IDEA Public Schools

Unit 5: Energy
UNIT PLAN

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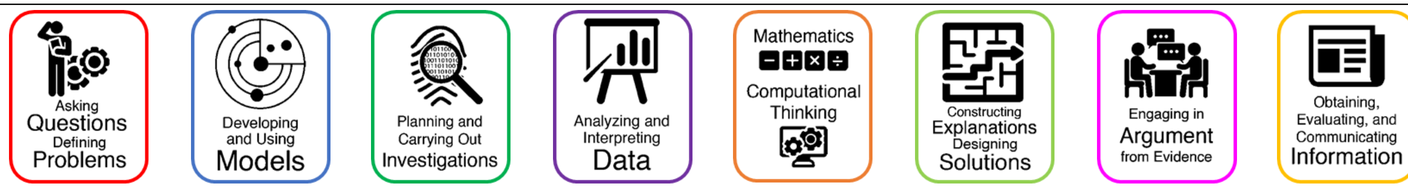
UNIT NARRATIVE
This unit begins with a teacher demonstration of an Anchoring Event and an Essential Question(s) (day 01) and two different options for the Anchoring Event are provided. First students will create models and attempt to explain the Anchoring Event and Essential Question using the physics concepts they have learned in previous units models. Throughout the units students will make connections between individual lessons and the Anchoring Event by updating the Summary Table, typically as an exit ticket. At the end of the unit students will revise their initial models to craft a Seamless Explanation for the Anchoring Event and Essential Question using the physics concepts about Mechanical Energy they have learned in this unit. The first section of this unit re-introduces students to Mechanical Energy, Kinetic Energy, and Potential Energy (as they have been introduced to these concepts in grades 6-8 science. Students will use the PhET Simulation – Energy Skate Park to make qualitative observations to describe how kinetic, potential and mechanical energy are related to position and velocity and each other (day 02). Students will also be introduced to Energy Bar Charts (LOL Charts) as a tool for modeling Mechanical Energy and Work in physics scenarios that should be used throughout the unit. Next students will describe the variable relationships that define elastic potential energy by completing a virtual lab using the PhET Simulation: Hooke's Law (day 03). In the next section of this unit students will be introduced to Work and explore the relationship between Work and Mechanical Energy. Students will complete hands on versions of similar experiments involving moving a cart to the top of a ramp and allowing it to roll down the ramp while calculating Work, KE and GPE to reinforce how these quantities relate to each other (days 04-05). Then students will explore the concept of Power as the rate that Work is done by completing a lab to measure and calculate the Work and Power for several students when they climb stairs or lift weights (day 06). Students will then analyze Force-Displacement graphs to calculate Work and hence change in KE(day 07), analyze stopping distance scenarios using variable relationships identified using Work-Energy relationship to make quantitative predictions(day 08) , and more practice analyzing a variety of physics scenarios to make quantitative predictions using the variable relationships described by the Work-Energy relationship (day 09). The last section of this unit focuses on making predictions using Conservation of Mechanical Energy. This section begins with a return to the PhET Simulation: Energy Skate Park where students will formally describe Mechanical Energy as the sum of potential and kinetic energies and describe the circumstances where Mechanical Energy is conserved (day 10). Then students will practice modeling conservation of energy scenarios using Energy Bar

Charts (day 11), the first step to creating a conservation of energy equation to represent a scenario, conduct a virtual experiment to explore the variable relationships described by common scenarios that demonstrate conservation of Mechanical Energy (day 12), and practice making quantitative predictions using the variable relationships from the conservation of energy equation that describes a physics scenario (day 13). Lastly students will analyze the motion of a pendulum by applying the conservation of energy (day 14), which relates directly to one of the Anchoring Event options and will be explored in more detail in Unit 7: Simple Harmonic Motion.

Finaly students will revisit the **Anchoring Event** and **Essential Question(s)** by reviewing their Summary Tables to revise their initial modeling and craft a **Seamless Explanation** that clearly explains the **Anchoring Event**.

Focus on Disciplinary Literacy

In science, disciplinary literacy is synonymous with the science and engineering practices. The SEPs are the context through which all science concepts should be taught. In the lessons, you will find the Science and Engineering practices icons when the SEPs are being explicitly used by students.



