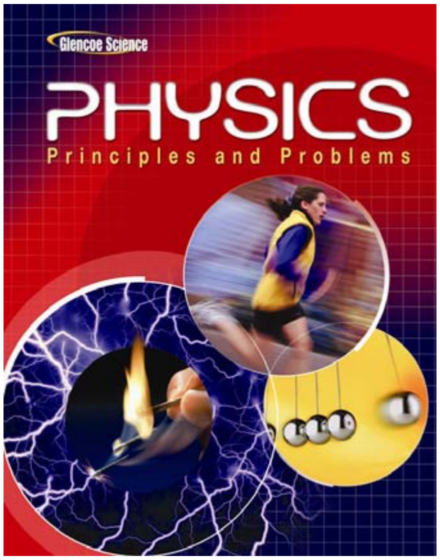
High School Science Content Expectations/Physics
Core Skills



PHYSICS

Principles and Problems

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.		
P1.1f	Predict what would happen if the variables, methods, or timing of an investigation were changed.	**Student Edition:** 8-10, 15, 19 *Internet Physics Lab* 20-21, 108-109, 246-247 *Physics Lab* 48-49, 186-187, 302-303, 332-333 **Teacher Wraparound Edition:** CD 6; CT 18; GF 21, 49, 333

Codes used for Teacher Wraparound Edition pages are the initial caps of headings on that page.

STANDARDS		PAGE REFERENCES
P1.1g	Based on empirical evidence, explain and critique the reasoning used to draw a scientific conclusion or explanation.	**Student Edition:** 8-10 *Design Your Own Physics Lab* 392-393, 532-533, 554-555 *Extreme Physics* 78, 188, 506 *Internet Physics Lab* 76-77 *MiniLAB* 8 *Physics Lab* 218-219, 420-421 **Teacher Wraparound Edition:** A 9; QD 5
P1.1h	Design and conduct a systematic scientific investigation that tests a hypothesis. Draw conclusions from data presented in charts or tables.	**Student Edition:** 8-10, 15-18 *Design Your Own Physics Lab* 160-161, 392-393, 532-533, 554-555, 660-661, 824-825 **Teacher Wraparound Edition:** BA 15; CT 18
P1.1i	Distinguish between scientific explanations that are regarded as current scientific consensus and the emerging questions that active researchers investigate.	**Student Edition:** 735-737, 760-761 *Extreme Physics* 78, 188, 366 *Future Technology* 248, 556, 826 *Technology and Society* 220, 394, 608, 716 **Teacher Wraparound Edition:** CB 9, 757; IM 736; TPK 747

STANDARDS		PAGE REFERENCES
	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.	
P1.2f	Critique solutions to problems, given criteria and scientific constraints.	**Student Edition:** 4, 67, 70, 97, 99 *Future Technology* 556, 826 *Launch Lab* 3, 515 *Technology and Society* 394, 608 **Teacher Wraparound Edition:** ICE 4; QD 66; R 17
P1.2g	Identify scientific tradeoffs in design decisions and choose among alternative solutions.	**Student Edition:** 9-10 *Extreme Physics* 792 *Future Technology* 556 *Physics Lab* 714-715 *Technology and Society* 304, 450, 608 **Teacher Wraparound Edition:** AIL 715
P1.2h	Describe the distinctions between scientific theories, laws, hypotheses, and observations.	**Student Edition:** 8-10, 93-95, 175-176, 326-331, 726-731, 776-783 *Internet Physics Lab* 20-21, 108-109 *Physics Lab* 332-333, 364-365 **Teacher Wraparound Edition:** A 9; B 78; CD 789; IM 729

