Physical Science, Quarter 3, Unit 3.1

Waves

Overview

Number of instructional days: 10 (1 day = 53 minutes)

Content to be learned

- Explain how energy is transmitted through waves.
- Examine energy transformations within a system.
- Describe and diagram multiple methods of energy transformation.
- Examine the transformation of kinetic and potential energy.

Processes to be used

- Observe, measure, and draw conclusions regarding simple harmonic motion.
- Perform calculations and manipulate algebraic equations.
- Analyze and create models, diagrams, charts, and data tables.
- Create and interpret graphs.
- Use logical, cause-and-effect reasoning.
- Compare and contrast.

Essential questions

- How is energy transmission different in a mechanical wave and an electromagnetic wave?
- How does particle motion in a wave relate to energy transfer in a wave?
- How does the direction of energy transfer compare to the direction of particle motion in a longitudinal and transverse wave?
- How is energy transformed/transferred in a system?

Written Curriculum

Grade Span Expectations

PS 2 - Energy is necessary for change to occur in matter. Energy can be stored, transferred, and transformed, but cannot be destroyed.

PS2 (9-11) POC+SAE -5

Demonstrate how transformations of energy produce some energy in the form of heat and therefore the efficiency of the system is reduced (chemical, biological, and physical systems).

PS2 (9-11)-5 Students demonstrate an understanding of energy by…

5a describing or diagraming the changes in energy (transformation) that occur in different systems ~~(eg. chemical = exo and endo thermic reactions, biological = food webs, physical = phase changes).~~

PS2 (Ext)– 5 Students demonstrate an understanding of energy by…

5aa Identifying, measuring, calculating and analyzing qualitative and quantitative relationships associated with energy transfer or energy transformation.

Clarifying the Standards

Prior Learning

In grades K–4, the standard image associated with waves was surface water waves. Students may have also been aware of radio waves, x-rays, etc., but they had little knowledge of interactions. Students were first introduced to waves in early grades through music, where they learned that vibrations cause all sounds. Students felt these vibrations on instruments while simultaneously hearing the sounds created by those instruments. Students later learned to differentiate among varying rates of vibration.

In grades 5–6, students furthered their understanding by describing sound as the transfer of energy through various materials. Students understood through investigation that vibrations in material cause wave-like disturbances that spread out from the center or source of the wave.

In grades 7–8, students learned that energy transfers from form to form and place to place quite easily. In eighth grade, students learned about different properties of waves using ropes and springs. However, they were mainly focused on determining wavelength and performed minimal calculations. They also understood that waves move at varying speeds.

Current Learning

The emphasis of this unit is the transmission of energy by wave motion. This includes how waves transmit energy from a source to a distant receiver without transferring matter, simple harmonic motion, and the differences between longitudinal and transverse waves. These energy changes can be quantified, analyzed, and graphed.

A pendulum can be used as a way to quantify energy. One point to examine in detail is the maximum amplitude and when the pendulum is at rest. Initially, students identify the system and total mechanical energy present in the system. The transformations between kinetic and gravitational potential energy can be calculated, graphed, and analyzed. A pendulum or spring is a classic example of a system exhibiting simple harmonic motion.

Emphasize that waves transmit energy without transmitting matter. This can be accomplished by emphasizing that mechanical waves are made up of a lot of individual simple harmonic oscillators. The oscillators stay in about the same position, but the energy and wave pulse moves throughout the medium.

Students need to have experience manipulating algebraic equations to calculate energy transformation. They also have to create and analyze graphs of energy transformation. Students will predict and then measure properties of a pendulum or spring (a simple harmonic oscillator) in laboratory conditions, analyze their results, and draw conclusions from their observations. Students need to be able to recognize the cyclic properties in systems involving SHOs or waves.

Learning about waves should include both inquiry-based and discussion-based classes. Students are asked to form hypotheses, observe systems, collect data, analyze data, and draw conclusions. This should include a lab on simple harmonic motion (springs or pendulums) so students can observe this type of system and see how it connects linear motion with cyclic motion. Observational data needs to be graphed and analyzed for trends. Conclusions should be drawn and compared against their original hypotheses. This can be reinforced and wrapped-up in class discussions.

