Earth Science Integration

PEER Physics' **Earth Science Anchoring Phenomena (APs)** and **Earth Science Explorations (ESEs)** were developed to support districts integrating Earth Science into a three-course model, where Disciplinary Core Ideas (DCIs) are incorporated into chemistry, biology, and physics. This document is designed to help teachers and districts effectively integrate Earth Science standards into their PEER Physics courses.

Background

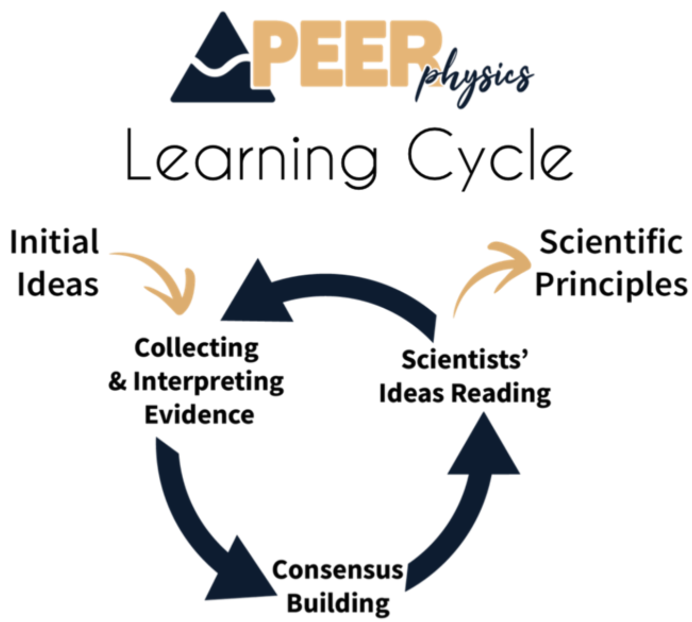
In partnership with districts in Colorado and California, we discovered that some states and districts are transitioning away from offering Earth Science as a stand-alone course, seeking instead to integrate Earth Science Disciplinary Core Ideas (DCIs) into physics, chemistry, and biology. Rather than tacking on disconnected Earth Science concepts at the end of existing science courses, districts hope for a more authentic integration of Earth Science objectives that would complement physics content. Through professional learning sessions and ongoing collaboration with teachers and district leaders, the PEER Physics development team expanded curriculum sequencing pathways to incorporate both Earth and physical science standards into a single physics course. PEER Physics has accomplished this authentic integration through Anchoring Phenomena and Earth Science Explorations that make connections between physics formalisms and their natural Earth science connections. **Anchoring Phenomena (APs)** in earth science contexts and **Earth Science Explorations (ESEs)** following the PEER Physics Learning Cycle are available to all of our partners.

Anchoring Phenomena

Each PEER Physics chapter is accompanied by an **Anchoring Phenomenon** in which teachers can situate the content learning and chapter storyline within a broader relevant scenario or event. **Anchoring Phenomena (APs)** are designed to appeal to students' natural curiosity for the world around them and guides student development and application of physics principles and models. In order to provide students with access to the most relevant phenomenon for their context, PEER Physics offers AP options so districts can select the phenomenon that is most relevant for their students and addresses their instructional goals. Chapters M & W include **Earth Science Explorations (ESEs)** that may be used as AP in contexts where instructional goals include integrating earth science within the physics course.

PEER Physics Learning Cycle

The PEER Physics Learning Cycle is the foundation for students to generate physics and/or earth science principles as they engage in authentic science practices. Students begin by considering their initial ideas about a particular phenomenon before diving into carefully sequenced guided inquiry laboratory investigations to make claims from evidence. Students finish each Learning Cycle with a consensus discussion, which is followed by readings designed to help students formalize and contextualize physics and/or earth science disciplinary core ideas, crosscutting concepts, and science practices. These readings confirm the ideas that students generated and formalize physics principles, science practices, and crosscutting concepts.



