Physical Science, Quarter 4, Unit 4.1

Atomic Models and Properties

Overview

Number of instructional days: 4 (1 day = 53 minutes)

Content to be learned

- Describe the three subatomic particles in an atom and where are they located.
- Understand the mass and charge values and relationships of the three subatomic particles.

Processes to be used

- Create, interpret, and analyze models and diagrams.
- Interpret models to demonstrate relative sizes and distances of subatomic particles.
- Calculate the mass and charge of given atoms.

Essential questions

- What are the distinguishing characteristics of the current model of the atom?
- How can the mass and charge of a given atom be calculated?
- How are the major particles of an atom different from each other?

Written Curriculum

Grade Span Expectations

PS1 - All living and nonliving things are composed of matter having characteristic properties that distinguish one substance from another (independent of size or amount of substance).

PS1 (9-11) MAS+ FAF – 4

Model and explain the structure of an atom or explain how an atom's electron configuration, particularly the outermost electron(s), determines how that atom can interact with other atoms.

PS1 (9-11)– 4 Students demonstrate an understanding of the structure of matter by …

4a comparing the three subatomic particles of atoms (protons, electrons, neutrons) and their location within an atom, their relative mass, and their charge.

Clarifying the Standards

Prior Learning

Students in grades K–4 focused on being able to describe objects according to similar physical properties. They also learned that things can be done to change those physical properties, but not all materials will respond to the change. Students began to describe properties of solids and liquids. They furthered this investigation by identifying and comparing solids and liquids. Students identified differences between and described properties of solids, liquids, and gases. Students also started to examine the changes in the properties of a material due to heating and cooling. They started to understand that many changes happen more quickly due to hotter conditions. Furthermore, they made logical predictions about the changes in the state of matter when adding or taking away heat (e.g., ice melting, water boiling or freezing, condensation/evaporation).

Students in grades 5–6 learned that objects are made up of parts and that the sum of those parts add up to the same weight as the whole object. They also learned that some parts of the object may be so small that they cannot be seen without the use of a magnification tool. Students learned that when a new object is formed, its properties are different than those properties that made up the original combination of objects. Students also began to recognize that different substances have properties, which allow them to be identified regardless of the size of the sample. They practiced classifying and comparing substances using characteristic properties (e.g., solid, liquid, gas, density, etc.). Students also continued to differentiate among the characteristics of solids, liquids, and gases. They used this knowledge to predict the effects of heating and cooling on the physical state, volume, and mass of a substance.

In seventh and eighth grade, students furthered their understanding of changes in matter by creating diagrams or models that represent the states of matter at the molecular level. Students made the connection between observable changes in matter and what is happening at the molecular level. For instance, they explained the effect of increased and decreased heat energy on the motion and arrangement of molecules. They related the physical processes of evaporation and condensation, or freezing and melting, and described these changes in terms of molecular motion and conservation of mass.

Current Learning

Students' understanding of characteristic properties of substances have grown so much by this stage that they are capable of identifying an unknown substance, given its characteristic properties. Students are also able to classify and compare substances using characteristic properties (e.g., solid, liquid, gas; metal, non-metal).

During this unit of study, the subatomic particles of the proton, neutron, and electron are examined in detail with regard to their position within the atom, mass, charge, and size. This also includes a brief discussion of the key features of the Bohr model.

Students should also be able to calculate the mass and charge of a given atom based on the number of subatomic particles present.

Properties that have been discussed before (i.e., matter, force, energy) are now being applied to atoms. For example, students are introduced to atoms as the building blocks of matter, and the topics of force and energy are now applied to subatomic particles with regard to charge, and later, fields of force. The topics of matter, force, energy, and properties related to atoms have been previously addressed, but not yet applied to atoms or subatomic particles.

Future Learning

In the next two units of this quarter, both static and moving charges will be examined. Students will need to understand the mass, position, charge, and mobility of subatomic particles in order to understand static and moving charges.

The atomic model and subatomic particles will be examined in greater detail in a chemistry course. Students will also learn how these properties play a role in the structure of the periodic table and their importance in chemical reactions and radioactive decay.

In a grade 11 or 12 physics course, students will build upon their understanding of electricity and magnetism to explore energy and force. In physics 2, a grade-12 course, the nuclear reactions within stars will be addressed.