Students' previous experience with waves concentrated largely on sound. Other types of waves are now being introduced as waves are experienced in a broader context. Students may have misconceptions about visible (string) waves and invisible (air, EM) waves. It should be emphasized that these are both examples of waves and that the same concepts, properties, and relationships apply to both. Although students have previously looked at energy and energy transfer, the function of waves as a means of energy transfer will be emphasized. The amount of energy transfer will be quantitatively analyzed both graphically and algebraically.

Future Learning

The subsequent unit further develops wave motion, properties, examples, and applications. Specific examples and applications of both mechanical and electromagnetic waves will be examined. Waves will be examined quantitatively in terms of wavelength, frequency, and velocity. Wave superposition and interference will be addressed as will other wave properties including refraction, diffraction, and reflection. In unit 3.4, students will see how these wave properties are applied to larger ideas in the world around us including Doppler shift and the Big Bang.

Waves will be addressed in much greater depth in an 11th and 12th grade course. This will include analytically calculating and applying Doppler shift, interference, tension in wave mediums, air density, sonic booms, optics, spectroscopy, emission and absorption spectra, sound, music, and electromagnetic wave phenomena. Waves are also essential for addressing relativity with regard to light clocks and travel at relativistic speeds near the speed of light.

Additional Research Findings

According to *Making Sense of Secondary Science*, students have trouble conceptualizing air as a medium for the transfer of sound (or other) mechanical waves. Students' understanding of sound causing vibrations is context specific to instruments in which the vibrations are more visible. For instance, students understand that plucking a guitar string causes vibrations, but they are less likely to associate wave vibration when discussing the sound of horns being played (p. 134).

Students need to understand simple harmonic motion. This facilitates the transition between particle motion and cyclic or wave motion. This foundational information is not mandated by the GSEs, but may need to be taught in order for students to fully understand the content in this unit of study.

Although students are able to recognize waves in visible mediums (i.e., vibrating strings), they have difficulty recognizing invisible waves (vibrating air, light, etc.). Students have trouble conceptualizing air as a medium for the transfer of sound (or other) mechanical waves (p. 134).

Teachers should plan to give students experiences of sound production in less obvious contexts as well as in contexts where the vibrations are more easily observed (p. 134). The ear is a good contextual example, since all students are familiar with ears as collectors of sound (p. 135). You can have students line up and "do the wave" (this would be a transverse wave). Students can also form a longitudinal wave by putting their hands palm to palm and creating a compression wave. Instruments, Slinkys, or vibrating strings can be brought in to demonstrate mechanical waves.

Notes About Resources and Materials

Physical Science, Quarter 3, Unit 3.2

Wave Properties

Overview

Number of instructional days: 10 (1 day = 53 minutes)

Content to be learned

- Qualify the relationships among the frequency, and wavelength of a wave.
- Describe the effects of electromagnetic waves as they interact with matter.
- Classify and give examples of different types of wave phenomena.

Processes to be used

- Diagram scientific phenomena.
- Observe, measure, and draw conclusions.
- Perform calculations and manipulate algebraic equations.
- Analyze and create models, diagrams, charts, and data tables.
- Create and interpret graphs.
- Logical cause-and-effect reasoning.
- Compare and contrast phenomena
- Make scientific explanations.

Essential questions

- What determines the colors you see in nature?
- What behaviors do waves display when they interact with other waves, other objects, or other media?
- How do amplitude, wavelength, and frequency relate to the energy in a wave?
- How does surface texture affect how waves are reflected or absorbed by the surface?

Written Curriculum

Grade Span Expectations

PS 3 - The motion of an object is affected by forces.

PS3 (9-11) SAE –10

Explain the effects on wavelength and frequency as electromagnetic waves interact with matter (e.g., light diffraction, blue sky).

PS3 (9-11)–10 Students demonstrate an understanding of waves by …

10a investigating examples of wave phenomena (e.g. ripples in water, sound waves, seismic waves).