We refer to the PEER Physics activities as Learning Cycle Activities. Each Learning Cycle Activity is lab-based and guides students through the development of physics and/or earth science principles by engaging in science practices. The Learning Cycle Activities are situated within a larger Anchoring Phenomenon that spans a PEER Physics chapter.

PEER Physics Standards Alignment

PEER Physics is aligned to the **Next Generation Science Standards (NGSS)** for high school physical science. It uses phenomena-based, **three-dimensional** learning, including engineering, that is integrated with Disciplinary Core Ideas. PEER Physics intentionally integrates phenomena, engineering design, storylines, evidence, science, engineering practices, and technological tools.

Using **Scientific Practices (SEPs),** students iteratively develop **Disciplinary Core Ideas (DCIs)** and **Crosscutting Concepts (CCCs)** through the PEER Physics Learning Cycle as they articulate their initial ideas and collect and **interpret evidence**, often leading to the development and revision of models of phenomena. They then engage in a **consensus-building activity**, from which they derive principles (DCIs and CCCs) that can explain their shared observations. These and other SEPs are embedded and assessed throughout the curriculum. Students read and respond to **Scientists' Ideas readings**, which introduce formalisms, language, and symbology for DCIs, CCCs, and SEPs.

Students apply DCIs and CCCs from each activity to the unit's **Anchoring Phenomenon**. These **Anchoring Phenomena** (APs) are designed to engage students with a socially relevant and age-appropriate phenomenological occurrences that is directly related to the content of the unit. At the end of each unit, students work through one or more of a variety of summative assessments intended to connect their newly developed scientific principles and practices to the Anchoring Phenomenon and to new contexts.

Engineering Design Challenges (EDCs) address socially relevant content and prompt students to consider financial and environmental costs. EDC topics include vehicle energy efficiency, suspension bridge design, and electromagnetism. Throughout each EDC, students engage in the engineering design process: brainstorming, designing, testing, analyzing, and finally optimizing a real-world product that can accomplish a specific task. They are asked to apply physics principles in each step of the process and to comprehensively analyze how their design and the functionality of their designed product relate to key ideas from the chapter.

Many PEER Physics activities include **Mathematical Model Building** activities which intentionally take place after students have developed the associated concepts from the PEER Physics Learning Cycle. Teachers have found that students are better able to interpret mathematical, graphical, and table information after they have grappled with the concepts.

PEER Physics Earth Science-at-a-Glance

The following tables include Key Topics, NGSS Performance Expectations (PEs), Disciplinary Core Ideas (DCIs), and focal Science and Engineering Practices (SEPs), and Crosscutting Concepts (CCCs) for each PEER Physics **Earth Science Anchoring Phenomenon (AP)** and **Earth Science Exploration (ESEs)**. Earth Science-specific PEs, DCIs, SEPs, and CCCs are marked with an asterisk (*). While this document specifically serves as a guide for integrating Earth Science standards into a PEER Physics course, including Earth Science APs and ESEs, teachers are encouraged to select <u>one</u> Anchoring Phenomenon per chapter that fits their unique instructional goals and context.

