Physical Science, Quarter 2, Unit 2.1

Gravity

Overview

Number of instructional days: 7 (1 day = 53 minutes)

Content to be learned

- Explain how mass and distance affect gravitational forces.
- Explain how gravitational forces between any two given objects are equal in magnitude, but opposite in direction.
- Predict how the force of gravity will affect the motion of a given object based on its mass and distance.
- Predict how the force of gravity and inertia will affect the motion of an object.

Processes to be used

- Observe, measure, and draw conclusions.
- Perform calculations and manipulate algebraic equations.
- Analyze and create models, diagrams, charts, and data tables.
- Explain conclusions in words.
- Create and interpret graphs.
- Use logical cause-and-effect reasoning.
- Compare and contrast.
- Examine patterns within systems.

Essential questions

- How does the force of gravity on an object change as the object's mass and the distance between it and other objects change?
- How does the Law of Universal Gravitation affect the gravitational force you exert on the earth compared with the gravitational force the earth exerts on you?
- How do gravity and inertia affect the motion of the planets?
- How does gravity affect the motion of a given object based on its mass and distance?

Written Curriculum

Grade Span Expectations

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

PS3 (9-11) POC –9

Apply the concepts of inertia, motion, and momentum to predict and explain situations involving forces and motion, including stationary objects and collisions.

PS3 (9-11)–9 Students demonstrate an understanding of forces and motion by…

9a explaining through words, charts, diagrams, and models the effects of distance and the amount of mass on the gravitational force between objects (e.g. Universal Gravitation Law).

Clarifying the Standards

Prior Learning

Students' understanding of gravity began in grade 2 when they identified that objects fall to earth unless something holds them up. By grade 4, students conducted experiments to demonstrate this concept. In grade 5, earth's gravity was more specifically defined as a force that pulls (without touching) any object on or near the earth toward its center. Students also determined that every object exerts gravitational force on every other object. Also, they identified that the amount of force depends on how much mass the objects have and on how far apart the objects are. They also learned that this force is hard to detect unless at least one of the objects has a lot of mass. By grades 7–8, students were able to understand and describe the relationship between mass and gravitational force among objects as well as the relationship between distance and gravitational force; however, they have no prior knowledge of the universal law of gravitation. In quarter 1 of the current year, students learned to describe forces using Newton's law of motion.

Current Learning

Some previously taught concepts need reviewing and further emphasis in this unit. Since students have no experience using the universal gravitation equation, it will need to be presented at the introductory level. Students may still have misconceptions about the relationship between mass and weight. These common misconceptions need to be further addressed.

Students understand gravity as an action-at-a-distance force that affects all objects with mass; they recognize that the strength of the force is proportional to an object's mass and that force weakens rapidly with increasing distance. These concepts can be tied into Newton's laws from the previous unit. In particular, Newton's third law should be emphasized with respect to gravitational force—specifically, that the gravitational force that object A exerts on object B is equal in magnitude and opposite direction. For example, the gravitational force you exert on the earth is EQUAL to the gravitational force the earth exerts on you. Students should be able to explain and model the relationships among the mass, distance, and gravitational force between objects. They will use the universal gravitational formula to identify directly- and inversely-proportional relationships. Students will identify these relationships as they apply to a number of circumstances, including the structure of the solar system, galaxy, and universe.

Future Learning

Gravity will continue to play an important role in this physics course, especially with regard to potential energy, cyclic processes, and wave applications. The force of gravity with regard to rotational motion, Kepler's laws, friction, and other topics will be further explored in a grade 11–12 physics 1 course. The distinction between force and energy will continue to be emphasized.

