130, 549-553 *Future Technology* 162, 248 *Internet Physics Lab* 108-109 *Physics Lab* 136-137 *Technology and Society* 138, 304 **Teacher Wraparound Edition:** CB 133; IM 552; PP 105; QD 100; RLP 154

STANDARDS		PAGE REFERENCES
P3.2B	Compare work done in different situations.	**Student Edition:** 258-261, 268, 286-289 **Teacher Wraparound Edition:** CD 258; CT 268; CU 265; RLP 260
P3.2C	Calculate the net force acting on an object.	**Student Edition:** 92, 105-106, 155, 354-356, 378-379, 573-574 **Teacher Wraparound Edition:** CB 92; CU 95; E 107; HSS 89; TPK 102; UM 103
	P3.3 Newton's Third Law Whenever one object exerts a force on another object, a force equal in magnitude and opposite in direction is exerted back on the first object.	
P3.3A	Identify the action and reaction force from examples of forces in everyday situations (e.g., book on a table, walking across the floor, pushing open a door).	**Student Edition:** 102-107 *Internet Physics Lab* 108-109 **Teacher Wraparound Edition:** BA 102; HSS 104; ICE 106; IM 103; R 107; UA 105
	P3.4 Forces and Acceleration The change of speed and/or direction (acceleration) of an object is proportional to the net force and inversely proportional to the mass of the object. The acceleration and net force are always in the same direction.	
P3.4A	Predict the change in motion of an object acted on by several forces.	**Student Edition:** 89, 105-107, 354-356, 572-574, 698-700 **Teacher Wraparound Edition:** CU 95; HSS 89; R 107; TPK 102; UM 103
P3.4B	Identify forces acting on objects moving with constant velocity (e.g., cars on a highway).	**Student Edition:** 38-42, 43-47, 92, 94-95, 100-101 **Teacher Wraparound Edition:** A 93; CB 92; CU 33, 95; D 34
P3.4C	Solve problems involving force, mass, and acceleration in linear motion (Newton's second law).	**Student Edition:** 93, 96-101, 182, 208-210 **Teacher Wraparound Edition:** D 96; ICE 97, 99, 129

STANDARDS		PAGE REFERENCES
P3.4D	Identify the force(s) acting on objects moving with uniform circular motion (e.g., a car on a circular track, satellites in orbit).	**Student Edition:** 153-156, 179-181 **Teacher Wraparound Edition:** BA 153; CD 179; CU 178; E 659; ICE 181; IM 154
	P3.5x Momentum A moving object has a quantity of motion (momentum) that depends on its velocity and mass. In interactions between objects, the total momentum of the objects does not change.	
	P3.6 Gravitational Interactions Gravitation is a universal attractive force that a mass exerts on every other mass. The strength of the gravitational force between two masses is proportional to the masses and inversely proportional to the square of the distance between them.	
P3.6A	Explain earth-moon interactions (orbital motion) in terms of forces.	**Student Edition:** 175-176, 179-181 *Physics Lab* 186-187 **Teacher Wraparound Edition:** CT 175; ICE 181; TPK 171, 179
P3.6B	Predict how the gravitational force between objects changes when the distance between them changes.	**Student Edition:** 175-176, 179-185 **Teacher Wraparound Edition:** CB 177; CD 176; ICE 181; QD 175
P3.6C	Explain how your weight on Earth could be different from your weight on another planet.	**Student Edition:** 96-98, 182 *Internet Physics Lab* 108-109 **Teacher Wraparound Edition:** BA 96; D 182; R 185
	P3.7 Electric Charges Electric force exists between any two charged objects. Oppositely charged objects attract, while objects with like charge repel. The strength of the electric force between two charged objects is proportional to the magnitudes of the charges and inversely proportional to the square of the distance between them (Coulomb's Law).	
P3.7A	Predict how the electric force between charged objects varies when the distance between them and/or the magnitude of charges change.	**Student Edition:** 549-553, 564-566, 573-574 *Design Your Own Physics Lab* 554-555 **Teacher Wraparound Edition:** ICE 551, 565; IM 552; R 550