STANDARDS		PAGE REFERENCES
P1.2i	Explain the progression of ideas and explanations that lead to science theories that are part of the current scientific consensus or core knowledge.	**Student Edition:** 8-10, 93-95, 102-103, 175-176, 184-185, 216-217, 236-237, 293-295, 326-331, 726-731, 747-759, 760-761, 775-781 **Teacher Wraparound Edition:** CB 182, 184; HSS 104; R 216, 731
P1.2j	Apply science principles or scientific data to anticipate effects of technological design decisions.	**Student Edition:** 9-10, 19, 266-273, 341-348 *Extreme Physics* 662, 792 *Future Technology* 476, 556 *Physics Lab* 714-715 *Technology and Society* 220, 304, 450, 608 **Teacher Wraparound Edition:** AIL 715; UA 348
P1.2k	Analyze how science and society interact from a historical, political, economic, or social perspective.	**Student Edition:** 19, 326-328, 500-501, 764-765, 811-814 *Extreme Physics* 50, 792 *Future Technology* 22, 826 *How It Works* 582, 634, 688 *Technology and Society* 220, 394, 608, 716 **Teacher Wraparound Edition:** CU 814; IM 9; RLP 5, 268, 501

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.	
P2.1g	Solve problems involving average speed and constant acceleration in one dimension.	**Student Edition:** 38-42, 43-47, 65-71 *Internet Physics Lab* 20-21, 76-77 *Launch Lab* 31 *Physics Lab* 48-49 **Teacher Wraparound Edition:** CD 43; CU 33, 42; D 34; ICE 45; IM 46
P2.1h	Identify the changes in speed and direction in everyday examples of circular (rotation and revolution), periodic, and projectile motions.	**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 179, 375; CT 378; D 34; E 380
	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.	
P2.2e	Use the area under a velocity-time graph to calculate the distance traveled and the slope to calculate the acceleration.	**Student Edition:** 66-68 **Teacher Wraparound Edition:** CT 68; HSS 67
P2.2f	Describe the relationship between changes in position, velocity, and acceleration during periodic motion.	**Student Edition:** 375, 378-379 *Design Your Own Physics Lab* 392-393 **Teacher Wraparound Edition:** E 380; ICE 379

STANDARDS		PAGE REFERENCES
P2.2g	Apply the independence of the vertical and horizontal initial velocities to solve projectile motion problems.	**Student Edition:** 148-152 *Launch Lab* 147 *Problem-Solving Strategies* 149 **Teacher Wraparound Edition:** AML 150; CD 148; ICE 151; R 152
	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.	
P2.3a	Describe and compare the motion of an object using different reference frames.	**Student Edition:** 96-99, 105-106, 216 *Applying Physics* 380 *Extreme Physics* 78 *Future Technology* 162 *How It Works* 110 *Internet Physics Lab* 108-109 **Teacher Wraparound Edition:** R 216

STANDARDS		PAGE REFERENCES
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).		
P3.1x 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.		
P3.1b	Explain why scientists can ignore the gravitational force when measuring the net force between two electrons.	**Student Edition:** 822 *Applying Physics* 802 **Teacher Wraparound Edition:** CD 542; PP 802
P3.1c	Provide examples that illustrate the importance of the electric force in everyday life.	**Student Edition:** 552-553, 577, 631 *Future Technology* 556 *How It Works* 582, 634 *Technology and Society* 450, 608 **Teacher Wraparound Edition:** AML 577; C 566, 574; CB 699; RLP 570

STANDARDS		PAGE REFERENCES
P3.1d	Identify the basic forces in everyday interactions.	**Student Edition:** 88-89, 94-95, 100-101, 107, 126-127, 156 *Future Technology* 162 *How It Works* 110, 276 *Internet Physics Lab* 108-109 *Launch Lab* 87 *Technology and Society* 138 **Teacher Wraparound Edition:** CB 91, 133, 177; CD 125; PP 105; QD 100
	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).	
P3.2d	Calculate all the forces on an object on an inclined plane and describe the object's motion based on the forces using free-body diagrams.	**Student Edition:** 132-135, 269-270 *MiniLAB* 135 *Physics Lab* 136-137 *Technology and Society* 138 **Teacher Wraparound Edition:** ICE 133
	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.	
P3.3b	Predict how the change in velocity of a small mass compares to the change in velocity of a large mass when the objects interact (e.g., collide).	**Student Edition:** 236-237, 241-242 *Launch Lab* 229 **Teacher Wraparound Edition:** ICE 237
P3.3c	Explain the recoil of a projectile launcher in terms of forces and masses.	**Student Edition:** 238-249 **Teacher Wraparound Edition:** ICE 240; IM 238