10c qualifying the relationship between frequency and wavelength of any wave.

Clarifying the Standards

Prior Learning

By grades 7–8, students knew that light from the sun is a mixture of colors. They recognized that we see light waves because they are reflected off objects and into the eye. The human eye responds to only a narrow range of wavelengths of electromagnetic radiation, called the visible portion of the electromagnetic spectrum. The difference in wavelengths within that range corresponds with the different colors. Students also learned about the differences in properties of electromagnetic waves as compared to mechanical waves.

Current Learning

Students learn about the relationships among the frequency, wavelength, and velocity of a wave; wave properties moving in and between different media; and the electromagnetic spectrum. The properties of diffraction, refraction, reflection, transmission, and interference are addressed and explored. Wave superposition and interference are discussed and graphed. Students use the standing wave model to visualize certain wave properties.

Students are exposed to more examples of different types of waves including transverse, longitudinal, mechanical, and electromagnetic. Students are also introduced to the electromagnetic spectrum. They identify different regions of the spectrum based on wavelength, frequency, and energy. The absorption, reflection, and transmission of wavelengths of light by different media with respect to color are addressed.

Students perform algebraic manipulation to calculate the wavelength, frequency, and velocity of a wave. They need to create amplitude versus wavelength graphs of a wave and use this graph to explore interference and superposition. They will be able to describe how ranges of frequencies and wavelengths relate to the amount of energy transmitted by those waves.

Learning about waves should include both inquiry-based and discussion-based classes. Students will be asked to form hypotheses, observe systems, collect data, analyze the data, and draw conclusions. This should include a lab on wave properties in a vibrating string (a standing wave). The concepts learned in this type of lab can be applied to light, sound. Observational data needs to be graphed and analyzed for trends. Conclusions should be drawn and compared against original hypotheses. Other examples of waves should be presented as mini demonstrations. This might include Slinkys, vibrating strings, music, or light. These concepts can be reinforced and wrapped-up in class discussions.

Students have some experience with the EM spectrum, how light is perceived, and how it behaves. This is reinforced and expanded in this unit. Specific ranges of wavelengths, frequencies, and energy are associated with the EM spectrum. Students now perform calculations to quantitatively see how wave properties (wavelength, frequency, and velocity) are related. Ideas such as superposition and the role of reflection and interference in superposition of waves are explored in depth.

Students are working towards a better understanding of the relationship between particles and waves; the properties of waves are now being quantified.

Future Learning

In unit 3.1, students were introduced to a variety of types of waves and how they behave. In unit 3.4, students will be exposed to waves in natural settings including Doppler shift, stars, and the Big Bang. The properties students have learned about waves are necessary to understanding wave behavior in these settings.

Waves will be addressed in much greater depth in an 11th and 12th grade course. This will include analytically calculating and applying Doppler shift, interference, tension in wave mediums, air density, sonic booms, optics, spectroscopy, emission and absorption spectra, sound, music, and electromagnetic wave phenomena. Waves are also essential for addressing relativity with regard to light clocks and travel at relativistic speeds near the speed of light.

Additional Research Findings

According to *Making Sense of Secondary Science*, students have a hard time understanding filters or objects that reflect only certain colors. They don't understand that filters only transmit certain wavelengths of light. They feel that the white light has been dyed or painted (p.131). Most students don't think white light is a mixture of all colors. They also believe that color is an innate property of an object. Students understand that light can bounce or reflect off mirrors, but they have a hard time understanding that light bounces or reflects off of a number of other objects. An early misconception of students is light travels different distances in the day and night and that is why it is dark at night. Many children think of shadows as obstacles that block the passage of light instead of projections of objects that block that light. Many children from early on are told that light is a form of energy. It is then left to their imagination to understand what light is while exploring its properties. By the middle-school years, students can identify light as a source (i.e., light bulb), an effect (i.e., patch of light on the ground), or a state (i.e., brightness), but they do not understand that it is a physical entity in space (p. 130).