<table>
<tr><th colspan="2">STANDARDS</th><th>PAGE REFERENCES</th></tr>
<tr><td>P3.7B</td><td>Explain why acquiring a large excess static charge (e.g., pulling off a wool cap, touching a Van de Graaff generator, combing) affects your hair.</td><td>Student Edition:
542-543, 546-548, 563-564, 567-568
Design Your Own Physics Lab 554-555
How It Works 582
Launch Lab 541, 563
Teacher Wraparound Edition:
CB 564; D 550</td></tr>
<tr><td></td><td colspan="2">P3.7x Electric Charges — Interactions
Charged objects can attract electrically neutral objects by induction.</td></tr>
<tr><td></td><td colspan="2">P3.p8 Magnetic Force (prerequisite)
Magnets exert forces on all objects made of ferromagnetic materials (e.g., iron, cobalt, and nickel) as well as other magnets. This force acts at a distance. Magnetic fields accompany magnets and are related to the strength and direction of the magnetic force. (prerequisite)</td></tr>
<tr><td></td><td colspan="2">P3.8x Electromagnetic Force
Magnetic and electric forces are two aspects of a single electromagnetic force. Moving electric charges produce magnetic forces and moving magnets produce electric forces (e.g., electric current in a conductor).</td></tr>
<tr><td></td><td colspan="2">STANDARD P4: FORMS OF ENERGY AND ENERGY TRANSFORMATIONS
Energy is a useful conceptual system for explaining how the universe works and accounting for changes in matter. Energy is not a “thing.” Students develop several energy-related ideas: First, they keep track of energy during transfers and transformations, and account for changes using energy conservation. Second, they identify places where energy is apparently lost during a transformation process, but is actually spread around to the environment as thermal energy and therefore not easily recoverable. Third, they identify the means of energy transfers: collisions between particles, or waves.</td></tr>
<tr><td></td><td colspan="2">P4.1 Energy Transfer
Moving objects and waves transfer energy from one location to another. They also transfer energy to objects during interactions (e.g., sunlight transfers energy to the ground when it warms the ground; sunlight also transfers energy from the Sun to the Earth).</td></tr>
<tr><td>P4.1A</td><td>Account for and represent energy into and out of systems using energy transfer diagrams.</td><td>Student Edition:
288-292, 293-295, 317-318, 323-325
MiniLAB 301
Teacher Wraparound Edition:
CH 294; CU 292; QD 297; R 299; UM 298</td></tr>
</table>

STANDARDS		PAGE REFERENCES
P4.1B	Explain instances of energy transfer by waves and objects in everyday activities (e.g., why the ground gets warm during the day, how you hear a distant sound, why it hurts when you are hit by a baseball).	**Student Edition:** 317-318, 327-331, 381-382, 404-406 *Launch Lab* 313 **Teacher Wraparound Edition:** CU 331; HSS 320; ICE 321; RLC 319; RLP 327; UM 324
	P4.1x Energy Transfer — Work Work is the amount of energy transferred during an interaction. In mechanical systems, work is the amount of energy transferred as an object is moved through a distance, $W = F d$, where d is in the same direction as F. The total work done on an object depends on the net force acting on the object and the object's displacement.	
	P4.2 Energy Transformation Energy is often transformed from one form to another. The amount of energy before a transformation is equal to the amount of energy after the transformation. In most energy transformations, some energy is converted to thermal energy.	
P4.2A	Account for and represent energy transfer and transformation in complex processes (interactions).	**Student Edition:** 315, 317-318, 323-324, 326-328, 348 *How It Works* 334 *Technology and Society* 394 **Teacher Wraparound Edition:** AP 317; CT 316; PP 330; QD 315; RLC 319; TPK 314
P4.2B	Name devices that transform specific types of energy into other types (e.g., a device that transforms electricity into motion).	**Student Edition:** 326-328, 601-602, 659, 675-678, 781-783, 811-813 *Extreme Physics* 662 *How It Works* 334 *Physics Lab* 332-333 **Teacher Wraparound Edition:** BA 285; IM 326; PP 330; R 328
P4.2C	Explain how energy is conserved in common systems (e.g., light incident on a transparent material, light incident on a leaf, mechanical energy in a collision).	**Student Edition:** 293-295, 297-301, 319-320 *Physics Lab* 302-303 **Teacher Wraparound Edition:** AIL 303; CB 298; CD 294; HSS 296; QD 295; R 731, 734