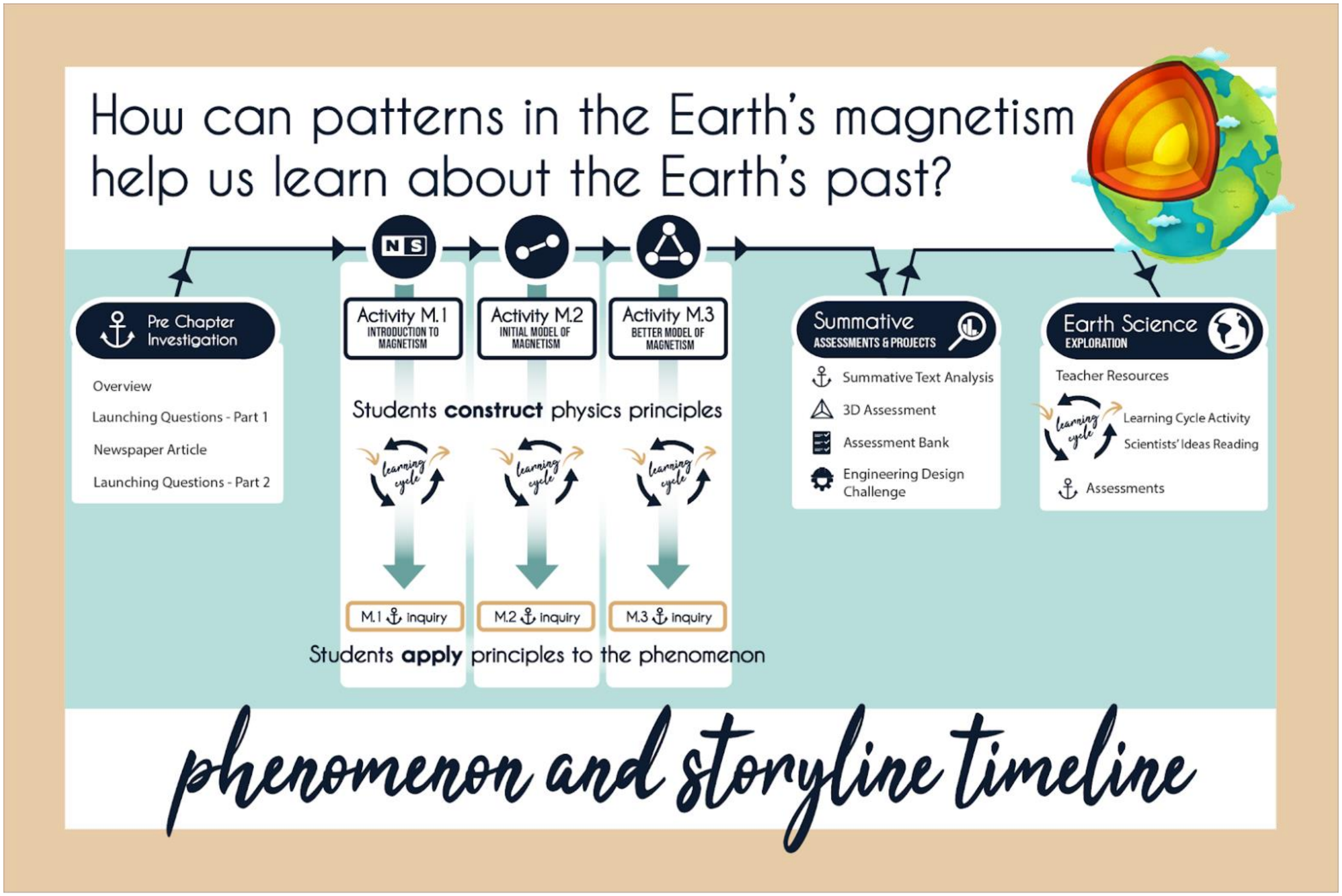
Anchoring Phenomena	Key Topics	NGSS Performance Expectations	DCIs	SEPs & CCCs
Earth Science Exploration: **How can patterns in the Earth's magnetism help us learn about the Earth's past? *** 	• Scientific models • Force at a distance • Magnetic poles • Domain Model of Magnetism • Electromagnetism • Magnetic striping* • Seafloor spreading* • Tectonic plates* • Mid-ocean ridges & trenches* • Convergent & divergent boundaries*	• **HS-PS2-5:** Electric Current and Magnetic Fields • **HS-ESS1-5:** Evidence of Plate Tectonics*	• **PS2.B** • **ESS1.C*** • **ESS2.B***	• **CCC1 -** Patterns • **CCC2 -** Cause and Effect • **CCC4 -** Systems and system models • **CCC7 -** Stability and change • **SEP2 -** Developing and using models • **SEP3 -** Planning and carrying out investigations • **SEP4 -** Analyzing and interpreting data • **SEP6 -** Constructing explanations and designing solutions