One challenge to teaching this content is the abstract nature of many invisible waves. Having students experiment and investigate with concrete visible waves (such as a string) would help eliminate the confusion that exists when students investigate sound and light waves.

Physical Science, Quarter 3, Unit 3.3

Formation of Stars

Overview

Number of instructional days: 10 (1 day = 52 minutes)

Content to be learned

- Describe the life cycles of stars of different sizes.
- Explain how the elements in our universe were created.
- Explain the importance and effect of gravity in the formation of our solar system and the universe.
- Explain how stars of different sizes are formed and the importance of the force of gravity in their formation.
- Use diagrams (i.e., H-R diagram) to compare different types of stars.

Processes to be used

- Analyze and create models, diagrams, charts, and data tables.
- Create and interpret graphs.
- Use logical cause-and-effect reasoning.
- Compare and contrast.
- Explain in words how energy is transmitted with regard to stars.

Essential questions

- How and why are the life cycles of low-mass stars different from the life cycles of high-mass stars?
- What are the relationships among the energy produced from nuclear reactions and the origin of elements?
- How does Newton's third law explain how the force of gravity is involved in star formation?
- How does heat energy dissipate throughout the body of a high-mass star and a low-mass star?

Written Curriculum

Grade Span Expectations

ESS3 - The origin and evolution of galaxies and the universe demonstrate fundamental principles of physical science across vast distances and time

ESS3 (9-11) NOS–5

Explain how scientific theories about the structure of the universe have been advanced through the use of sophisticated technology (e.g., space probes; visual, radio and x-ray telescopes).

ESS3 (9-11)–5 Students demonstrate an understanding of the origins and evolution of galaxies and the universe by…

5a using appropriate prompts (diagrams, charts, narratives, etc.) students will explain how scientific knowledge regarding the structure of the universe has changed over time due to advances in technology which accumulates new evidence to redefine scientific theories and ideas.

ESS3 (9-11) POC+SAE – 8

Explain the relationships between or among the energy produced from nuclear reactions, the origin of elements, and the life cycle of stars.

ESS3 (9-11)–8 Students demonstrate an understanding of the life cycle of stars by …

8a relating the process of star formation to the size of the star and including the interaction of the force of gravity, ~~fusion, and energy release in the development of the star identifying and describing the characteristics common to most stars in the universe~~.

8b Describing the ongoing processes involved in star formation, their life cycles and their destruction.

Clarifying the Standards

Prior Learning

Since star formation is caused mainly by gravity, students gather the steps related to the understanding of star formation early on, They also understand that earth rotating on its axis every 24 hours creates night and day.

In grades 3–5, students were introduced to astronomy, and they began to learn about the structure and formation of stars. They learned that we can't determine how the solar system is put together just by looking at it. In grades 5–6, students learned that the sun's gravitational pull holds the earth and other planets in orbit, just as the planet's gravitational pull keeps its moons in orbit. They also learned that the stars' relative positions in the sky change based on the time of year and that the sun is a medium-sized star on the edge of a disc-shaped galaxy of stars. They furthered this understanding in grades 6–8 as they identified and compared the size, location, distance, and movement of the objects in our solar system (e.g., orbit of planets, path of meteors). In grades 7–8, students learned that the universe contains many billions of galaxies and that each galaxy contains many billions of stars.

By identifying major discoveries from various cultures (using timeline, research project, picture book) and describing how these discoveries have contributed to our understanding of the solar system, students gained an introductory understanding of how technological advances have allowed scientists to reevaluate or extend ideas about the solar system.

In grades 5–6, students learn that all planets, including the earth, and all stars, including the sun, are approximately spherical.

In grades 7–8, students learned that anything on or near earth is pulled to earth's center due to gravity. They also learned that every object exerts a gravitational force on any other object. Furthermore, this amount of gravitational force depends on the mass of the objects and the distances between them. They also realized that this force is hard to detect unless the amount of mass is great.