STANDARDS		PAGE REFERENCES
P4.2D	Explain why all the stored energy in gasoline does not transform to mechanical energy of a vehicle.	**Student Edition:** 326-331 **Teacher Wraparound Edition:** CD 327; IM 326
	P4.3 Kinetic and Potential Energy Moving objects have kinetic energy. Objects experiencing a force may have potential energy due to their relative positions (e.g., lifting an object or stretching a spring, energy stored in chemical bonds). Conversions between kinetic and gravitational potential energy are common in moving objects. In frictionless systems, the decrease in gravitational potential energy is equal to the increase in kinetic energy or vice versa.	
P4.3A	Identify the form of energy in given situations (e.g., moving objects, stretched springs, rocks on cliffs, energy in food).	**Student Edition:** 213, 244-245, 288-292, 314-315, 403-407, 569-571, 811-814 *Applying Physics* 265 *How It Works* 334 *Launch Lab* 313 *Technology and Society* 220 **Teacher Wraparound Edition:** CD 593; CU 292; HSS 296
P4.3B	Describe the transformation between potential and kinetic energy in simple mechanical systems (e.g., pendulums, roller coasters, ski lifts).	**Student Edition:** 258-259, 287-290, 293-295, 376-380, 726-732 *Launch Lab* 285 *Physics Lab* 302-303 **Teacher Wraparound Edition:** CU 292; HSS 288, 296; R 299
P4.3C	Explain why all mechanical systems require an external energy source to maintain their motion.	**Student Edition:** 126-130, 268, 326-327, 328-331 **Teacher Wraparound Edition:** CD 327; CT 268
	P4.3x Kinetic and Potential Energy — Calculations The kinetic energy of an object is related to the mass of an object and its speed: $KE = 1/2\ mv^2$.	

STANDARDS		PAGE REFERENCES
	P4.4 Wave Characteristics Waves (mechanical and electromagnetic) are described by their wavelength, amplitude, frequency, and speed.	
P4.4A	Describe specific mechanical waves (e.g., on a demonstration spring, on the ocean) in terms of wavelength, amplitude, frequency, and speed.	**Student Edition:** 375-379, 382-385, 404-407, 437-438, 445-447 *Design Your Own Physics Lab* 392-393 *Physics Lab* 420-421 **Teacher Wraparound Edition:** CT 383; ICE 385; PP 382, 437; UA 404
P4.4B	Identify everyday examples of transverse and compression (longitudinal) waves.	**Student Edition:** 381-382, 404-406 *Extreme Physics* 506 *Launch Lab* 375 *Technology and Society* 394 **Teacher Wraparound Edition:** QD 383; R 405; RLP 389; UM 381
P4.4C	Compare and contrast transverse and compression (longitudinal) waves in terms of wavelength, amplitude, and frequency.	**Student Edition:** 381-382, 404-406 *Technology and Society* 394 **Teacher Wraparound Edition:** QD 383; R 405; RLP 389; UM 381
	P4.4x Wave Characteristics — Calculations Wave velocity, wavelength, and frequency are related by $v = \lambda f$. The energy transferred by a wave is proportional to the square of the amplitude of vibration and its frequency.	
	P4.5 Mechanical Wave Propagation Vibrations in matter initiate mechanical waves (e.g., water waves, sound waves, seismic waves), which may propagate in all directions and decrease in intensity in proportion to the distance squared for a point source. Waves transfer energy from one place to another without transferring mass.	
P4.5A	Identify everyday examples of energy transfer by waves and their sources.	**Student Edition:** 381-382 *Technology and Society* 394 **Teacher Wraparound Edition:** BA 403; PP 382; RLP 389