Additional Research Findings

See the National Science Digital Library's science literary map (Strand map: The Physical Setting / Gravity 9-12; <http://strandmaps.nsdl.org/?id=SMS-MAP-1372> for the following research on common student misconceptions:

- Student ideas about the shape of the earth are closely related to their ideas about gravity and the direction of *down*. Students cannot accept that gravity is center-directed if they do not know that the earth is spherical—nor can they believe in a spherical earth without some knowledge of gravity to account for why people on the "bottom" do not fall off. Students are likely to say many things that sound right, even though their ideas may be very far off base. For example, they may say that the earth is spherical, but believe that people live on a flat place on top or inside of it—or believe that the round earth is "up there" like other planets, while people live "down here." Research suggests teaching the concepts of spherical earth, space, and gravity in close connection to each other. Some research indicates that, by grade 5, students can understand basic concepts of the earth's shape and gravity if their ideas are directly discussed and corrected in the classroom.
- Elementary school students typically do not understand gravity as a force. They see the phenomenon of a falling body as "natural," or they ascribe an object with an internal effort that makes it fall. If students do view weight as a force, they usually think it is the air that exerts this force. Misconceptions about the causes of gravity persist after traditional high school physics instruction, however these misconceptions can be overcome through specially designed instruction.
- Students of all ages may hold misconceptions about the magnitude of the earth's gravitational force. Even after a physics course, many high school students believe that gravity increases with height above the earth's surface. Many high school students cannot predict whether the force of gravity will be greater on a lead ball or a wooden ball of the same size. High school students also have difficulty conceptualizing gravitational forces as interactions. In particular, they have difficulty understanding that the magnitudes of the gravitational forces exerted by two objects of different mass are equal. These difficulties persist even after specially designed instruction.

Notes About Resources and Materials

Physical Science, Quarter 2, Unit 2.2

Types of Energy

Overview

Number of instructional days: 5 (1 day = 53 minutes)

Content to be learned

- Identify, measure, and analyze qualitative relationships associated with energy.
- Identify, measure, calculate, and analyze quantitative relationships associated with energy.

Processes to be used

- Perform algebraic calculations.
- Manipulate algebraic equations.
- Use logical cause-and-effect reasoning.
- Compare and contrast.
- Analyze patterns and relationships within a system.

Essential questions

- How can the types and amounts of energy in a closed system be identified, measured, and calculated?
- How are the mechanical, kinetic, and potential energy within a system interrelated?

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 (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–5, students learned that the sun is a source of heat and that heat can move among different objects, even at a distance. Heat was understood to move from hot objects to cooler ones. Students also learned that heat can be generated by electrical devices and by rubbing two objects together.

In grades 6–8, students learned that energy can take different forms and that it can be transformed within a system. They also learned that heat and gravity are associated with energy.

Current Learning

Students identify a closed system and define the elements of a system. They learn that mechanical energy is the sum of all the potential and kinetic energy in a closed system. Instruction should reinforce the idea that kinetic energy deals with motion, while potential energy is stored energy by virtue of condition or position. Many forms of energy fall under these two categories, and students should be able to identify the types of energy present. Students also analyze the relationships among different forms of energy in a system. They understand that, although various forms of energy appear very different, each can be measured individually. Students also calculate the amount of kinetic and potential energy in a system. The focus of this unit is identifying types of energy and calculating amounts of energy.

Future Learning

In the next unit, students will delve deeper into energy topics, including energy transformation, transfer, conservation, and work. Energy will continue to play an important role in this course as students learn about electromagnetic waves, the rock cycle, the lifecycle of stars, and electricity. These topics will be further addressed in a grade 11 or 12 physics course.

Additional Research Findings

See the National Science Digital Library's science literary map (Strand map: The Physical Setting / Energy Transformations 9-12; <http://strandmaps.nsdl.org/?id=SMS-MAP-2071> for the following research on common student misconceptions:

Even after some years of physics instruction, students do not distinguish well between heat and temperature when they explain thermal phenomena. The belief that temperature is the measure of heat is particularly resistant to change. Long-term teaching interventions are required for upper middle school students to start differentiating between heat and temperature.

Few middle school and high school students understand the molecular basis of heat conduction even after instruction. For example, students attribute properties such as "hotness" and "coldness" to particles or believe that heat is produced by particles rubbing against each other.

During instruction, upper elementary school students use ideas that give heat an active drive or intent to explain observations of convection currents. They also draw parallels between evaporation, the water cycle, and convection, sometimes explicitly explaining the upward motion of convection currents as evaporation.

Students rarely think energy is measurable and quantifiable. Alternative conceptualizations of energy influence students' interpretations of textbook representations of energy.