Anchoring Phenomena	Key Topics	NGSS Performance Expectations	DCIs	SEPs & CCCs
Earth Science Exploration: **How do scientific models help us prepare for natural disasters? *** 	• Scientific models • Longitudinal waves • Sound energy • Amplitude • Frequency • Wavelength • Transverse waves • Constructive & destructive interference • Electromagnetic Spectrum • Emission spectra • Speed of light • Earthquake magnitude* • Transform boundaries* • Seismic waves* • Earth's interior*	• **HS-PS4-1**: Wave Properties in Various Media • **HS-PS4-3**: Wave-Particle Duality of Electromagnetic Radiation • **HS-ESS3-1**: Global Impacts on Human Activity (Partially addressed - focuses specifically on natural hazards & disasters)*	• **PS3.A** • **PS3.D** • **PS4.A** • **PS4.B** • **ESS2.A*** • **ESS3.B*** • **PS4.C**	• **CCC1** - Patterns • **CCC2** - Cause and effect • **CCC3** - Scale, proportion, and quantity • **CCC4** - Systems and system models • **CCC5** - Energy and matter • **SEP2** - Developing and using models • **SEP4** - Analyzing and interpreting data • **SEP5** - Using mathematics and computational thinking • **SEP6** - Constructing explanations and designing solutions

Detailed PEER Physics Earth Science Anchoring Phenomena (APs) and Earth Science Explorations (ESEs)

Magnetic Striping and Seafloor Spreading

This Anchoring Phenomenon for Chapter M provides an opportunity for instructors seeking to integrate earth science into their PEER Physics courses. In this Anchoring Phenomenon students are prompted to apply their observations of magnetic objects, as well as their models of magnetism, to develop explanations for why large sections of the ocean floor are magnetized in particular ways. Following the Anchoring Phenomenon, instructors can implement an associated Earth Science Exploration about mid-ocean ridges, divergent tectonic plate boundaries, and seafloor spreading



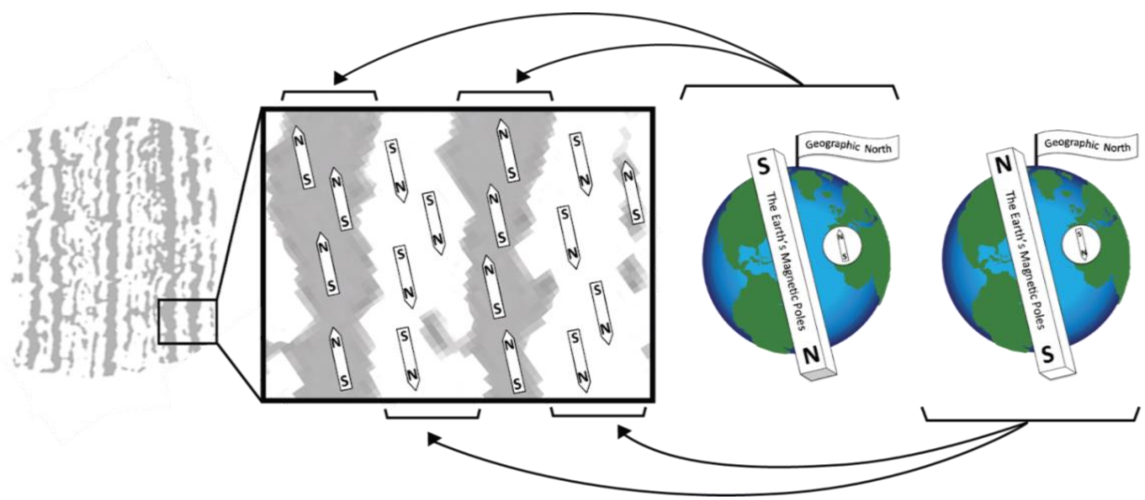
Before engaging with the Anchoring Phenomenon, students read a newspaper article about the discovery of seafloor magnetic striping and why it is significant. They then conduct a short investigation experiment to simulate the discovery of magnetic striping, in which they reflect on how the behavior of a compass needle demonstrates the alternate magnetization that characterizes this phenomenon.

