



CURRICULUM CONNECTIONS

PERIMETER RESOURCES & NEXT GENERATION SCIENCE STANDARDS

PERIMETER RESOURCES → NGSS STANDARDS

The Next Generation Science Standards (NGSS) address much of the science content needed to succeed in first-year university courses worldwide. The classroom needs to be an environment where every student has the chance to succeed. Over the past few decades teaching strategy has evolved to include more than simply lecture style delivery to investigative, inquiry-based learning. Giving students the tools to succeed isn't enough: they must learn to use them in scenarios requiring higher-order thinking and 21st Century skills.

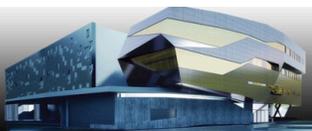
Traditionally, students practised these skills by problem-solving from question lists in textbooks; now they are taught skills that help them extend their own knowledge, allowing them to adapt to new scenarios by building and testing their models and theories. Not only does this method enhance critical thinking skills, it inspires students to peer deeper into the subject. This perspective isn't just for physicists: self-motivated explorers are an asset to any subject that requires thinking, and nurturing curiosity will boost science literacy across the board.

The NGSS approach is progressive and refreshing. The curriculum covers many important concepts while allowing freedom for investigation by learners. If used correctly, students taught the NGSS will have necessary skills for success at the post-secondary level

For example, Perimeter distributes a lab based on quantum mechanics entitled "Measuring Planck's Constant." The following are its connections to the NGSS curriculum:

Perimeter's Lab: Measuring Planck's Constant

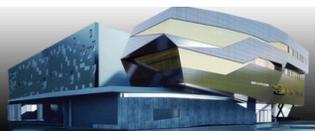
Topic	Connection to Planck's Constant & NGSS	Relevant Materials
Current Electricity	The experiment is centred around a laboratory activity in which students measure Planck's constant using a simple electronic circuit consisting of a 6-volt battery, an LED, a resistor, a voltmeter, a few wires, and a variable resistor.	Planck's Constant Lab
Photons & Quantum Mechanics	The electrical energy that is lost by each electron that crosses the LED is converted into $E = hf$. (HS-PS4-4)	Planck's Constant Lab
Laboratory Skills	By using careful laboratory skills, student will be able to measure a fundamental constant of nature that has a value with a magnitude of 10^{-34} . (HS-PS4-5)	Planck's Constant Lab



In addition to Planck's Constant Lab, Perimeter has also created a resource based on the skills necessary to be successful in any occupation. The skills acquired in STEM based high school courses can be successfully applied to any subject area and allow the student to succeed at a high level of achievement.

Career Moves: Skills for the Journey

Topic	Connection to Career Moves & NGSS	Relevant Materials
Introducing Essential Skills	Students should be able to identify the essential career skills necessary to be successful and reflect on where they might develop them. (HS-PS1-3, HS-PS2-5, HS-PS3-4, HS-LS1-3, HS-ESS2-5, HS-ETS1-1, HS-ETS1-2, HS-ETS1-3)	Activity 1: Video Review Activity 2: Learning from Others Activity 3: Build Your Skills Activity 10: Senior Advice Activity 11: STEM Skills
Considering Pathways	Students will be able to consider specific pathways and reflect on which ones are best suited for them.	Activity 1: Video Review Activity 4: Employee or Entrepreneur? Activity 5: Comparing Career Paths Activity 6: Thinking Globally Activity 7: Thinking About a Career in...
Consolidating Learning	Students will be able to put their learning into action by reviewing and revising their course selections. (HS-ETS1-1, HS-ETS1-2, HS-ETS1-3)	Activity 8: Individual Pathways Plan Activity 9: Pitch a Career Plan



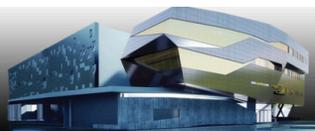
Perimeter Explorations 01: The Mystery of Dark Matter