UNPACKED CONTENT STANDARDS

Texas TEKS Physics Standards

Standard ID	Standard Description
C.7	The student knows that changes occur within a physical system and applies the laws of conservation of energy and momentum. The student is expected to:
C.7.A	calculate and explain work and power in one dimension and identify when work is and is not being done by or on a system;
C7.B	investigate and calculate mechanical, kinetic, and potential energy of a system;
C.7.C	apply the concept of conservation of energy using the work-energy theorem, energy diagrams, and energy transformation equations, including transformations between kinetic, potential, and thermal energy;

College Board AP Physics Standards

Topic		Learning Objective		Essential Knowledge	
3.1	Translational Kinetic Energy	3.1.A	Describe the translational kinetic energy of an object in terms of the object's mass and velocity.	3.1.A.1	An object's translational kinetic energy is given by the **equation** - $K = \frac{1}{2}mv^2$
				3.1.A.2	Translational kinetic energy is a scalar quantity.
				3.1.A.3	Different observers may measure different values of the translational kinetic energy of an object, depending on the observer's frame of reference.
3.2	Work	3.2.A	Describe the work done on an object or system by a given force or collection of forces.	3.2.A.1	Work is the amount of energy transferred into or out of a system by a force exerted on that system over a distance. i. The work done by a conservative force exerted on a system is path-independent and only depends on the initial and final configurations of that system. ii. The work done by a conservative force on a system—or the change in the potential energy of the system—will be zero if the system returns to its initial configuration. iii. Potential energies are associated only with conservative forces. iv. The work done by a nonconservative force is path independent. v. Examples of nonconservative forces are friction and air resistance.
				3.2.A.2	Work is a scalar quantity that may be positive, negative, or zero.

				3.2.A.3	The amount of work done on a system by a constant force is related to the components of that force and the displacement of the point at which that force is exerted. I. Only the component of the force exerted on a system that is parallel to the displacement of the point of application of the force will change the system's total energy. **Relevant equation -->** $W = F_{\|\|}d = fd\ cos\theta$ ii. The component of the force exerted on a system perpendicular to the direction of the displacement of the system's center of mass can change the direction of the system's motion without changing the system's kinetic energy.
				3.2.A.4	The work-energy theorem state that the change in an object's kinetic energy is equal to the sum of the work (net work) being done by all forces exerted on the object. **Relevant equation-->** $\Delta \boldsymbol{K} = \boldsymbol{\Sigma W} = \boldsymbol{\Sigma F_{\|\|} d}$ i. An external force may change the configuration of a system. The component of the external force parallel to the displacement times the displacement of the point of application of the force gives the change in kinetic energy of the system. ii. If the system's center of mass and the point of application of the force move the same distance when a force is exerted on a system, then the system may be modeled as an object, and only the system's kinetic energy can change. iii. The energy dissipated by friction is typically equated to the force of friction times the length of the path over which the force is exerted, **Derived equation -->** $\Delta \boldsymbol{E_{mech}} = \boldsymbol{F_f d cos\theta}$
				3.2.A.5	Work is equal to the area under the curve of a graph of F as a function of displacement.
		BOUNDARY STATEMENT: *AP Physics 1 only expects students to analyze the transfer of mechanical energy (as defined in Unit 3, Topic 4: Conservation of Energy), although students should be aware that mechanical energy may be dissipated in the form of thermal energy or sound. In AP Physics 2, students will also study how thermal energy can be transferred between systems through heating or cooling.*			
3.3	Potential Energy	3.3.A	Describe the potential energy of a system.	3.3.A.1	A system composed of two or more objects has potential energy if the objects within that system only interact with each other through conservative forces.
				3.3.A.2	Potential energy is a scalar quantity associated with the position of objects within a system.
				3.3.A.3	The definition of zero potential energy for a given system is a decision made by the observer considering the situation to simplify or otherwise assist in analysis.

				3.3.A.4	The potential energy of common physical systems can be described using the physical properties of that system. i. The elastic potential energy of an ideal spring is given by the following equation, where Δx is the distance the spring has been stretched or compressed from its equilibrium length. **Relevant equation --> $U_S = \frac{1}{2}k(\Delta x)^2$** ii. The general form for the gravitational potential energy of a system consisting of two approximately spherical distributions of mass (e.g., moons, planets or stars) is given by the **Relevant equation --> $U_g = -G\frac{m_1 m_2}{r}$** iii. Because the gravitational field near the surface of a planet is nearly constant, the change in gravitational potential energy in a system consisting of an object with mass m and a planet with gravitational field of magnitude g when the object is near the surface of the planet may be approximated by the **Relevant equation --> $U_g = mg\Delta y$**
				3.3.A.5	The total potential energy of a system containing more than two objects is the sum of the potential energy of each pair of objects within the system.
3.4	Conservation of Energy	3.4.A	Describe the energies present in a system.	3.4.A.1	A system composed of only a single object can only have kinetic energy.
				3.4.A.2	A system that contains objects that interact via conservative forces or that can change its shape reversibly may have both kinetic and potential energies.
		3.4.B	Describe the behavior of a system using conservation of mechanical energy principles.	3.4.B.1	Mechanical energy is the sum of a system's kinetic and potential energies.
				3.4.B.2	Any change to a type of energy within a system must be balanced by an equivalent change of other types of energies within the system or by a transfer of energy between the system and its surroundings.
				3.4.B.3	A system may be selected so that the total energy of that system is constant.
				3.4.B.4	If the total energy of a system changes, that change will be equivalent to the energy transferred into or out of the system.
		3.4.C	Describe how the selection of a system determines whether the energy of that system changes.	3.4.C.1	Energy is conserved in all interactions.
				3.4.C.2	If the work done on a selected system is zero and there are no nonconservative interactions within the system, the total mechanical energy of the system is constant.
				3.4.C.3	If the work done on a selected system is nonzero, energy is transferred between the system and the environment.
		BOUNDARY STATEMENT: *AP Physics 1 expects students to know that mechanical energy can be dissipated as thermal energy or sound by nonconservative forces.*			
3.5	Power	3.5.A	Describe the transfer of energy into, out of, or	3.5.A.1	Power is the rate at which energy changes with respect to time, either by transfer into or out of a system or by conversion from one type to another within a system.