In college, a thorough understanding of atoms and subatomic particles will be essential to success in a modern physics or quantum mechanics course. Basic principles of physics will also be applied to atoms and subatomic particles on a regular basis.

Additional Research Findings

Middle school students may think everything that exists is matter, including heat, light, and electricity. Alternatively, they may believe that matter does not include liquids and gases or that these substances are weightless. With specially designed instruction, some middle school students can learn the scientific notion of matter.

Middle school and high school students are deeply committed to a theory of continuous matter. Although some students may think that substances can be divided up into small particles, they do not recognize the particles as building blocks, but as being formed out of continuous substances under certain conditions.

Students at the beginning of middle school may be at different points in their conceptualization of a theory of matter. Although some third-graders may start seeing weight as a fundamental property of all matter, many students in sixth and seventh grade still appear to think of weight simply as "felt weight." Therefore, substances with weights that can't be perceived through touch are considered to have no weight at all. Accordingly, some students believe that if one keeps dividing a piece of Styrofoam, one would soon obtain a piece that weighed nothing.

Students of all ages show a wide range of beliefs about the nature and behavior of particles. They lack an appreciation of the very small size of particles; attribute macroscopic properties to particles; believe there must be something in the space between particles; have difficulty in appreciating the intrinsic motion of particles in solids, liquids, and gases; and have problems in conceptualizing forces between particles. Despite these difficulties, there is some evidence that carefully designed instruction carried out over a long period of time may help middle school students develop correct ideas about particles.

Students also occasionally have a hard time differentiating between the nucleus of an atom and the nucleus of a cell. This can cause students to incorrectly assume that atoms are living.

Physical Science, Quarter 4, Unit 4.2

Static Charges

Overview

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

Content to be learned

- Understand that electricity and magnetism are interrelated.
- Understand the relationships between like and unlike charges and how they are affected by distance.

Processes to be used

- Analyze and diagram how charges and subatomic particles move between objects.
- Compare and contrast how unlike charges interact with each other.
- Calculate how charge, distance, and field strength are interrelated.
- Interpret, understand, analyze, and create charge model diagrams.

Essential questions

- How is an electrical charge transferred between a piece of fur rubbed on an acrylic rod different from an electrical charge transferred between a piece of silk rubbed on a glass rod?
- What is the relationship among charge, distance, and field strength?
- How do charge, distance, and field strength change relative to each other?
- If two spheres with a net negative charge on each are brought near to each other, how would those charges be distributed over the surface of the spheres?

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) –SAE – 7

Explain relationships between and among electric charges, magnetic fields, electromagnetic forces, and atomic particles.

PS2 (9-11) –7 Students demonstrate an understanding of electromagnetism by…

7a <u>explaining through words, diagrams, models, or electrostatic demonstrations the principle that like charges repel and unlike charges attract.</u>

7b <u>explaining through words, charts, diagrams, and models the effects of distance and the amount of charge on the strength of the electrical force present</u>.

Clarifying the Standards

Prior Learning

In grades K–4, students had limited understanding of electricity and magnetism. Students learned that the way to change how something is moving is by pushing or pulling (forces). They also learned that magnets can move some objects (pushing and pulling). They used this knowledge to predict whether or not something will be attracted to a magnet and they described what happens when like and opposite poles of a magnet are placed near each other.

In grades 5–6, students furthered their investigation into electrical and magnetic forces by understanding that electric currents and magnets can exert a force on each other without touching. They also understood that magnets pull on all things made of iron and either push or pull other magnets.

In grades 7 and 8, students understood that energy can be transferred from place to place and converted from one form to another. They also understood that materials vary in how they respond to electric currents, magnetic forces, and other electromagnetic waves.

Current Learning

The focus of this unit is solely on static charge. The idea that a charge can be moved and transferred between objects via electron movement is analyzed. Students should be able to interpret, understand, analyze, and create charge model diagrams for given objects. Demonstrating the difference between what happens when fur is rubbed on an acrylic rod versus when silk is rubbed on a glass rod is a classic example. Students should also be able to predict and diagram how charged objects will interact when brought near other charged objects.