Topic	Connection to Dark Matter and NGSS	Relevant Materials
Orbital Motion	Planets orbit around the sun in a predictable way. Planets that are further away travel more slowly than planets that are nearby. (HS-PS2-4, HS-ESS1-4)	Activity 1: Video Summary Activity 2: Key Concepts Activity 3: Gravity and Orbital Motion Video Chapter 1, 2, 3
Uniform Circular Motion	One of the strongest pieces of evidence for dark matter comes from the orbital speeds of stars in uniform circular motion. (HS-PS2-4, HS-ESS1-4)	Activity 1: Video Summary Activity 2: Key Concepts Activity 3: Gravity and Orbital Motion Activity 4: Dark Matter within a Galaxy Activity 6: Dark Matter Lab Predict, Observe, Explain Demonstration Video Chapter 1, 2, 3
Universal Gravitation	As we cannot see dark matter, we can only know of its existence via its gravitational effects. (HS-PS2-4, HS-ESS1-4)	Activity 1: Video Summary Activity 2: Key Concepts Activity 3: Gravity and Orbital Motion Activity 4: Dark Matter within a Galaxy Predict, Observe, Explain Demonstration Video Chapter 1, 2, 3
Two-Dimensional Collisions	A number of experiments are underway worldwide to try to detect dark matter particles in rare elastic collisions with atomic nuclei. (HS-PS2-2)	Activity 2: Key Concepts Activity 5: Advanced Mathematical Analysis Video Chapter 7
Nature of Science	There are a number of competing theories about what dark matter is made of. Some physicists do not even think dark matter exists. (HS-ESS1-4)	Activity 1: Video Summary Activity 2: Key Concepts Video Chapter 7
Mathematical Relationships	The relationship between the speed of a star and the mass of a galaxy within the $(v \propto \sqrt{M_{\text{gal}}})$. Physicists use this relationship to infer the existence of dark matter. (HS-PS2-2, HS-PS2-4)	Activity 2: Key Concepts Activity 4: Dark Matter within a Galaxy Activity 5: Advance Mathematical Analysis Activity 6: Dark Matter Lab Predict, Observe, Explain Demonstration Video Chapter 2, 3
Gravitational Lensing	Mass warps spacetime. Light passing through warped spacetime is deflected, revealing the presence of unseen mass. (HS-ESS1-4)	Activity 5: Advanced Mathematical Analysis Hands-on Demonstration Video Chapter 5
Process of Scientific Modelling	We build scientific models to explain complex phenomena. Good models must be logically self-consistent, explain the observations accurately, make testable predictions of new observations, and give new insights into the phenomena. (HS-PS2-1, HS-PS2-4, HS-PS3-1, HS-PS3-2, HS-ESS1-4)	Activity 3: Gravity and Orbital Motion Activity 6: Dark Matter Lab Predict, Observe, Explain Demonstration Hands-On Demonstration: Gravitational Lensing



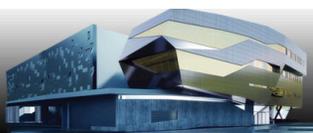
Perimeter Explorations 02: The Challenge of Quantum Reality