			within a system in terms of power.	3.5.A.2	Average power is the amount of energy being transferred or converted, divided by the time it took for that transfer or conversion to occur. **Relevant equation-->** $P_{avg} = \frac{\Delta E}{\Delta t}$
				3.5.A.3	Because Work is the change in energy of an object or system due to a force, average power is the total Work done, divided by the time during which that Work was done. **Relevant equation -->** $P_{avg} = \frac{\Delta W}{\Delta t}$
				3.5.A.4	The instantaneous power delivered to an object by the component of a constant force parallel to the object's velocity can be described with the **derived equation -->** $P_{inst} = F_{\parallel} v = Fv\,cos\theta$

KEY UNDERSTANDINGS AND QUESTIONS

Important big ideas and processes for the unit.

Key Understandings

- ❑ Total Energy is conserved ALWAYS.
- ❑ Energy can be stored or transferred between objects and systems.
- ❑ Mechanical systems involve transformations between different forms of energy.
- ❑ Energy can be stored, transferred, or transformed.
- ❑ Moving objects and raised objects have energy.
- ❑ Energy can change from one form to another (for example, potential ↔ kinetic).
- ❑ Mechanical Energy (ME) is the sum of Potential and Kinetic Energy.
- ❑ Friction transforms some ME into thermal energy, reducing total ME.
- ❑ When friction is negligible, ME remains constant even as PE and KE change
- ❑ Elastic Potential Energy (EPE) depends on spring constant (k) and displacement (x). Equation **-** $\boldsymbol{PE_S = \frac{1}{2}kx^2}$
- ❑ Displacement on a spring can be compression or stretch. Both work the same in how they affect EPE.
- ❑ The spring constant is the stretchiness of the spring. With higher spring constants being stiffer springs.
- ❑ Changing the amount of mass on the spring has no effect on the EPE
- ❑ Lifting an object increases its gravitational potential energy.
- ❑ Work transfers energy into or out of a system.
- ❑ The work done to lift an object equals the change in potential energy. $W = mgh$
- ❑ Work and energy share the same units (joules).
- ❑ Inclines reduce the force required, but not the total work done
- ❑ Gravitational potential energy converts into kinetic energy as an object moves downward.
- ❑ If friction is ignored, total energy remains constant.
- ❑ Speed at the bottom depends on height, not mass.
- ❑ Kinetic energy can be calculated with equation - $\boldsymbol{K = \frac{1}{2}mv^2}$
- ❑ Power measures how quickly work is done. $\boldsymbol{P = \frac{W}{t}}$
- ❑ The same amount of work can be done in more or less time.
- ❑ More power means work is done faster.
- ❑ Both work and power depend on force and distance.
- ❑ The area under a Force–Displacement graph represents work done.
- ❑ Work changes an object's kinetic energy.
- ❑ Positive work adds energy; negative work removes it.
- ❑ The Work–Energy Theorem links work and kinetic energy.
- ❑ Friction transforms motion energy into heat.
- ❑ Work can add or remove energy from a system.