In M.1, students explore properties of magnets. Students develop the idea that magnets are attracted to ferromagnetic objects (M.1a). In the Anchoring Phenomenon, students apply these ideas to the ocean floor context, making inferences about the mineral composition of ocean floor rock, and applying ideas about ferromagnetic and non-ferromagnetic materials.

Students build an initial model of magnetism in M.2. Because students have not yet developed their model of magnetism, they cannot yet provide a mechanism for why seafloor magnetic striping exists or have a high-confidence model for what it means for the stripes to be magnetized. However, students can apply their initial models to this larger scale context, and reflect on how this process can lead to insights about models.

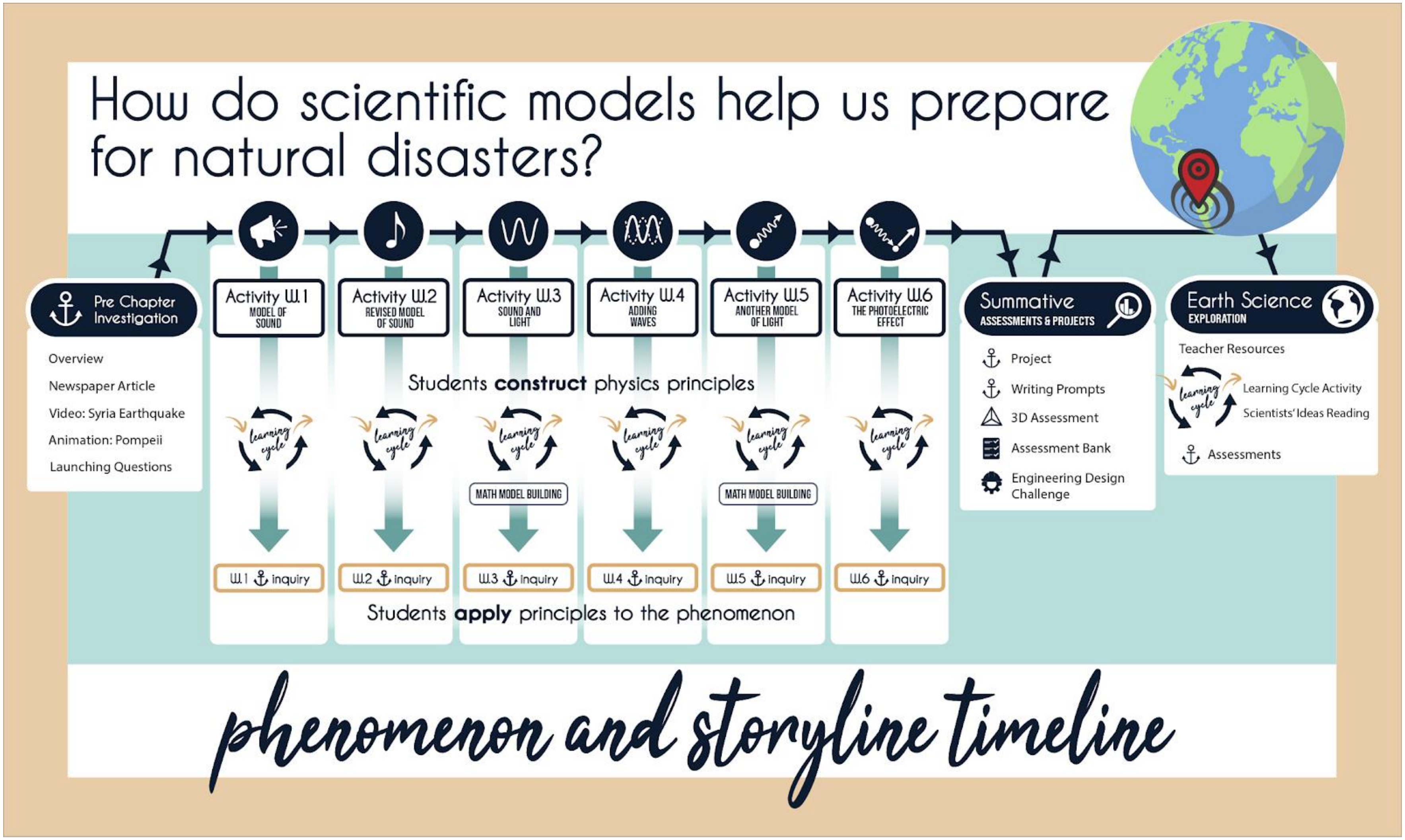
Students will not be able to fully why magnetic striping exists until after activity M.3, when they have developed the idea of demagnetization and finalized their model of magnetism. Students will be able to use the Domain Model of Magnetism (M.3b) and the idea that domains rotate (M.3c) to describe how magnetic stripes in seafloor rock "capture" the Earth's magnetization at different times, and how the process of seafloor spreading continually creates new magnetic stripes at the ocean floor.