Topic	Connection to Quantum Physics and NGSS	Relevant Materials
Classical Particle Behaviour	Classical particles are localized and follow predictable trajectories. When two particles collide, their trajectories are changed. (HS-PS4-3)	Activity 1: Video Summary Activity 4: Investigating the Nature of the Electron Video Chapter 1
Classical Wave Behaviour	Classical waves are non-localized and transfer energy as they propagate. When two waves overlap they interfere, generating maxima and minima. (HS-PS4-1, HS-PS4-3)	Activity 1: Video Summary Activity 4: Investigating the Nature of the Electron Video Chapter 1
Wave-Particle Duality of Electrons	Electrons exhibit both wave and particle behaviour. In the double-slit experiment electrons are detected as localized particles that produce a wave-like interference pattern. (HS-PS4-3)	Activity 1: Video Summary Activity 2: Further Investigation of Wave-Particle Duality Activity 3: Advanced Mathematical Analysis Activity 4: Investigating the Nature of the Electron Video Chapter 2
Wave Nature of Matter	Quantum objects demonstrate wave properties like diffraction and interference. The de Broglie wavelength for matter is given by $\lambda = h/p$. (HS-PS4-3)	Activity 1: Video Summary Activity 2: Further Investigation of Wave-Particle Duality Activity 3: Advanced Mathematical Analysis Video Chapter 2, 3
Wave-Particle Duality of Light	In single photon experiments light demonstrates both wave and particle behaviour by striking the detector as localized particles but producing an interference pattern over time. (HS-PS4-3)	Activity 1: Video Summary Activity 2: Further Investigation of Wave-Particle Duality Video Chapter 3
Quantization of Light Energy	A light particle is called a photon and has energy $E = hf$. (HS-PS4-3)	Activity 1: Video Summary Activity 2: Further Investigation of Wave-Particle Duality Activity 3: Advanced Mathematical Analysis Video Chapter 3
Measurement Disturbance	In the electron double-slit experiment, measuring which slit the electron passes through destroys the interference pattern. (HS-PS4-3)	Activity 1: Video Summary Activity 3: Advanced Mathematical Analysis Video Chapter 4
Scientific Models	There are several competing models, or interpretations, that attempt to explain what an electron actually is, and what it is doing during the double-slit experiment. (HS-PS4-1, HS-PS4-3, HS-PS4-5)	Predict, Observe, Explain Demonstration Activity 1: Video Summary Activity 2: Further Investigation of Wave-Particle Duality Activity 4: Investigating the Nature of the Electron Video Chapter 5
Application of Wave-Particle Duality	Using the laws of quantum physics has led to technological innovations that have changed society. The most dramatic example is the transistor, which is the heart of the computer and the information age. (HS-PS4-1, HS-PS4-2, HS-PS4-3, HS-PS4-5)	Activity 1: Video Summary Activity 2: Further Investigation of Wave-Particle Duality Video Chapter 5
Process of Scientific Modelling	We build scientific models to explain complex phenomena. Good models must be logically self-consistent, explain the observations accurately, make testable predictions of new observations, and give new insights into the phenomena. (HS-PS4-1, HS-PS4-3, HS-PS4-4)	Activity 4: Investigating the Nature of the Electron Video Chapter 1, 2, 3 Black Box Demonstration



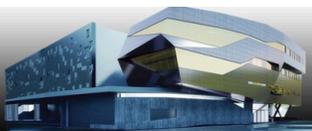
Perimeter Explorations 03: Beyond the Atom: Remodelling Particle Physics

Topic	Connection to Particle Physics and NGSS	Relevant Materials
Nature of Science	Scientists use models to explain complex phenomena. These models are often based on patterns and make testable predictions. Experiments are designed to test models. (HS-PS2-5)	Activity 2: Scattering Experiment Activity 4: Taming the Particle Zoo Video Chapter 1, 3, 5
Models of Matter	Experiments have refined our models of matter from Dalton to Thompson to Rutherford. Increasing energies have allowed scientists to probe deeper into matter, leading to the standard model. (HS-PS2-4, HS-PS2-6)	Activity 1: Video Summary Activity 2: Scattering Experiment Activity 4: Taming the Particle Zoo Video Chapter 1, 3, 4
Rutherford Scattering	Rutherford used alpha particles to probe the structure of matter. He concluded that the positive charge and almost all the mass were concentrated in a very small volume. (HS-PS2-4)	Activity 1: Video Summary Activity 2: Scattering Experiment Video Chapter 1
Fields	Forces act at a distance through fields. Electromagnetic fields are used to accelerate and guide beams of charged particles. Magnetic fields are used in particle detectors to identify the charges and momenta of particles. (HS-PS2-4, HS-PS3-5)	Activity 3: Bubble Chamber Detective Activity 5: Finding the Top Quark Video Chapter 1, 2
Standard Model	The Standard Model of matter used six quarks, six leptons, and four bosons to give a complete description of matter and forces. The Large Hadron Collider is testing the Standard Model. (HS-PS2-4)	Activity 1: Video Summary Activity 4: Taming the Particle Zoo Activity 5: Finding the Top Quark Video Chapter 3, 4
Energy-Mass Equivalence	Particle accelerators put enough energy into a small volume that matter is $E = mc^2$. (HS-PS1-8)	Activity 1: Video Summary Activity 5: Finding the Top Quark Video Chapter 2, 3, 4
Conservation Laws	Particle collisions obey the laws of conservation of momentum, and of charge (HS-PS2-2, HS-PS2-4)	Activity 3: Bubble Chamber Detective Activity 5: Finding the Top Quark Video Chapter 2, 3, 4
Process of Scientific Modelling	We build scientific models to explain complex phenomena. Good models must be logically self-consistent, explain the observations accurately, make testable predictions of new observations, and give new insights into the phenomena. (HS-PS2-4, HS-PS3-1, HS-PS3-5)	Activity 2: Scattering Experiment Activity 4: Taming the Particle Zoo