STANDARDS		PAGE REFERENCES
P4.5B	Explain why an object (e.g., fishing bobber) does not move forward as a wave passes under it.	**Student Edition:** 382 **Teacher Wraparound Edition:** CB 390; R 405; RLP 389
P4.5C	Provide evidence to support the claim that sound is energy transferred by a wave, not energy transferred by particles.	**Student Edition:** 404-405 **Teacher Wraparound Edition:** BA 403; HSS 405
P4.5D	Explain how waves propagate from vibrating sources and why the intensity decreases with the square of the distance from a point source.	**Student Edition:** 382-383, 404-405, 406-407 **Teacher Wraparound Edition:** BA 403; CT 383; IM 382; R 386; UA 404; UM 706
P4.5E	Explain why everyone in a classroom can hear one person speaking, but why an amplification system is often used in the rear of a large concert auditorium.	**Student Edition:** 406-407 **Teacher Wraparound Edition:** UA 404
	P4.6 Electromagnetic Waves Electromagnetic waves (e.g., radio, microwave, infrared, visible light, ultraviolet, x-ray) are produced by changing the motion (acceleration) of charges or by changing magnetic fields. Electromagnetic waves can travel through matter, but they do not require a material medium. (That is, they also travel through empty space.) All electromagnetic waves move in a vacuum at the speed of light. Types of electromagnetic radiation are distinguished from each other by their wavelength and energy.	
P4.6A	Identify the different regions on the electromagnetic spectrum and compare them in terms of wavelength, frequency, and energy.	**Student Edition:** 708, 713 *Challenge Problem* 709 *Technology and Society* 716 **Teacher Wraparound Edition:** IM 710; PP 711; R 706, 713
P4.6B	Explain why radio waves can travel through space, but sound waves cannot.	**Student Edition:** 404-405, 706-708 **Teacher Wraparound Edition:** CD 706

STANDARDS		PAGE REFERENCES
P4.6C	Explain why there is a delay between the time we send a radio message to astronauts on the moon and when they receive it.	**Student Edition:** 438, 706-708 *Applying Physics* 13 **Teacher Wraparound Edition:** A 437; TPK 705
P4.6D	Explain why we see a distant event before we hear it (e.g., lightning before thunder, exploding fireworks before the boom).	**Student Edition:** 404-405, 437-438 *Physics Lab* 420-421 **Teacher Wraparound Edition:** A 437; CD 706

P4.6x Electromagnetic Propagation

Modulated electromagnetic waves can transfer information from one place to another (e.g., televisions, radios, telephones, computers and other information technology devices). Digital communication makes more efficient use of the limited electromagnetic spectrum, is more accurate than analog transmission, and can be encrypted to provide privacy and security.

P4.r7x Quantum Theory of Waves *(recommended)*

Electromagnetic energy is transferred on the atomic scale in discrete amounts called quanta. The equation $E = h\,f$ quantifies the relationship between the energy transferred and the frequency, where h is Planck's constant. *(recommended)*

P4.8 Wave Behavior — Reflection and Refraction

The laws of reflection and refraction describe the relationships between incident and reflected/refracted waves.

P4.8A	Draw ray diagrams to indicate how light reflects off objects or refracts into transparent media.	**Student Edition:** 432, 440-442, 461-463, 486-489, 494-499, 500-503 **Teacher Wraparound Edition:** CB 459; IM 466; R 433; RLP 442
P4.8B	Predict the path of reflected light from flat, curved, or rough surfaces (e.g., flat and curved mirrors, painted walls, paper).	**Student Edition:** 458-460 **Teacher Wraparound Edition:** BA 457; D 460; QD 459

P4.8x Wave Behavior — Diffraction, Interference, and Refraction

Waves can bend around objects (diffraction). They also superimpose on each other and continue their propagation without a change in their original properties (interference). When refracted, light follows a defined path.

STANDARDS		PAGE REFERENCES
	P4.9 Nature of Light Light interacts with matter by reflection, absorption, or transmission.	
P4.9A	Identify the principle involved when you see a transparent object (e.g., straw, piece of glass) in a clear liquid.	**Student Edition:** 489 *Launch Lab* 485 **Teacher Wraparound Edition:** R 492
P4.9B	Explain how various materials reflect, absorb, or transmit light in different ways.	**Student Edition:** 431-434, 440-442 **Teacher Wraparound Edition:** R 433; RLP 442
P4.9C	Explain why the image of the Sun appears reddish at sunrise and sunset.	**Student Edition:** 442
	P4.r9x Nature of Light — Wave-Particle Nature *(recommended)* The dual wave-particle nature of matter and light is the foundation for modern physics. *(recommended)*	
	P4.10 Current Electricity — Circuits Current electricity is described as movement of charges. It is a particularly useful form of energy because it can be easily transferred from place to place and readily transformed by various devices into other forms of energy (e.g., light, heat, sound, and motion). Electrical current (amperage) in a circuit is determined by the potential difference (voltage) of the power source and the resistance of the loads in the circuit.	
P4.10A	Describe the energy transformations when electrical energy is produced and transferred to homes and businesses.	**Student Edition:** 603-605, 675-678 **Teacher Wraparound Edition:** CT 602