STANDARDS		PAGE REFERENCES
P3.3d	Analyze why seat belts may be more important in autos than in buses.	**Student Edition:** 231-232 **Teacher Wraparound Edition:** PP 232
	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.	
P3.4e	Solve problems involving force, mass, and acceleration in two-dimensional projectile motion restricted to an initial horizontal velocity with no initial vertical velocity (e.g., ball rolling off a table).	**Student Edition:** 147-149 *MiniLAB* 148 *Problem-Solving Strategies* 149 **Teacher Wraparound Edition:** QD 148
P3.4f	Calculate the changes in velocity of a thrown or hit object during and after the time it is acted on by the force.	**Student Edition:** 230-232 **Teacher Wraparound Edition:** CD 230
P3.4g	Explain how the time of impact can affect the net force (e.g., air bags in cars, catching a ball).	**Student Edition:** 229-231 **Teacher Wraparound Edition:** CD 230
	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.	
P3.5a	Apply conservation of momentum to solve simple collision problems.	**Student Edition:** 236-237, 241-242 *Internet Physics Lab* 246-247 **Teacher Wraparound Edition:** HSS 240; ICE 237, 242; TPK 236

STANDARDS		PAGE REFERENCES
	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.	
P3.6d	Calculate force, masses, or distance, given any three of these quantities, by applying the Law of Universal Gravitation, given the value of *G*.	**Student Edition:** 175-176, 178, 182-183 **Teacher Wraparound Edition:** CT 175; D 176
P3.6e	Draw arrows (vectors) to represent how the direction and magnitude of a force changes on an object in an elliptical orbit.	**Student Edition:** 172-174 *Physics Lab* 186-187 **Teacher Wraparound Edition:** CU 178; HSS 174
	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).	
	P3.7x Electric Charges — Interactions Charged objects can attract electrically neutral objects by induction.	
P3.7c	Draw the redistribution of electric charges on a neutral object when a charged object is brought near.	**Student Edition:** 546-548 *Design Your Own Physics Lab* 554-555 **Teacher Wraparound Edition:** CT 547
P3.7d	Identify examples of induced static charges.	**Student Edition:** 548, 552-553 *MiniLAB* 549 **Teacher Wraparound Edition:** QD 551
P3.7e	Explain why an attractive force results from bringing a charged object near a neutral object.	**Student Edition:** 547 **Teacher Wraparound Edition:** CD 546

STANDARDS		PAGE REFERENCES
P3.7f	Determine the new electric force on charged objects after they touch and are then separated.	**Student Edition:** 548 **Teacher Wraparound Edition:** CB 548
P3.7g	Propose a mechanism based on electric forces to explain current flow in an electric circuit.	**Student Edition:** 592-594 **Teacher Wraparound Edition:** CD 593; UA 592
	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)*	
	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).	
P3.8b	Explain how the interaction of electric and magnetic forces is the basis for electric motors, generators, and the production of electromagnetic waves.	**Student Edition:** 652-659, 672-678, 705-713 *Design Your Own Physics Lab* 660-661 **Teacher Wraparound Edition:** CD 675; CT 656, 677; CU 678; IM 655; QD 676