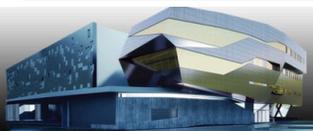
Perimeter Inspirations 01: Everyday Einstein: GPS & Relativity

Topic	Connection to GPS and NGSS	Relevant Materials
Process of Science & Innovation	Science involves the discovery of new ideas that are used to create new technologies. (HS-ETS1-1, HS-ETS1-2, HS-ETS1-3)	Activity 2: Scattering Experiment Activity 4: Taming the Particle Zoo Video Chapter 1, 3, 5
Science and Society	The GPS is used by millions of people every day in thousands of applications. (HS-PS4-5, HS-ETS1-1, HS-ETS1-2, HS-ETS1-3)	Activity 1: Video Summary Activity 2: Scattering Experiment Activity 4: Taming the Particle Zoo Video Chapter 1, 3, 4
Science and Numbers	The ability to comprehend and manipulate numbers is useful for understanding how the GPS works. (HS-PS2-4, HS-PS3-1, HS-PS3-2, HS-ESS1-4)	Activity 1: Video Summary Activity 2: Scattering Experiment Video Chapter 1
Space	GPS satellites orbit in space 20 200 km above Earth. (HS-PS2-4, HS-PS3-1, HS-PS3-2, HS-ESS1-4)	Activity 3: Bubble Chamber Detective Activity 5: Finding the Top Quark Video Chapter 1, 2
Uniform Circular Motion	GPS satellites move in circular orbits. (HS-PS2-4, HS-ESS1-4)	Activity 1: Video Summary Activity 4: Taming the Particle Zoo Activity 5: Finding the Top Quark Video Chapter 3, 4
Universal Gravitation	GPS satellites are held in orbit by the gravitational force between them and Earth. (HS-PS2-4, HS-ESS1-4)	Activity 1: Video Summary Activity 5: Finding the Top Quark Video Chapter 2, 3, 4
Momentum and Energy	The orbit of a GPS satellite dictates the values of its kinetic and gravitational potential energy. (HS-PS3-1, HS-PS3-2, HS-ESS1-4)	Activity 3: Bubble Chamber Detective Activity 5: Finding the Top Quark Video Chapter 2, 3, 4
Special Relativity	The GPS is so precise that it must take into account the effects of time dilation. (HS-ETS1-2)	Activity 3: Energy in Satellites Activity 4: Time and Relativity
General Relativity	The GPS is so precise that it must take into account the effects of general relativity. (HS-ETS1-2)	Activity 3: Energy in Satellites Activity 4: Time and Relativity Activity 5: Frames of Reference and General Relativity
Kinematics	The GPS uses the equation $d = vt$ to locate your position. (HS-PS2-1)	Activity 2: GPS Simulation
Measurement	The GPS uses a large number of significant figures in its calculations of distance to achieve its high degree of accuracy. (HS-PS2-4, HS-PS3-1, HS-PS3-2, HS-ESS1-4)	Activity 2: GPS Simulation Activity 3: Energy in Satellites Activity 4: Time and Relativity
Frames of Reference	The effect of gravity on time can be predicted by considering accelerated frames. (HS-ESS1-4)	Activity 5: Frames of Reference and General Relativity
Process of Scientific Modelling	We build scientific models to explain complex phenomena. Good models must be logically self-consistent, explain the observations accurately, make testable predictions of new observations, and give new insights into the phenomena. (HS-PS2-4, HS-PS3-2, HS-ESS1-4)	Predict, Observe, Explain Demonstration Activity 4: Time and Relativity