- ❑ More starting kinetic energy leads to a longer stopping distance.
- ❑ Stopping distance depends on both initial kinetic energy and friction.
- ❑ Work done is equal to an object's change in kinetic energy.
- ❑ The same work produces the same energy change, even if force and distance vary.
- ❑ Energy transforms between potential, kinetic, and thermal forms.
- ❑ Friction changes mechanical energy into thermal energy.
- ❑ The total energy of a system remains constant when all forms are included.
- ❑ Visual models (bar charts) show how energy changes throughout its motion in any given scenario.
- ❑ Energy bar graphs represent the amount and type of energy in a system.
- ❑ The total height of the bars represents total system energy.
- ❑ Energy can shift between forms but total energy remains constant.
- ❑ Mechanical energy is the sum of potential and kinetic energy.
- ❑ When no external forces act, mechanical energy is conserved.
- ❑ GPE converts to KE as objects fall; EPE converts to KE as springs release.
- ❑ Velocity and height or displacement are connected through energy relationships since Max GPE = Max KE when ME is conserved
- ❑ The total mechanical energy of a system is conserved in the absence of friction (or other outside forces acting on the system).
- ❑ Conservation of Energy equations representing a scenario describe variable relationships that allow prediction of velocity, height, or displacement.
- ❑ A pendulum demonstrates conservation of mechanical energy.
- ❑ GPE is highest at the endpoints, and KE is highest at the lowest point.
- ❑ Pendulum motion involves repeated energy transformations between GPE and KE.
- ❑ The relationship between angle and energy is non-linear but predictable.
- ❑ Models represent understanding of how energy is stored, transferred, and transformed.
- ❑ Scholars should use evidence from experiments and simulations supports scientific models.
- ❑ Energy conservation explains motion across all observed scenarios.
- ❑

Key Questions

- How is Mechanical Energy different from total energy?
- Under what circumstances is the total mechanical energy of a system conserved?
- How can we make accurate predictions about the different types of mechanical energy an object has?
- How can we use energy relationships to make predictions about the movement of objects?
- What is Work?
- Does friction do Work on a system?
- How is Work related to Mechanical Energy?
- What is Power?

VERTICAL STANDARDS

This section details the **progression** of key student expectations/standards** in the courses **before** and **after** this course. This will help you understand what **prior knowledge skills to build upon** and guide you in knowing what **skills you are preparing your students** for in the subsequent course.

5th Grade Science	6/7 Grade Hybrid Science	8th Grade Science
3-5(7) Force, motion, and energy. The student knows the nature of forces and the patterns of their interactions. The student is expected to: 5.7A investigate and explain how equal and unequal forces acting on an object cause patterns of motion and transfer of energy. **3-5(8) Force, motion, and energy. The student knows that energy is everywhere and can be observed in cycles, patterns, and systems. The student is expected to:** 5(8)(A) investigate and describe the transformation of energy in systems such as energy in a flashlight battery that changes from chemical energy to electrical energy to light energy; 5(8)(B) demonstrate that electrical energy in complete circuits can be transformed into motion, light, sound, or thermal energy and identify the requirements for a functioning electrical circuit; and	**6(8) Force, motion, and energy. The student knows that the total energy in systems is conserved through energy transfers and transformations. The student is expected to:** 6(8)(A) compare and contrast gravitational, elastic, and chemical potential energies with kinetic energy; 6(8)(B) describe how energy is conserved through transfers and transformations in systems such as electrical circuits, food webs, amusement park rides, or photosynthesis; and **7(8) Force, motion, and energy. The student understands the behavior of thermal energy as it flows into and out of systems. The student is expected to:** 7(8)(A) investigate methods of thermal energy transfer into and out of systems, including conduction, convection, and radiation; 7(8)(B) investigate how thermal energy moves in a predictable pattern from warmer to cooler until all substances within the system reach thermal equilibrium; and 7(8)(C) explain the relationship between temperature and the kinetic energy of the particles within a substance.	None

VOCABULARY GLOSSARY

Domain-specific words and definitions for this unit.

Key Content Vocabulary
Energy Bar Chart – a model to represent the energy transformations and movement in a scenario. **Mechanical Energy –** the sum of potential energy and kinetic energy of an object or system of objects. $ME = KE + U_G + U_S$ **Gravitational Potential Energy –** the potential energy and object possess due to its position relative to the Earth. $U_G = mgh$ **Kinetic Energy –** the energy that an object possesses due to its motion. $KE = \frac{1}{2}.mv^2$ **Conservation of Energy -** states that the total energy of an isolated system remains constant; it is said to be *conserved* over time. **Work -** the energy transferred to or from an object/system via the application of force along a displacement. $W = Fdcos\theta$ **Power –** the rate of doing Work or the rate of energy transfer, units: Joules/sec = Watt $P = \frac{\Delta W}{t} \ or \ P = \frac{\Delta E}{t}$ **Spring Force (Hooke's Law) -** a law of physics that states that the force (*F*) needed to extend or compress a spring by some distance (*x*) scales linearly with respect to that distance. $F_s = -kx$ $k = spring\ constant$ $x = displacement\ of\ spring\ from\ equilibrium\ position$ **Spring Constant** – a measure the of the stiffness of a spring. Larger numbers indicate a stiffer spring. Often measured in N/m. **Spring/Elastic Potential Energy -** the mechanical potential energy stored in the configuration of a material or physical system as it is subjected to elastic deformation by work performed upon it. $U_S = \frac{1}{2}k\Delta x^2$

Related Vocabulary

Thermal Energy				