After both Chapter M and this phenomenon, instructors may decide to implement the Earth Science Exploration (ESE) to support students with building ideas about tectonic plates and convergent and divergent plate boundaries. This ESE builds upon concepts developed in this phenomenon; they are designed for authentic integration of earth science and physics.



Natural Disasters and Seismic Waves

This Anchoring Phenomenon for Chapter W provides an opportunity for instructors seeking to integrate Earth Science into their PEER Physics courses. In this Anchoring Phenomenon students are prompted to apply ideas from their wave and particle models of sound and light to situations involving earthquakes, tsunamis, and natural disaster relief. By the end of the Anchoring Phenomenon, students will be able to reflect on how scientific models help scientists understand how earthquakes are created and where they are located. Following the Anchoring Phenomenon, instructors can implement an associated Earth Science Activity about earthquake magnitude, transform tectonic plate boundaries, and about how geophysicists study the Earth's interior.



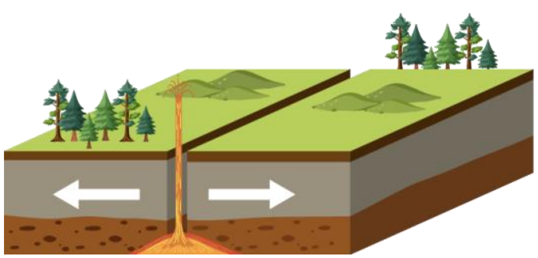
Prior to starting Chapter W, students will engage with a newspaper article about natural disasters throughout human history and answer reflection questions about different kinds of natural disasters. This lays the foundation for students to connect storyline ideas about wave and particle models to situations involving earthquakes.

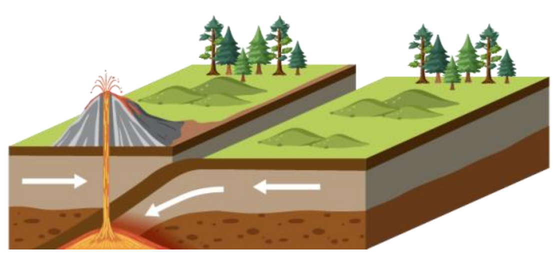
In Activities W.1 and W.2, students build and revise a model for sound propagation. Following Activity W.1, students apply their model to the Anchoring Phenomenon to make sense of primary waves and how they propagate through solid media. Various ideas from students' initial wave models of sound are applicable to situations involving p-waves, and students are supported in using them to make claims about energy propagation, the movement of seismic wave disturbances, and the movement of particles in a solid medium. Following Activity W.2, students continue to deepen this application of wave model concepts to the Anchoring Phenomenon by relating wave diagrams, as well as ideas about amplitude, wavelength, and frequency, to seismograms and seismic waves. They engage in a short investigation experiment to generate their own seismograms, before being supported in making sense of the data represented in them.