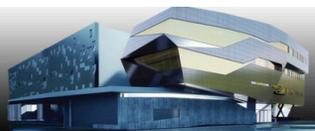
Perimeter Inspirations 02: Process of Science

Topic	Connection to the Resource and NGSS	Relevant Materials
Nature of Science	Science is a collaborative enterprise that involves both creative and critical thinking. Theories are rigorously tested and refined by other scientists as they are developed. (HS-PS1-2, HS-PS4-3, HS-PS4-4)	Asking Questions Science In The News Thinking Deeper Making Models
Process of Scientific Modelling	We build scientific models to explain complex phenomena. Good models must be logically self-consistent, explain the observations accurately, make testable predictions of new observations, and give new insights into the phenomena. (HS-PS1-1, HS-PS1-4, HS-PS2-1, HS-PS3-1, HS-PS3-2, HS-PS3-5, HS-PS4-1, HS-PS4-3, HS-PS4-4, HS-LS1-1, HS-LS1-2, HS-LS1-4, HS-LS1-5, HS-LS1-6, HS-LS1-7, HS-LS2-5, HS-LS4-1, HS-LS4-2, HS-ESS1-1, HS-ESS2-1, HS-ESS2-3, HS-ESS2-4, HS-ESS2-6)	Asking Questions Why Is It Like That? Science In The News Making Models
Observation and Inference	Scientists observe the world with their senses and instruments to gather information then use prior knowledge and logic to make sense of those observations. (HS-PS1-1, HS-PS1-2, HS-PS1-4, HS-PS2-1, HS-PS2-4, HS-PS3-2, HS-PS4-1, HS-PS4-3, HS-PS4-5, HS-LS1-3, HS-LS1-4, HS-LS1-5, HS-LS1-6, HS-LS1-7, HS-LS2-5, HS-LS3-2, HS-LS4-1, HS-LS4-2, HS-LS4-4, HS-ESS1-1, HS-ESS1-2, HS-ESS1-4, HS-ESS1-6, HS-ESS2-2)	Asking Questions Why Is It Like That? What Do You See?
Scientific Inquiry	Science is the art of asking questions and thinking deeply about possible answers. Good questions lead to new insights and often to more questions. (HS-PS1-2, HS-PS1-4, HS-PS2-2, HS-PS2-3, HS-PS2-4, HS-PS2-5, HS-PS3-1, HS-PS3-2, HS-PS3-4, HS-PS4-1, HS-PS4-2, HS-PS4-3, HS-LS1-1, HS-LS1-2, HS-LS1-4, HS-LS1-5, HS-LS1-6, HS-LS1-7, HS-LS2-5, HS-LS3-1, HS-LS3-2, HS-LS4-2, HS-LS4-4, HS-ESS1-2, HS-ESS1-4, HS-ESS1-6, HS-ESS2-5, HS-ESS2-7, HS-ESS3-1, HS-ESS3-5, HS-ETS1-2)	Asking Questions Why Is It Like That? Thinking Deeper
Diversity of Life	There is great beauty and wonder in the world around us. Scientists examine the many fascinating forms of life that exist, and look for reasons behind the many different forms. (HS-LS1-2, HS-LS1-3, HS-LS1-4, HS-LS1-6, HS-LS1-7, HS-LS4-1, HS-LS4-2, HS-LS4-4)	Asking Questions Why Is It Like That?
Atoms and Elements	All matter is made of atoms. Scientists synthesize heavy elements in accelerators. The discovery of new elements is an important part of understanding matter. (HS-PS1-1, HS-PS1-7, HS-PS1-8)	Case Study: Element 118
Space Exploration	Scientists have discovered amazing things about our universe. Careful analysis of observations points to new planets, the Big Bang, and maybe even Dark Matter. (HS-ESS1-2, HS-ESS1-4)	Science In The News Case Study: CMB Case Study: Dark Matter Case Study: Neptune
Ecosystems	Living organisms are closely connected with their environment. Small changes to the environment can have a large impact on populations. (HS-LS1-5, HS-LS2-1, HS-LS2-2, HS-LS2-5, HS-LS2-6, HS-LS2-7, HS-LS4-1, HS-LS4-2, HS-LS4-4, HS-LS4-5)	Case Study: Bisphenol-A Science In The News
Cells And Systems	Cells are the fundamental unit of living organisms. Scientists study how cells respond to subtle changes in their environment. (HS-LS1-2, HS-LS1-3, HS-LS1-4, HS-LS1-6, HS-LS1-7, HS-LS4-1, HS-LS4-2)	Case Study: Bisphenol-A Science In The News