Middle school and high school students tend to think that energy transformations involve only one form of energy at a time. Although students may differentiate among forms of energy, they most often describe energy change only in terms of perceivable effects. The transformation of motion to heat seems to be difficult for students to accept, especially in cases with no temperature increase. Finally, it may not be clear to students that some forms of energy, such as light, sound, and chemical energy, can be used to make things happen.

The idea of energy conservation seems counterintuitive to middle and high school students because they often hold on to the everyday use of the term "energy." Teaching heat dissipation and energy conservation simultaneously may help alleviate this difficulty. Even after instruction, however, students do not seem to appreciate that energy conservation is a useful way to explain phenomena.

A key difficulty students have in understanding conservation appears to derive from not considering the appropriate system and environment. In addition, middle school and high school students tend to use their own conceptualizations of energy to interpret energy conservation ideas. For example, some students interpret the idea that "energy is not created or destroyed" to mean that energy is stored up in the system and can be released again in its original form. Students may also say that "energy is not lost" when no energy remains at the end of a process because the process produced a measurable effect (for example, a weight was lifted). Although teaching approaches that accommodate students' difficulties about energy appear to be more successful than traditional science instruction, the main deficiencies outlined above remain.

Notes About Resources and Materials

Physical Science, Quarter 2, Unit 2.3

Energy Transformation and Conservation

Overview

Number of instructional days: 12 (1 day = 53 minutes)

Content to be learned

- Explain how the Law of Conservation of Energy relates to the efficiency of a system.
- Use diagrams to show energy transformations that occur within a system.
- Identify, measure, and calculate how energy transformation reduces the efficiency of a system.

Processes to be used

- Calculate and manipulate algebraic equations.
- Design and implement experimental procedures.
- Analyze data to form conclusions.
- Compare and contrast systems.
- Analyze systems for changes.
- Compare cause-and-effect relationships.

Essential questions

- How is energy transferred within a system?
- How can mathematics be used to show that energy does not always appear to be conserved within a closed system?
- If energy does not appear to be conserved within a closed system, then what happens to the "lost" energy?
- How can you tell if energy has been transformed within a system?
- What is the relationship between the efficiency of a system and energy transformations?

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

5b explaining the Law of Conservation of Energy as it relates to the efficiency (loss of heat) of a system.

Clarifying the Standards

Prior Learning

Students were first introduced to the transfer of energy in grades K–2 when they learned that the sun warms both land and water. In grades 3–4, they described how heat moves from warm objects to cold objects, changing the temperature of both objects until they are the same temperature. In grades 5–6, students identified other energy transformations, including sound as the transfer of energy through various materials (e.g., solids, liquids, gases).

In grades 7–8, students identified energy transformations in a number of different systems. The transfer of potential energy to kinetic energy was shown in real-world examples, and students constructed models to explain the transformation of energy from one form to another (e.g., a circuit changing electrical energy to light energy in a light bulb). Students identified real-world applications where heat energy is transferred and showed the direction in which heat energy travels. They also explained the difference among conduction, convection, and radiation, and created a diagram to explain how heat energy travels in different directions and through different methods. Lastly, students were introduced to the Law of Conservation of Energy and learned that, while energy may be stored, transferred, or transformed, the total amount of energy is conserved.

Current Learning

Students track how much of one form of energy is converted into another. They understand that when the amount of energy in one place diminishes, the amount of energy in other places (or in other forms) increases by the same amount. This concept is taught at the reinforcement level of instruction. Students interpret and determine the efficiency of systems through collecting, recording, and analyzing data related to physical-phase changes. Students should understand that even though the energy of individual components of a system may change, the total amount of energy in the system remains constant.

Students are introduced to experiments and real-world examples dealing with the transfer of potential, kinetic, chemical, and elastic energy. By the end of this unit, students are able to recognize if energy has been transferred; calculate energy transfer using the Law of Conservation of Energy; analyze a system; describe the efficiency within a system; and explain why the system is not 100 percent efficient. Energy transfers produce heat and sound as byproducts. It should also be emphasized that different types of fuel are not different types of energy. For example, coal is not coal energy. Coal is chemical potential energy, just like gasoline, food, or wood.

Students should also be introduced to the work energy theorem, which states that energy is the ability to do work. If work has been done, then energy has been transferred or transformed. Energy is allowed to be transferred due to a force acting within the system, hence work being done.