The relationship among charge, field strength, and distance is also explored through Coulomb’s law. This law is similar to the Law of Universal Gravitation, and can be handled in a similar manner. Students should be able to predict that if a charge is twice as strong, the electromagnetic force will also be twice as strong. Or, if charges are moved twice as far apart, that the field strength will decrease by a power of four.

Students should be reminded that protons themselves do not actually move; it is the movement of electrons that carry charge. Students should also be familiar with how inverse square laws work and how these can be applied to Coulomb's law when calculating electromagnetic field strength.

During this unit, teachers need to use various materials to demonstrate electric charge so students can see and feel the effects of static electric charge. Students should be able to explain and diagram the movement of static electric charge and demonstrate an understanding of electron movement.

Students also use Coulomb's law to describe the relationships among charge, field strength, and distance, similar to our treatment of the Law of Universal Gravitation.

This unit extends students' understanding of the function of subatomic particles with regard to electric fields and charge. Unlike previous learning, in this unit, students examine subatomic particles and their relative positions and charges within the atom and how these subatomic particles are related to static charge in objects.

Future Learning

Students will apply knowledge learned in this unit to the next unit when they learn about moving electrical currents and magnets. Students will learn about how electric charge flows in a circuit and how electromagnets work.

Students will need this information if they take elective physics courses. In these courses, they will take a more quantitative approach to electricity and magnetism, including applying Coulomb's Law, complex circuits, and the causes and effects of electromagnetic fields. This can also be applied to the electromagnetic fields in stars and star formation in future high school physics classes.

Additional Research Findings

According to Eylon and Ganiel, authors of "Macro-micro relationships: The missing link between electrostatics and electrodynamics in students' reasoning," students need to understand that it is the flow or movement of electrons that cause particles to become charged.

Before instruction, many elementary and middle school students are not aware of the bipolarity of batteries and light bulbs, they do not recognize the need for a complete circuit to make a bulb light, and they do not succeed in making a lamp light when given a battery and a number of connecting wires. However, many high school and university students also fail at this task. This suggests that they also do not understand or cannot apply the concept of a complete circuit. Teaching sequences that take account of students' ideas can help middle school students make progress in this area. Students of all ages have difficulty reasoning that all parts of a circuit are interrelated and influence each other. Instead, they think of circuits in terms of electric current traveling around the circuit meeting each component in turn. They think of a change in the circuit affecting only those components that come after the change. This "sequential" reasoning underlies many problems that students have in understanding electric circuits and is highly resistant to change.

Students tend to start instruction with one concept for electricity in electric circuits, which has the properties of movement, storability, and consumability and which students label "current," "energy," or "electricity." Even after instruction, many students of all ages do not differentiate between electric current and electric energy. They also tend to think that the battery is the source of the current and that the circuit is initially empty of the stuff that flows through the wires. Many students after instruction believe that a battery releases the same amount of current regardless of the circuit to which it is attached, and that the fixed current flows out of the battery and diminishes every time it goes through a circuit element that uses up the current so that there is less current at the end of the circuit. These beliefs are highly resistant to change. Identifying energy as the quantity that is dissipated can help students reconcile their intuitive belief that something is used up in circuits with the formal knowledge that electric current is conserved.

Little is known about students' reasoning about the microscopic mechanisms that underlie electric current and their interpretation in terms of electrostatic entities. After instruction, high school students may not be inclined to or, when prompted, may have difficulties relating macroscopic parameters (such as electric current) to microscopic processes and electrostatic interactions (such as forces on charged electrons). Students may think of the battery as the only source of electrons that move in the circuit (i.e., the battery releases electrons into the wires, which play no active role). They may also think of electrons moving through a circuit as single unconnected particles moving around.

Elementary school students are usually aware of the behavior of magnets but may not explain the behavior in terms of forces (i.e., they may think of a magnet sticking to or moving toward another magnet but may not recognize this as the effect of a pull or force). Students of all ages may think of gravity and magnetism interchangeably. They may refer to magnetism as a "type of gravity," but they may also explain gravity in terms of the earth acting like a magnet on objects. Students may think that magnets do not work in a place where there is no air, just like they think about gravity. Students of all ages may also confuse electrostatic and magnetic effects. For example, they may predict that north magnetic poles repel positively charged objects.

Students do not readily recognize the magnetic effect of an electric current. Some think of the wire, rather than the electric current, as being the cause of the magnetic effect. Students may think that insulation around the wire prevents the existence of magnetic forces when current flows.