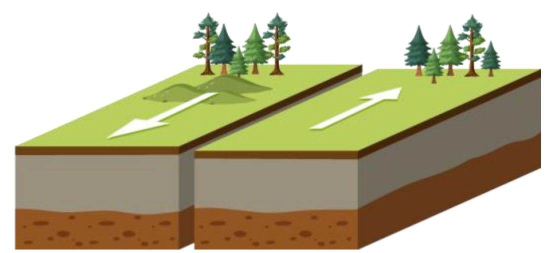
In Activity W.3, students compare and contrast observations of sound and light to establish similarities and differences between wave models for sound and light. In this process, students also explore transverse waves and contrast them to longitudinal waves. Students apply these ideas to the Anchoring Phenomenon by exploring secondary waves. They first contrast s-waves with p-waves, then engage in a scaffolded process of triangulating the location of an earthquake's epicenter.

After Activity W.4, where students build concepts of wave interference, students apply these principles to the Anchoring Phenomenon by considering how destructive and constructive seismic wave interference can help explain why some areas are more affected by an earthquake than others.

In Activity W.5 and Activity W.6, students develop a particle model of light and reflect on how certain phenomena are best explained by applying a particle model, instead of a wave model. In the Anchoring Phenomenon, students consider how tsunami detection systems rely on ideas from both kinds of models and reflect on differences between electromagnetic radiation and other forms of wave communication in terms of natural disaster prevention. After exploring the photoelectric and photovoltaic effects in Activity W.6, students consider how natural disaster relief depends on technologies that employ the photovoltaic effect. They are also prompted to consider ideas about the engineering design process in connection to natural disaster relief technology.







Sequence Recommendations for General Physics with Earth Science Integration

PEER Physics chapters are not numbered because they are generally flexible in terms of how they are sequenced. Each *core* chapter is accompanied by an **Anchoring Phenomenon** in which teachers can situate the content learning and chapter storyline within a broader relevant scenario or event, including earth science topics. The six PEER Physics units are Charge (C), Magnetism (M), Energy (E), Gravitation (G), and Waves (W). An additional chapter, Chapter P – Patterns, offers activities meant to be integrated within the sequences of the six core chapters. These activities explore Disciplinary Core Ideas and Crosscutting Concepts that provide connections and extend the storyline activities throughout the curriculum. Specific sequence recommendations and resources, including and excluding earth science integration, can be found here.

Objective: Earth Science Integration Conceptual Course		
Activity, Assessment, Project	**# of Expts**	**Contact Minutes**
Phenomenon Launch	NA	30
C.1 – Initial Model of Static Electricity	3	225
P.1 – Electric Fields	3	225
C.2 – Revised Model of Static Electricity	3	225
P.2 – Coulomb's Law	3	225
Chapter Assessment	NA	50
Phenomenon Project	NA	100
EDC	NA	100
Phenomenon Launch	NA	30
P.3 – Magnetic Fields	3	225
M.1 – Introduction to Magnetism	4	250
M.2 – Initial Model of Magnetism	2	200
M.3 – Better Model of Magnetism	3	225
ESE.M	4	250
P.4 – Electromagnetism	3	225
Chapter Assessment	NA	50
Phenomenon Project	NA	100
EDC (Electromagnetism)	NA	100
Phenomenon Launch	NA	30
W.1 – Model of Sound	3	225
W.2 – Revised Model of Sound	4	250
W.3 – Sound and Light	3	225
W.4 – Adding Waves	2	200