Current Learning

The life cycles of stars are explored. This will include the formation, evolution, and end of life stages for low-, medium-, and high-mass stars. Students read and interpret H-R diagrams so they can identify where different types of stars are placed. This includes being able to determine what zones of the diagram stars can be found in at various stages of their life cycles. Students discuss and explain the life cycles of various stars and locate them on H-R diagrams.

It should be emphasized that at every stage of its life, mass is the main determinant of how a star will behave. It is also important to emphasize what elements are synthesized during various stages of stellar evolution and the role that supernovae play in synthesizing elements. Low-mass stars are capable of creating elements up to carbon (atomic number 6) and oxygen (atomic number 8) through fusion. High-mass stars can fuse higher mass elements until they are left with an iron (atomic number 26) core. Supernovae are needed to create the rest of the elements on the periodic table. This happens during the core collapse, core bounce, and explosion of the supernovae. The roles of gravity combating thermal pressure (hydrostatic equilibrium) and the methods of heat energy transfer in a star (convection and radiation, depending on size) should also be explored. Students need to explain the energy transfer mechanisms that exist in various types and layers of stars

Students also discuss how the force of gravity relates to star formation; the size, life cycle, and structure of a star; the interplay between the force of gravity and thermodynamic forces in stars; and how gravitational forces allow for the recycling of matter—through supernovae—to create new stars. The importance of energy and heat can be used to transition into the next unit.

During this unit, students will need to examine a good deal of scientific data largely in chart, map, or graph form. To help students visualize stars, teacher-lead class discussions and PowerPoint presentations showing the life cycle of stars can be used.

Future Learning

Since the next unit will cover energy, the thermodynamic properties of stars will be a good transition point. Fusion reactions inside stars will be addressed in chemistry. The life cycle of stars will be further reviewed in grades 11–12 at the end of physics, and more deeply addressed in physics 2.

In chemistry and in 11th or 12th grade physics, students will continue to look at the inner working of stars. This will include specific chemical reactions that synthesize elements and give off heat and radiation. The interaction of gravity and effects of relativity near stars will be analyzed and analytically calculated.

Additional Research Findings

Students have a hard time conceptualizing changes that occur over time periods as long as those involved the formation of stars. When dealing with changes, which occur very slowly, it is hard for students to understand that these changes are still occurring.

According to *Making Sense of Secondary Science*, only 55% of adults think of the sun as a star; 20% thought it was a planet (p. 175).

Physical Science, Quarter 3, Unit 3.4

Structure of the Universe

Overview

Number of instructional days: 8 (1 day = 53 minutes)

Content to be learned

- Use scientific evidence to explain and justify the Big Bang theory.
- Use the Doppler Effect and line spectra to explain how we know if stellar bodies are moving toward or away from us.
- Explain how the Doppler Effect provides evidence for the expansion of the universe.
- Explain how scientific knowledge regarding the structure of the universe has changed over time.

Science processes to be used

- Observe, measure, and draw conclusions.
- Analyze and create models, diagrams, charts, maps, and data tables.
- Create and interpret graphs.
- Use logical cause-and-effect reasoning.

Essential questions

- What evidence supports our current understanding of the Big Bang theory?
- How does the Doppler Effect help us understand the movement of stellar bodies
- How has new scientific knowledge changed our ideas about the formation of the universe?
- What role does gravity play in the formation of our universe?

Written Curriculum

Grade Span Expectations

ESS3 - The origin and evolution of galaxies and the universe demonstrate fundamental principles of physical science across vast distances and time

ESS3 (9-11) SAE -7

Based on the nature of electromagnetic waves, explain the movement and location of objects in the universe or their composition (e.g., red shift, blue shift, line spectra)

ESS3 (9-11)–7 Students demonstrate an understanding of processes and change over time within the system of the universe (Scale, Distances, Star Formation, Theories, Instrumentation) by...

7a applying the properties of waves/particles to explain the movement, location, ~~and composition~~ of the stars and other bodies in the universe.

ESS3 (9-11) NOS–6

Provide scientific evidence that supports or refutes the "Big Bang" theory of how the universe was formed

ESS3 (9-11)–6 Students demonstrate an understanding of the formation of the universe by…

6a using data (diagrams, charts, narratives, etc.) to explain how the "Big Bang" theory has developed over time citing evidence to support its occurrence (Doppler Effect/red shift).