Future Learning

The next unit will look specifically at energy transfer in earth processes. Energy will continue to play an important role in this course, continuing with the rock cycle, the life cycle of stars, electromagnetic waves, and electricity. These topics will be further addressed in a grade 11 or 12 physics course. The crossed-out portions of this GSE will be addressed in chemistry and biology.

Additional Research Findings

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Notes About Resources and Materials

Physical Science, Quarter 2, Unit 2.4

Energy in Earth Processes

Overview

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

Content to be learned

- Explain the causes of the rock cycle, including heat, pressure, friction, and radioactive decay.
- Explain how energy transfer by convection drives the rock cycle, affect plate movement, and cause seismic activity.
- Explain how the Law of Conservation of Matter relates to the rock cycle.
- Explain how advances in technology have changed our understanding of plate tectonics over time.
- Explain how heat energy fuels geologic processes.
- Explain how the physical processes of the Earth alter the Earth's crust.
- Analyze maps and graphs to identify areas of seismic activity.

Processes to be used

- Analyze energy transfer.
- Describe processes.
- Predict plate movement.
- Analyze geologic maps.
- Discuss historical and technological developments.
- Examine cyclical changes in earth systems.

Essential questions

- In what ways do energy transfer and changes in temperature and density affect the rock cycle?
- How has technology changed and improved understanding of plate tectonics?
- What evidence can be used to predict the kinds of land formations you would expect to find on different types of margins?
- How does heat from the earth's core transferred by convection affect the geologic features of the earth's crust?

Written Curriculum

Grade Span Expectations

ESS1 - The earth and earth materials as we know them today have developed over long periods of time, through continual change processes.

ESS1 (9-11) SAE+ POC–3

Explain how internal and external sources of heat (energy) fuel geologic processes (e.g., rock cycle, plate tectonics, sea floor spreading).

ESS1 (9-11)–3 Students demonstrate an understanding of processes and change over time within earth systems by …

3a explaining how heat (produced by friction, radioactive decay and pressure) affects the Rock Cycle.

3b explaining how convection circulations of the mantle initiate the movement of the crustal plates which then cause plate movement and seismic activity.

3c investigating and using evidence to explain that conservation in the amount of earth materials occurs during the Rock Cycle.

3d explaining how the physical and chemical processes of the Earth alter the crust (e.g. seafloor spreading, hydrologic cycle, weathering, element cycling).

ESS1(9-11)INQ+POC-1

Provided with geologic data (including movement of plates) on a given locale, predict the likelihood for an Earth event (e.g., volcanos, mountain ranges, islands, earthquakes).

ESS1 (9-11)-1 Students demonstrate an understanding of processes and changes over time within Earth systems by…

1a plotting the location of mountain ranges and recent earthquakes and volcanic eruptions to identify any existing patterns

ESS1 (9-11) NOS–2

Trace the development of the theory of plate tectonics or provide supporting geologic/geographic evidence that supports the validity of the theory of plate tectonics.

ESS1 (9-11)–2 Students demonstrate an understanding of processes and change over time within earth systems by …

2a using given data (diagrams, charts, narratives, etc.) and advances in technology to explain how scientific knowledge regarding plate tectonics has changed over time.

Clarifying the Standards

Prior Learning

On earth geology and plate tectonics:

Students began learning about plate tectonics when they were introduced to earth materials. In kindergarten, they sorted, described, and compared different earth materials according to physical properties (size, shape, texture, smell, etc.). They also practiced recording observations and data. In grades 3 and 4, they sorted and ordered materials with more complexity, classifying matter as *alike* or *different* and explaining why.

In fifth grade, students started describing the differences among layers of earth materials. They also started plotting the locations of volcanoes and earthquakes and explaining the relationship between these phenomena and faults. Students began to understand why these events only occur in certain spots.

In grades 7 and 8, students developed an idea that the earth is made of plates and that these plates move. They were able to rationalize and support this with fossil evidence, layers of sedimentary rock, location of mineral deposits, and the shapes of the continents. They also began to understand why these plates move. The earth's interior is hot. This heat triggers movement of earth material, which causes earthquakes and volcanic eruptions and creates mountains and ocean basins.