STANDARDS	PAGE REFERENCES
P4.10B Identify common household devices that transform electrical energy to other forms of energy, and describe the type of energy transformation.	**Student Edition:** 648-649, 652-659, 672-678, 679-685 *Design Your Own Physics Lab* 660-661 *Extreme Physics* 662 *How It Works* 688 *Launch Lab* 671 *Physics Lab* 686-687 **Teacher Wraparound Edition:** CD 675; CH 680; CT 656; CU 678; D 655; E 659; R 649; RLP 648
P4.10C Given diagrams of many different possible connections of electric circuit elements, identify complete circuits, open circuits, and short circuits and explain the reasons for the classification.	**Student Edition:** 595-600, 617-626, 627-631 *How It Works* 634 *Launch Lab* 591, 617 *Physics Lab* 632-633, 790-791 *Problem-Solving Strategies* 629 **Teacher Wraparound Edition:** CU 600, 626, 631; D 623; ICE 625; IM 627; R 596, 628
P4.10D Discriminate between voltage, resistance, and current as they apply to an electric circuit.	**Student Edition:** 591-597, 618-621, 623-626 *Physics Lab* 606-607, 632-633 **Teacher Wraparound Edition:** AML 625; CB 595; CD 593, 619; ICE 621; IM 594; QD 597; R 596; UA 592

P4.10x Current Electricity — Ohm's Law, Work, and Power

In circuits, the relationship between electric current, *I*, electric potential difference, *V,* and resistance, *R*, is quantified by $V = I R$ (Ohm's Law). Work is the amount of energy transferred during an interaction. In electrical systems, work is done when charges are moved through the circuit. Electric power is the amount of work done by an electric current in a unit of time, which can be calculated using $P = I V$.

STANDARDS	PAGE REFERENCES
P4.11x Heat, Temperature, and Efficiency Heat is often produced as a by-product during energy transformations. This energy is transferred into the surroundings and is not usually recoverable as a useful form of energy. The efficiency of systems is defined as the ratio of the useful energy output to the total energy input. The efficiency of natural and human-made systems varies due to the amount of heat that is not recovered as useful work.	
P4.12 Nuclear Reactions Changes in atomic nuclei can occur through three processes: fission, fusion, and radioactive decay. Fission and fusion can convert small amounts of matter into large amounts of energy. Fission is the splitting of a large nucleus into smaller nuclei at extremely high temperature and pressure. Fusion is the combination of smaller nuclei into a large nucleus and is responsible for the energy of the Sun and other stars. Radioactive decay occurs naturally in the Earth's crust (rocks, minerals) and can be used in technological applications (e.g., medical diagnosis and treatment).	
P4.12A Describe peaceful technological applications of nuclear fission and radioactive decay.	**Student Edition:** 811-814 *Future Technology* 826 **Teacher Wraparound Edition:** CB 809; RLC 811; RLP 816
P4.12B Describe possible problems caused by exposure to prolonged radioactive decay.	**Student Edition:** 811 **Teacher Wraparound Edition:** E 814; RLC 811
P4.12C Explain how stars, including our Sun, produce huge amounts of energy (e.g., visible, infrared, ultraviolet light).	**Student Edition:** 822-823 *Future Technology* 826 **Teacher Wraparound Edition:** RLP 813
P4.12x Mass and Energy In nuclear reactions, a small amount of mass is converted to a large amount of energy, $E = mc^2$, where c is the speed of light in a vacuum. The amount of energy before and after nuclear reactions must consider mass changes as part of the energy transformation.	