Eylon, B., Ganiel, U. (1990). *International Journal of Science Education*, vol. 12. (pp. 79–94)

Physical Science, Quarter 4, Unit 4.3

Moving Charges

Overview

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

Content to be learned

- Understand the relationship between moving electric charges and magnetic fields.
- Diagram the energy transformations within a system.

Processes to be used

- Use calculations to represent scientific information.
- Produce and explain scientific diagrams

Essential questions

- How would you visually depict a series circuit with a battery, switch, and light bulb to make a closed circuit?
- What is the relationship between voltage, current, and resistance in a simple series circuit?
- How do moving electric charges create a magnetic field?

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) –SAE – 7

Explain relationships between and among electric charges, magnetic fields, electromagnetic forces, and atomic particles.

PS2 (9-11) –7 Students demonstrate an understanding of electromagnetism by…

7c describing the relationship between moving electric charges and magnetic fields.

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).

Clarifying the Standards

Prior Learning

In third and fourth grade, students started drawing, diagramming, building, and explaining a complete electrical circuit.

In grades 5–6, according to the National Science Benchmarks and Rhode Island GSEs, there is no content addressed specific to moving charges at these grade levels.

In grades 7–8, students furthered their understanding that electrical circuits require a complete loop through which an electric current can pass. Additionally, students described the effect of changing voltage in an electrical circuit.

Current Learning

Moving electric charge in a circuit is explored. The primary focus is on series circuits, but parallel circuits may be introduced at the teacher's discretion. Circuits are diagramed with basic components including batteries, switches, lamps (light bulb), voltmeters, and ammeters. Students also calculate voltage, resistance, and current using Ohm's law. They explore the relationship between moving charges and magnetic fields. One analogy for electricity is water flow through pipes. Voltage is like water coming from a dam—a source of flow for the rest of the circuit. It is also important to point out that more wire in a series circuit innately adds more resistance. The type of wire (i.e., copper vs. gold) can affect the resistance of the circuit. For example, buying a connecting cable with gold tips, but copper wire, will not make a significant difference in electricity transmission.

Students should have basic algebraic skills in order to perform calculations. They should also be able to read, create, and interpret circuit diagrams. Students examine and create circuit diagrams and explore the properties of circuits through laboratory activities. The importance of Ohm's law in daily life is also stressed; for example, how many appliances can be turned on in a room before a fuse is blown.

In the previous unit, Static Charges, Unit 4.2, we looked at static electric charges. Now we are looking at moving electric charges. Students further explore the relationship between moving electric charge and magnetic fields.

Future Learning

This is the last unit of Fundamentals of Physics. This information will be developed in later courses.

In a grade 11 or 12 physics course, circuits will be developed further. Students will look at parallel circuits in detail and the relationship between electric and magnetic fields can also be explored in more depth.

In chemistry, a fundamental understanding of electricity is important for understanding electrolysis and related processes. In anatomy or biology, electricity is important to the understanding of biological processes (i.e., nervous impulses, action potential, defibrillation, etc.).

Additional Research Findings

Misconceptions regarding the current unit and misconceptions about magnetism and electricity in general are addressed in the previous unit (4.2, Static Charges). Material specific to this current unit is below.

Students often think circuits are only affected by "upstream" factors. Therefore, students often mistakenly believe that switches and resistors have to be placed before the object they are designed to affect.

Students believe that current, like energy, is used up in a circuit.

"When asked whether a circuit diagram would 'work' in practice, [students] more often judged symmetrical diagrams to be functional than non-symmetric ones" (*Making Sense of Secondary Science*, p. 124).

Students may have difficulty with spatial abilities (e.g., a circuit rotated 90 degrees may no longer be recognized as the same circuit with the same properties). Students also generally do not have a great deal of background knowledge due to the abstract nature of the subject. Teachers may have difficulty connecting this with real life circuitry. (Shipstone, D. "Electricity in simple circuits." *Children's Ideas in Science.* Driver, R. (Ed.). Columbus, OH: McGraw-Hill. (1985). pp. 33–51.)