STANDARDS		PAGE REFERENCES
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.*		
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).		
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.		
P4.1c	Explain why work has a more precise scientific meaning than the meaning of work in everyday language.	**Student Edition:** 258-259, 263-265 **Teacher Wraparound Edition:** CD 258; R 259
P4.1d	Calculate the amount of work done on an object that is moved from one position to another.	**Student Edition:** 259-260, 266-268 *Physics Lab* 274-275 *Problem-Solving Strategies* 260 **Teacher Wraparound Edition:** R 259
P4.1e	Using the formula for work, derive a formula for change in potential energy of an object lifted a distance h.	**Student Edition:** 258-260, 288-289 **Teacher Wraparound Edition:** ICE 290; QD 287

STANDARDS		PAGE REFERENCES
	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.	
P4.2e	Explain the energy transformations as an object (e.g., skydiver) falls at a steady velocity.	**Student Edition:** 100-101 **Teacher Wraparound Edition:** AML 101, 183
P4.2f	Identify and label the energy inputs, transformations, and outputs using qualitative or quantitative representations in simple technological systems (e.g., toaster, motor, hair dryer) to show energy conservation.	**Student Edition:** 272, 656, 675-676 *Applying Physics* 265 *How It Works* 276 *Launch Lab* 285 **Teacher Wraparound Edition:** CB 656; CD 673; ICE 261, 290; RLP 260, 268
	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.	
	P4.3x Kinetic and Potential Energy — Calculations The kinetic energy of an object is related to the mass of an object and its speed: $KE = 1/2\ mv^2$.	
P4.3d	Rank the amount of kinetic energy from highest to lowest of everyday examples of moving objects.	**Student Edition:** *Future Technology* 162, 248 *How It Works* 276 *Internet Physics Lab* 20-21 *Physics Lab* 186-187, 302-303 *Technology and Society* 138, 608 **Teacher Wraparound Edition:** ICE 299; RLP 260

STANDARDS		PAGE REFERENCES
P4.3e	Calculate the changes in kinetic and potential energy in simple mechanical systems (e.g., pendulums, roller coasters, ski lifts) using the formulas for kinetic energy and potential energy.	**Student Edition:** 291-292, 293-295, 297-301 *Design Your Own Physics Lab* 392-393 *Internet Physics Lab* 108-109, 246-247 *Technology and Society* 138 **Teacher Wraparound Edition:** CU 292; HSS 296; ICE 290; RLP 260, 268
P4.3f	Calculate the impact speed (ignoring air resistance) of an object dropped from a specific height or the maximum height reached by an object (ignoring air resistance), given the initial vertical velocity.	**Student Edition:** 72-75 *Internet Physics Lab* 76-77 **Teacher Wraparound Edition:** R 75; UM 74
	P4.4 Wave Characteristics Waves (mechanical and electromagnetic) are described by their wavelength, amplitude, frequency, and speed.	
	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.	
P4.4d	Demonstrate that frequency and wavelength of a wave are inversely proportional in a given medium.	**Student Edition:** 382-385, 706-708 **Teacher Wraparound Edition:** CD 385; R 386, 706
P4.4e	Calculate the amount of energy transferred by transverse or compression waves of different amplitudes and frequencies (e.g., seismic waves).	**Student Edition:** 381-386 **Teacher Wraparound Edition:** CT 383

STANDARDS		PAGE REFERENCES
	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.	
	P4.6 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.	
	P4.6x 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.	
P4.6e	Explain why antennas are needed for radio, television, and cell phone transmission and reception.	**Student Edition:** 707-708, 712 **Teacher Wraparound Edition:** D 712
P4.6f	Explain how radio waves are modified to send information in radio and television programs, radio-control cars, cell phone conversations, and GPS systems.	**Student Edition:** 705-708, 709-712 *Applying Physics* 710 *Technology and Society* 716 **Teacher Wraparound Edition:** CB 710
P4.6g	Explain how different electromagnetic signals (e.g., radio station broadcasts or cell phone conversations) can take place without interfering with each other.	**Student Edition:** 707-708, 712 *Applying Physics* 710 **Teacher Wraparound Edition:** D 712
P4.6h	Explain the relationship between the frequency of an electromagnetic wave and its technological uses.	**Student Edition:** 707-708, 712 *Technology and Society* 716 **Teacher Wraparound Edition:** D 712