Clarifying the Standards

Prior Learning

On stars and galaxies:

By second grade, students knew that there are more stars in the sky than anyone can easily count. They also knew that stars are not scattered evenly and that they differ in brightness and color. By grade 4, students knew that stars are found in patterns called constellations.

By the end of fifth grade, students knew that the pattern of stars in the sky stays the same even as the stars themselves appear to move with earth's rotation. Students also understood that different stars are visible during different seasons. They learned that telescopes allow us to see more stars and they recognized the sun as a medium-sized star that, if it were further away, would look like a single point of light (as other stars do).

By eighth grade, students paid increasing attention to the scale of the universe. They had an idea of just how far away objects outside our solar system are. They also understood that the sun is just one star in a galaxy, that the universe contains billions of galaxies, and that each galaxy contains billions of stars.

On the Big Bang theory:

Students enter ninth grade with limited knowledge of the Big Bang theory. They have most likely heard of it in popular media, but it is not a topic that is traditionally covered in school up until this point.

Current Learning

In this unit, students study the beginning of our universe—the Big Bang—and cosmic background microwave radiation (CMB) as evidence for the Big Bang. There is brief discussion of spectroscopy (emission and absorption spectra) with regard to stars, including whether they are Doppler shifted (*red* and *blue* shift). Students determine if stars and galaxies are moving toward or away from us based on the direction of the shift. This is an important piece of evidence for the Big Bang. Students do not use the Doppler equation or perform calculations. They should, however, be able to create graphical representations or recognize the effect in data and spectra. Spectroscopy will be further explored in chemistry.

Students will read charts, graphs, and tables including spectroscopy spectra and CMB maps. They should be able to read information off these maps and draw conclusions regarding the phenomena they represent. Using this information, they should be able to predict future events and justify theories about the formation of the universe.

Additionally, students chart how the growing use of technology has increased and changed our understanding of the universe's formation and structure. Students will learn about earlier scientific models of the universe—from those of the ancient Greeks to modern day—and how technology has contributed additional information to change these views. Important historical figures such as Kepler and Hubble should also be mentioned. The use of X-ray data, radio data, improved telescopy, space probes, satellites, particle accelerator simulations, etc., is discussed.

Future Learning

These topics will not be addressed again in this course until the final exam. However, the data-analysis and critical-thinking skills developed in this unit are necessary for further studies.

In chemistry, spectroscopy will be discussed in much greater detail (including flame tests, looking at spectra of gasses, and spectroscopy labs). This will be further developed in a 12th-grade physics course. Spectra of stars, the Doppler Effect, and equations will be explored in greater depth in physics.

In college, entire courses can be taken on astronomy.

Additional Research Findings

Some difficulties in learning this unit include the variety of topics and the abstract nature of the subject. Students will need to synthesize prior knowledge from previous topics in order to fully understand the material at this level. If students have a weak understanding of physical properties (i.e., waves, energy, forces), then they will have continued difficulty with this topic and some re-teaching may be necessary. Comprehensive diagrams and models will greatly facilitate student understanding of these concepts. Making sure students have a thorough understanding of previously learned topics will make this section go more smoothly.

According to *Making Sense of Secondary Science*, students have a hard time understanding the scale of different objects in space. Most students in middle school identify the sun, moon, and earth as approximately the same size. Without proper instruction, students often mistakenly believe the sun is only three or four times the size of the earth, when it is actually much larger. It is also difficult for students to understand the great distances between space objects such as the sun, moon, and other stars. These are all considered "far from earth" to students, and it is challenging for them to grasp the differences between these distances (p. 170).

Students also have misconceptions about the word *theory*, as in the Big Bang theory. Some students confuse scientific theories, which are backed up by broad amounts of evidence, with a lay definition of the word theory, which is far less formal. This can cause skepticism among students about the depth of support for scientific theories.

Notes About Resources and Materials