Perimeter Inspirations 03: Revolutions in Science

Topic	Connection to the Resource and NGSS	Relevant Materials
Nature of Science	Science involves both creative thinking, leading to new and sometimes revolutionary ways of understanding nature. Educated guesswork and intuitive leaps can lead the scientific imagination to very strange ideas, but as long as these ideas fit the experiment evidence they must be taken seriously. The ultimate judge of a theory is how well it matches observations, not how well it matches our commonsense. (HS-PS1-2)	1, 2, 3
Process of Scientific Modelling	We build scientific models to explain complex phenomena. Good models must be logically self-consistent, explain the observations accurately, make testable predictions of new observations, and give new insights into the phenomena. (HS-PS1-1, HS-PS1-8, HS-PS4-3, HS-LS2-5, HS-ESS1-2)	1, 2, 3
Force and Acceleration	Newton's second law of motion dictates that acceleration is a result of a net force. In Newton's model, gravity is a force causing acceleration; in Einstein's model, gravity is not a force so objects in free fall are not accelerating. (HS-PS2-1, HS-PS2-4, HS-ESS1-4)	1
Weight	For Newton, weight is the force of gravity pulling down on you. For Einstein, gravity is not a force; weight is the magnitude of the force needed to accelerate you up along with the accelerating ground. An object in free fall (e.g. an astronaut in orbit) is weightless. (HS-PS2-1, HS-PS2-4)	1
Gravity	Students challenge their belief in Newton's mysterious "force of gravity," which has no known cause, and replace it with Einstein's curved spacetime model, which makes the cause of gravitational effects transparent. (HS-PS2-1, HS-PS2-4, HS-ESS1-4)	1
Frames of Reference	All observations are made relative to a frame of reference. If that frame is moving with constant velocity, there is no experiment that can be done to show that it is moving. If the frame is accelerating, the law of inertia seems to be violated inside the frame so we invent fictitious forces (e.g. Newton's force of gravity) to reconcile our experiences. (HS-PS2-1)	1, 3
Bohr-Rutherford Model of the Atom	The Bohr-Rutherford model of the atom is an obsolete scientific model. The idea of electrons orbiting around a nucleus is examined and shown to fail due to simple, classical concepts that are within the student's grasp. (HS-PS1-2, HS-PS4-3)	2
Quantum Mechanical Model of the Atom	The quantum mechanical model of the atom uses waves to describe the behaviour of particles. Electrons can behave as if they are in many places at the same time, solving the problems encountered by the classical (and Bohr-Rutherford) models. (HS-PS4-3)	2
Wave-Particle Duality	The electron is a point-like particle that behaves like a wave. This allows the electron to act as if it is in many places, or travelling in many directions, at the same time. (HS-PS4-3)	2
Electromagnetic Fields	The electron is charged so it is surrounded by an electric field. Accelerating electrons create changing electric fields so they emit electromagnetic waves. (HS-PS2-4, HS-PS2-5)	2
Relative Motion	Two observers watching the same event might have very different descriptions of the event if they are moving relative to each other. There is no preferred frame of reference in the universe so all motion is relative.	3
Time Dilation	The Newtonian concept of absolute time is wrong. Two observers moving relative to each other will measure the other's time passing at a different rate – moving clocks run slow.	3
Length Contraction	Two observers moving relative to each other will measure the others space to be contracted in the direction of motion – moving objects occupy less space.	3
Energy	Energy is not just "the ability to do work." Closer inspection of energy leads to the surprising result that all forms of energy have inertia – heating a cup of coffee increases its resistance to acceleration. (HS-ESS1-1)	3
Inertia	Inertia is not just "the ability to resist acceleration." The inertia of even an object at rest represents the presence of energy, as described by $E = mc^2$. (HS-PS2-1)	3