STANDARDS		PAGE REFERENCES
	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.	
	P4.8x 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.	
P4.8c	Describe how two wave pulses propagated from opposite ends of a demonstration spring interact as they meet.	**Student Edition:** 388-389 *Launch Lab* 375 **Teacher Wraparound Edition:** CD 389
P4.8d	List and analyze everyday examples that demonstrate the interference characteristics of waves (e.g., dead spots in an auditorium, whispering galleries, colors in a CD, beetle wings).	**Student Edition:** 418-419, 516-523, 524-531 *Design Your Own Physics Lab* 532-533 *Launch Lab* 515 *Problem-Solving Strategies* 521 **Teacher Wraparound Edition:** A 522; BA 515; CD 521; HSS 526; R 523; UM 419, 516
P4.8e	Given an angle of incidence and indices of refraction of two materials, calculate the path of a light ray incident on the boundary (Snell's Law).	**Student Edition:** 486-489 **Teacher Wraparound Edition:** IM 486; R 492
P4.8f	Explain how Snell's Law is used to design lenses (e.g., eye glasses, microscopes, telescopes, binoculars).	**Student Edition:** 493-499 *Physics Lab* 504-505 **Teacher Wraparound Edition:** CD 494; E 499; UM 498

STANDARDS	PAGE REFERENCES
P4.9 Nature of Light Light interacts with matter by reflection, absorption, or transmission.	
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.	
P4.10x 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 $P = I V$.	
P4.10e Explain energy transfer in a circuit, using an electrical charge model.	**Student Edition:** 592-593, 601-605 *Technology and Society* 608 **Teacher Wraparound Edition:** CB 599; CD 593; CU 605; ICE 602; R 596
P4.10f Calculate the amount of work done when a charge moves through a potential difference, V.	**Student Edition:** 569-571 **Teacher Wraparound Edition:** HSS 571
P4.10g Compare the currents, voltages, and power in parallel and series circuits.	**Student Edition:** 618-620, 623-626 *MiniLAB* 623 *Physics Lab* 632-633 *Problem-Solving Strategies* 629 **Teacher Wraparound Edition:** AML 625; CD 619; CT 620; CU 626

STANDARDS		PAGE REFERENCES
P4.10h	Explain how circuit breakers and fuses protect household appliances.	**Student Edition:** 627 *How It Works* 634 *Launch Lab* 617 **Teacher Wraparound Edition:** IM 627; R 628
P4.10i	Compare the energy used in one day by common household appliances (e.g., refrigerator, lamps, hair dryer, toaster, televisions, music players).	**Student Edition:** 604-605 **Teacher Wraparound Edition:** CU 605
P4.10j	Explain the difference between electric power and electric energy as used in bills from an electric company.	**Student Edition:** 604-605 **Teacher Wraparound Edition:** CU 605
	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.	
P4.11a	Calculate the energy lost to surroundings when water in a home water heater is heated from room temperature to the temperature necessary to use in a dishwasher, given the efficiency of the home hot water heater.	**Student Edition:** 593, 595-597 **Teacher Wraparound Edition:** CD 327; CU 605; ICE 602
P4.11b	Calculate the final temperature of two liquids (same or different materials) at the same or different temperatures and masses that are combined.	**Student Edition:** 315, 317-321 **Teacher Wraparound Edition:** HSS 320

STANDARDS	PAGE REFERENCES
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).	
P4.12x 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.	
P4.12d Identify the source of energy in fission and fusion nuclear reactions.	**Student Edition:** 802-805, 811-814 *Future Technology* 826 **Teacher Wraparound Edition:** A 802; CD 803; CH 804, 812; CU 805, 814; TPK 806