Objective: Earth Science Integration with Math Model Building		
Activity, Assessment, Project	**# of Expts**	**Contact Minutes**
Phenomenon Launch	NA	30
C.1 – Initial Model of Static Electricity	3	225
P.1 – Electric Fields	3	225
C.2 – Revised Model of Static Electricity	3	225
C.3 – Model of Charges in Conductors	3	225
P.2 – Coulomb's Law	3	225
Chapter Assessment	NA	50
Phenomenon Project	NA	100
Phenomenon Launch	NA	30
P.3 – Magnetic Fields	3	225
M.1 – Introduction to Magnetism	4	250
M.2 – Initial Model of Magnetism	2	200
M.3 – Better Model of Magnetism	3	225
ESE.M	4	250
P.4 – Electromagnetism	3	225
Chapter Assessment	NA	50
Phenomenon Project or EDC	NA	100
Phenomenon Launch	NA	30
W.1 – Model of Sound	3	225
W.2 – Revised Model of Sound	4	250
W.3 – Sound and Light	3	225
W.3 Math – Sound and Light	NA	50
W.4 – Adding Waves	2	200

W.5 – Another Model of Light	2	200
P.5 – Photelectric Effect	3	225
ESE.W	3	225
Chapter Assessment	NA	50
Phenomenon Project	NA	100
EDC	NA	100
Phenomenon Launch	NA	30
E.1 – Exploring Velocity	4	250
E.2 – Motion and Energy	3	225
E.3 – Slowing and Stopping	2	200
E.4 – Energy and Elastic Objects	3	225
P.8 – Momentum	2	200
Chapter Assessment	NA	50
Phenomenon Project or EDC	NA	100
Phenomenon Launch	NA	30
F.1 – Forces and Motion	2	200
F.2 – Force, Mass, and Acceleration	3	225
F.3 – Combinations of Forces	4	250
Chapter Assessment	NA	50
Phenomenon Project or EDC	NA	100
Phenomenon Launch	NA	30
G.1 – Gravitational Force and Acceleration	3	225
G.2 – Falling Objects and Energy	2	200
G.3 – Circular Motion	3	225
ESE.G – Kepler's Laws	3	225
G.5 – Gravitational Force, Distance, and Mass	4	250
Chapter Assessment	NA	50
Phenomenon Project or EDC	NA	100
	Total Minutes	**8105**

W.5 – Another Model of Light	2	200
W.5 Math – Another Model of Light	NA	50
P.5 – Photelectric Effect	3	225
ESE.W	3	225
Chapter Assessment	NA	50
Phenomenon Project or EDC	NA	100
Phenomenon Launch	NA	30
E.1 – Exploring Velocity	4	250
E.2 – Motion and Energy	3	225
E.3 – Slowing and Stopping	2	200
E.4 – Energy and Elastic Objects	3	225
E.4 Math – Energy and Elastic Objects	NA	50
P.8 – Momentum	2	200
Chapter Assessment	NA	50
Phenomenon Project or EDC	NA	100
Phenomenon Launch	NA	30
F.1 – Forces and Motion	2	200
F.1 Math – Forces and Motion	NA	50
F.2 – Force, Mass, and Acceleration	3	225
F.2 Math – Force, Mass, and Acceleration	NA	50
F.3 – Combinations of Forces	4	250
F.3 Math – Combinations of Forces	NA	50
Chapter Assessment	NA	50
Phenomenon Project or EDC	NA	100
Phenomenon Launch	NA	30
G.1 – Gravitational Force and Acceleration	3	225
G.1 Math – Gravitational Force and Acceleration	NA	50
G.2 – Falling Objects and Energy	2	200
G.2 Math – Falling Objects and Energy	NA	50
G.3 – Circular Motion	3	225
ESE.G – Kepler's Laws	3	225
G.5 – Gravitational Force, Distance, and Mass	4	250
G.5 Math – Gravitational Force, Distance, and Mass	NA	50
Chapter Assessment	NA	50
Phenomenon Project or EDC	NA	100
	Total Minutes	**8480**