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PERIMETER RESOURCES & NEXT GENERATION SCIENCE STANDARDS

NGSS STANDARDS → PERIMETER RESOURCES

In the following charts, the expectations from the NGSS curriculum have been listed. Along with the listed standards are the applicable Perimeter Institute resources that connect to each item. Please refer to the following legend for all reference:

Legend of PI Resources:

Ex1: Perimeter Investigations 01: Measuring Planck's Constant Lab

CM: Perimeter BrainSTEM: Career Moves: Skills for the Journey

E1: Perimeter Explorations 01: The Mystery of Dark Matter

E2: Perimeter Explorations 02: The Challenge of Quantum Reality

E3: Perimeter Explorations 03: Beyond the Atom: Remodelling Particle Physics

I1: Perimeter Inspirations 01: Everyday Einstein: GPS & Relativity

I2: Perimeter Inspirations 02: Process of Science

I3: Perimeter Inspirations 03: Revolutions in Science

HS-PS1 Matter and Its Interactions

Students who demonstrate understanding can:

Code	Curriculum Expectation	PI Resource
HS-PS1-1	Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.	I2, I3
HS-PS1-2	Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table and knowledge of the patterns of chemical properties.	I2, I3
HS-PS1-3	Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.	I2, CM
HS-PS1-4	Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends on the changes in the total bond energy.	I2
HS-PS1-5	Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.	I2
HS-PS1-6	Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.	I2
HS-PS1-7	Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.	I2
HS-PS1-8	Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the process of fission, fusion, and radioactive decay.	I2, I3



HS-PS2 Motion and Stability: Forces and Interactions

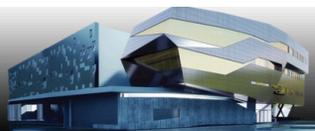
Students who demonstrate understanding can:

Code	Curriculum Expectation	PI Resource
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.	I1, I2, I3
HS-PS2-2	Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.	E1, E3, I2
HS-PS2-3	Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.	I2
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.	E1, E3, I1, I2, I3
HS-PS2-5	Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.	E3, I2, I3, CM
HS-PS2-6	Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.	E3

HS-PS3 Energy

Students who demonstrate understanding can:

Code	Curriculum Expectation	PI Resource
HS-PS3-1	Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.	I1, I2
HS-PS3-2	Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects).	I1, I2
HS-PS3-3	Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.	
HS-PS3-4	Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperatures are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).	I2, CM
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.	E3, I2



HS-PS4 Waves and Their Applications in Technologies for Information Transfer

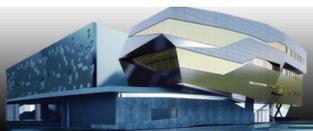
Students who demonstrate understanding can:

