SUFFOLK COUNTY VANDERBILT
Mansion | Museum | Planetarium

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New York State Science Learning Standards
Otherworldly Forces

Middle School

Performance Expectations:

Structure and Properties of Matter

- **MS-PS1-4.** Develop a model that predicts and describes changes in particle motion, temperature, and phase (state) of a substance when thermal energy is added or removed.

Forces and Interactions

- **MS-PS2-2.** Plan and conduct an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.
- **MS-PS2-4.** Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of the interacting objects and the distance between them.

Energy

- **MS-PS3-6.** Make observations to provide evidence that energy can be transferred by electric currents

Waves and Electromagnetic Radiation

- **MS-PS4-1.** Develop a model and use mathematical representations to describe waves that includes frequency, wavelength, and how the amplitude of a wave is related to the energy in a wave.
- **MS-PS4-2.** Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

Space Systems

- **MS-ESS1-1.** Develop and use a model of the Earth-Sun-Moon system to describe the cyclic patterns of lunar phases, eclipses of the Sun and Moon, and seasons.
- **MS-ESS1-2.** Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.
- **MS-ESS1-3.** Analyze and interpret data to determine scale properties of objects in the Solar System.

History of Earth

- **MS-ESS2-2.** Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying temporal and spatial scales.

Earth's Systems

- **MS-ESS2-4.** Develop a model to describe the cycling of water through Earth's systems driven by energy from the Sun and the force of gravity.

Weather and Climate

- **MS-ESS2-5.** Collect data to provide evidence for how the motions and complex interactions of air masses results in changes in weather conditions.

- **MS-ESS2-6.** Develop and use a model to describe how unequal heating and rotation of Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.

Disciplinary Core Ideas:

PS1.A: Structure and Properties of Matter

- Substances are made of one type of atom or combinations of different types of atoms. Individual atoms are particles and can combine to form larger particles that can range in size from two to thousands of atoms.
- The changes of state that occur with variations in temperature and/or pressure can be described and predicted using […] models of matter.

PS2.A: Forces and Motion

- For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law).
- The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion.

PS2.B: Types of Interactions

- Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass – e.g., Earth and the Sun.
- Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object.

PS3.B: Conservation of Energy and Energy Transfer

- Energy is spontaneously transferred out of hotter regions or objects and into colder ones.

PS4.A: Wave Properties

- A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude.

PS4.B: Electromagnetic Radiation

- When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light.
- The path that light travels can be traced as straight lines, except when it hits a surface between different transparent materials […] obliquely where the light path bends.
- A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light […].

ESS1.A: The Universe and its Stars

- Patterns of the apparent motion of the Sun, the Moon, and the stars in the sky can be observed, described, predicted, and explained with models.

ESS1.B: Earth and the Solar System

- The solar system consists of the Sun and a collection of objects including planets, their moons, comets, and asteroids that are held in orbit around the Sun by its gravitational pull on them.
- This model of the solar system can explain eclipses of the Sun and the Moon. Earth's spin axis is fixed in direction over the short term but tilted relative to its orbit around the Sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.

ESS2.C: The Roles of Water in Earth's Surface Processes

- Water's movements – both on land and underground – cause weathering and erosion, which change the land's surface features and create underground formations.
- Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation, sublimation, deposition, precipitation, infiltration, and runoff.
- Global movements of water and its changes in form are driven by sunlight and gravity.
- The complex patterns of the changes and the movement of water in the atmosphere determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns.

ESS2.A: Earth's Materials and Systems

- All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the Sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms.

ESS2.D: Weather and Climate

- Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns.

Cross-cutting Concepts:

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Scale, Proportion, and Quantity

- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.

Systems and Models

- Models can be used to represent systems and their interactions.

Energy and Matter

- Energy may take different forms […].
- Within a natural system, the transfer of energy drives the motion and/or cycling of matter.

Scientific Knowledge Assumes Order and Consistency in Natural Systems

- Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation.

Patterns

- Patterns can be used to identify cause and effect relationships.

High School

Performance Expectations:

Structure and Properties of Matter

- **HS-PS1-8.** Develop Models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.
- **HS-PS1-9.** Analyze data to support the claim that the combined gas law describes the relationships among volume, pressure, and temperature for a sample of an ideal gas.

Forces and Interactions

- **HS-PS2-1.** Analyze data to support the claim that Newton's Second Law of Motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.
- **HS-PS2-4.** Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.

Energy

- **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.

Waves and Electromagnetic Radiation

- **HS-PS4-1.** Use mathematical representations to support a claim regarding relationships among the period, frequency, wavelength, and speed of waves traveling and transferring energy (amplitude, frequency) in various media.

Space Systems

- **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 that eventually reaches Earth in the form of radiation.
- **HS-ESS1-4.** Communicate scientific ideas about the way stars, over their life cycle, produce elements.
- **HS-ESS1-7.** Construct an explanation using evidence to support the claim that the phases of the moon, eclipses, tides, and seasons change cyclically.

History of the Earth

- **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.

Earth's Systems

- **HS-ESS2-5.** Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.

Weather and Climate

- **HS-ESS2-4.** Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.
- **HS-ESS2-8.** Evaluate data and communicate information to explain how the movement and interactions of air masses result in changes in weather conditions.

Disciplinary Core Ideas:

PS1.A: Structure and Properties of Matter

- Each atom has a charged substructure consisting of a nucleus which is made of protons and neutrons, surrounded by electrons.

PS1.C: Nuclear Processes

- Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei involve release or absorption of energy. […]

PS2.A: Forces and Motion

- Newton's second law accurately predicts changes in the motion of macroscopic objects.

PS2.B: Types of Interactions

- Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects.
- Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. […]

PS3.A: Definitions of Energy

- Energy is a quantitative property of a system that depends on 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.
- At the macroscopic scale, energy manifests itself in multiple ways, such as motion, sound, light, and thermal 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.

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.

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.
- 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.

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.
- Earth and celestial phenomena can be described by principles of relative motion and perspective.

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.

ESS2.D: Weather and Climate

- The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space.

Cross-cutting Concepts:

Energy and Matter

- In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.
- 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.
- Energy can be transferred between one place and another place, between objects and/or fields, or between systems.
- Energy drives the cycling of matter within and between systems.
- Energy cannot be created or destroyed – only moved between one place and another place, between objects, and/or fields, or between systems.

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.
- 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.

Systems and System Models

- Models can be used to predict the behavior of a system, but these predictions have limited precision due to the assumptions and approximations inherent in 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.