On Earth Systems:

Students begin to learn about cyclical processes by first understanding ways of describing the current state of the earth. Students begin to record observations and data about weather, geological features and climate. They then realize that some of the features (such as weather,) change.

By the end of fifth grade students learn that water in many forms, and wind can reshape earth's surface by eroding rock and soil. Students also learn that things may change in steady repetitive ways or irregular ways. Additionally, they may sometimes change in more than one way at a time.

By eighth grade students learn that some changes to earth's surface are abrupt while some take place over long amounts of time. They also learn that the earth's surface is shaped by the forces of water and wind over long periods of time which act to level mountain ranges. Additionally, they learn how human's carbon foot print, and environmental impact make lasting changes to the earth's surface. Finally, they understand that the earth's surface is composed of varying land forms such as coastlines, mountains, canyons, etc. Students then can match these different land forms, such as coastlines, to predict previous locations of these landforms on the earth.

Throughout grades K–8, students demonstrated knowledge of change processes that occur over time in a number of earth systems. In grades K–2, students began documenting earth changes by monitoring the local weather patterns from season to season and day to day. This process continued as students learned about weathering, erosion, and climate changes with increasing detail in grades 3–8. Changes in earth systems specific to the current unit were first addressed in grades 5–6, where students represented the process of the rock cycle in words, diagrams, or models. Additionally, they cited evidence and developed logical arguments to explain the formation of different rocks, given their characteristics and location (e.g., classifying rock type using identification resources). In grades 7–8, they also evaluated fast processes
(e.g., erosion, volcanoes, and earthquakes) to determine how the earth has changed and will continue to

change over time. As students' abstract reasoning skills develop in later grades and courses, instruction builds on this foundational knowledge to teach about slow processes of change.

In grade 8 and in the previous unit on energy transformation, students addressed convection and convection currents. Students were introduced to conservation of matter in grades 3–4, when they identified that the whole mass of an object is the sum of the mass of its parts. Knowledge in this area has increased until grade 8, when students learn that the mass before physical and chemical reactions is the same as the mass after the change in a closed system.

Current Learning

Prior student experience with Earth processes pre 9th grade has focused primarily on the effects of weather and coastal erosion. Students will see how prior learning about energy in Units 2.2 and 2.3 will continue to play a part in shaping Earth's crust.

Students will be able to explain the causes of the rock cycle—including heat, pressure, friction, and radioactive decay. Students know that the earth has a molten mantle. They elaborate on how this causes plate movement and subduction, especially with regard to convection and density. The separating of plates creates rifts (i.e., Mid-Atlantic Rift) while the converging of plates involves subduction and creates mountains, volcanic activity, and earthquakes. It should be made clear that the rock cycle is an example of the Law of Conservation of Matter.

Students learn how convection circulation within the mantle causes differences among plate margins (convergent, divergent, transform, subduction zones, and rifts). Students should be able to read a geological map (see the NECAP reference sheet) to predict the type of movement that takes place where two crustal plates meet. They will be able to read a geologic map to identify and predict locations of mountain ranges, earthquakes, volcanic eruptions, and plate movement Students must be able to read and interpret the map as opposed to memorizing it.

The role of energy in shaping geologic processes will also be examined. The role of thermal plumes in crustal movement, seafloor spreading, and subduction zones will be examined. They will be further analyzed in detail in unit 3.4.

Advances in technology are explored to see how scientific understanding of plate tectonics has changed over time. This discussion can include sensor tracking along fault lines, triangulating epicenters, magnetic polar shifts, carbon dating, fossil evidence, sonar technology, etc.

Future Learning

Chemical and nuclear changes will be further developed in chemistry next year. The earth will not be further addressed in this course.

Additional Research Findings

See the National Science Digital Library's science literary map (Strand map: The Physical Setting / Changes in the Earth's Surface 9-12; <http://strandmaps.nsdl.org/?id=SMS-MAP-0048> for the following research on

common student misconceptions:

Students of all ages may hold the view that the world has always been as it is now, or that any changes that have occurred must have been sudden and comprehensive. The students in these studies did not, however, have any formal instruction on the topics investigated. Moreover, middle school students taught by traditional means are not able to construct coherent explanations about the causes of volcanoes and earthquakes.