Code	Curriculum Expectation	PI Resource
HS-PS4-1	Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves travelling in various media.	E2, I2
HS-PS4-2	Evaluate questions about the advantages of using digital transmission and storage of information	E2, I2
HS-PS4-3	Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.	E2, I2, I3
HS-PS4-4	Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.	Ex1, I2
HS-PS4-5	Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.	Ex1, E2, I1, I2

HS-LS1 From Molecules to Organisms: Structure and Processes

Students who demonstrate understanding can:

Code	Curriculum Expectation	PI Resource
HS-LS1-1	Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out essential functions of life through systems of specialized cells.	I2
HS-LS1-2	Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.	I2
HS-LS1-3	Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.	I2, CM
HS-LS1-4	Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.	I2
HS-LS1-5	Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.	I2
HS-LS1-6	Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and / or other large carbon-based molecules.	I2
HS-LS1-7	Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.	I2



HS-LS2 Ecosystems: Interactions, Energy, and Dynamics

Students who demonstrate understanding can:

Code	Curriculum Expectation	PI Resource
HS-LS2-1	Use mathematical and / or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.	I2
HS-LS2-2	Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.	I2
HS-LS2-3	Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.	
HS-LS2-4	Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.	
HS-LS2-5	Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.	I2
HS-LS2-6	Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively constant numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.	I2
HS-LS2-7	Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.	I2
HS-LS2-8	Evaluate the evidence for the role of group behavior on individual species' chances to survive and reproduce.	

HS-LS3 Heredity: Inheritance and Variation of Traits

Students who demonstrate understanding can:

Code	Curriculum Expectation	PI Resource
HS-LS3-1	Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.	I2
HS-LS3-2	Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and / or (3) mutations caused by environmental factors.	I2
HS-LS3-3	Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.	



HS-LS4 Biological Evolution

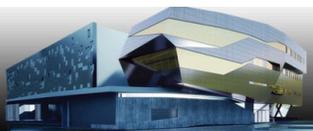
Students who demonstrate understanding can:

Code	Curriculum Expectation	PI Resource
HS-LS4-1	Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.	I2
HS-LS4-2	Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.	I2
HS-LS4-3	Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.	
HS-LS4-4	Construct an explanation based on evidence for how natural selection leads to adaptation of populations.	I2
HS-LS4-5	Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.	I2
HS-LS4-6	Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.	

HS-ESS1 Earth's Place in the Universe

Students who demonstrate understanding can:

Code	Curriculum Expectation	PI Resource
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.	I2, I3
HS-ESS1-2	Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.	I2, I3
HS-ESS1-3	Communicate scientific ideas about the way stars, over their life cycle, produce elements.	
HS-ESS1-4	Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.	E1, I1, I2, I3
HS-ESS1-5	Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks.	
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.	I2



HS-ESS2 Earth's Systems

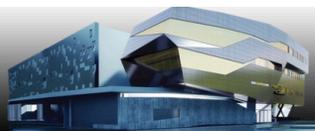
Students who demonstrate understanding can:

Code	Curriculum Expectation	PI Resource
HS-ESS2-1	Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.	I2
HS-ESS2-2	Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.	I2
HS-ESS2-3	Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.	I2
HS-ESS2-4	Use a model to describe how variations in the flow of energy into and out of Earth's systems results in changes in climate.	I2
HS-ESS2-5	Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.	I2, CM
HS-ESS2-6	Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.	I2
HS-ESS2-7	Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth.	I2

HS-ESS3 Earth and Human Activity

Students who demonstrate understanding can:

Code	Curriculum Expectation	PI Resource
HS-ESS3-1	Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.	I2
HS-ESS3-2	Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.	
HS-ESS3-3	Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.	
HS-ESS3-4	Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.	
HS-ESS3-5	Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.	I2
HS-ESS3-6	Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.	



HS-ETS1 Engineering Design

Students who demonstrate understanding can:

Code	Curriculum Expectation	PI Resource
HS-ETS1-1	Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.	I1, CM
HS-ETS1-2	Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.	I1, I2, CM
HS-ETS1-3	Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.	I1, CM
HS-ETS1-4	Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.	