It is important to allow students to connect their understanding of moving charges with real life examples. Giving students hands on time with circuits will allow them to apply their understanding and thus reach a deeper level of comprehension. (McDermott, L., Shaffer, P. "Research as a guide for curriculum development: An example from introductory electricity. Part I: Investigation of student understanding." *American Journal of Physics*. (1992). vol. 60, pp. 994–1003.)

Physical Science, Quarter 4, Unit 4.4

Review for Common Course Assessment

Overview

Number of instructional days: 15 (1 day = 53 minutes)

Suggested outline:

- 3 days for 4th quarter common task
- 6 days for common course assessment review
- 5 days to administer, score, return, revise, and rescore the performance CCA
- 1 day to administer objective CCA

Content to be learned

- Complete 4th quarter common task.
- Review for CCA.
- Complete performance portion of CCA.
- Complete objective portion of CCA.

Processes to be used

- Create, interpret, and analyze graphs and diagrams.
- Perform algebraic manipulations of equations.
- Draw conclusions.
- Analyze data.
- Explain historical significance.
- Exhibit reading comprehension.

Essential questions

- What are the relationships among velocity, displacement, and acceleration?
- What are Newton's three laws and how do they relate to inertia and momentum?
- How can energy be transferred and transformed within a closed system?
- What is the rock cycle and how does it relate to plate tectonics and seismic activity?
- What is the basic process of star formation and what are the different stages within a star's life cycle?
- Explain the effects on wavelength and frequency as electromagnetic waves interact with matter (e.g., light diffraction, blue sky).
- What are the masses, charges, and locations of the three major subatomic particles?
- How would a series circuit with a battery, switch, and light bulb be diagrammed to make the bulb light up?

Written Curriculum

Clarifying the Standards

Current Learning

Use this time to perform the fourth quarter common task, prepare for the CCA, administer the performance CCA, and administer the objective CCA. Students will need to use the Common Study Guide in the Resource section to review for the CCA.

Notes About Resources and Materials

There are two versions of the Common Study Guide for CCA. The first is an outline and the second details specific skills students will need to perform well on the CCA.

Common Study Guide for CCA – Outline format

1. Scientific toolkit
    a. Units
    b. Vector vs. scalar
    c. Graphing; independent/dependent variable
    d. Algebraic manipulation
    e. Scientific method
    f. Collect and analyze data
2. Properties of motion
    a. Velocity, displacement, acceleration
3. Forces
    a. Newton's laws
    b. Equilibrium forces
    c. Inertia
4. Momentum
    a. Momentum
    b. Momentum with regard to force, velocity, and time
    c. Collisions: elastic and inelastic
5. Gravity
    a. Universal gravitation
    b. Gravity's role in the formation of stars and the universe
6. Energy
    a. Types of energy (e.g., mechanical, potential, kinetic, thermal, etc.)
    b. Energy transformations
    c. Work

7. Cyclic processes
    a. The rock cycle
    b. Recognizing patterns in seismic activity, plate tectonics
    c. Star formation
    d. Stellar types and H-R diagram
8. Waves
    a. Mechanical and EM Waves
    b. Velocity, wavelength, and frequency (or period) relationships
    c. Energy transfer
    d. Wave behavior
9. Wave applications
    a. Big Bang theory and its evolution
    b. Wave phenomena related to star formation/position/spectra
    c. P and S waves with regard to seismic activity
    d. Doppler shifts
10. Atomic model
    a. Subatomic particles and their mass, charge, and location
11. Static charge
    a. Static charge behavior
    b. Relationship between charges and field forces
    c. Coulomb's law
    d. Magnetism
12. Moving charges
    a. Ohm's law
    b. Relationship between moving charges and field forces
    c. Circuit diagrams

Common Study Guide for CCA – Detailed format

1. Scientific toolkit
    a. Be able to identify the units for all quantities discussed this year.
    b. Be able to identify quantities as vectors or scalars and explain the difference between the two quantities.
    c. Given a data table, students should be able to identify variables, construct a graph with an appropriate scale, plot the data, draw a trend line, derive an equation for the trend line, and both interpret and predict information regarding the data.
    d. Understand what variables represent in given equations and be able to insert data into equations to solve for specific variables.
    e. Be able to state the steps of the scientific method and perform experiments following the scientific method.
    f. When performing an experiment, be able to record data in an organized fashion (tables or graphs) and analyze it for patterns or trends.
2. Properties of motion: Velocity, displacement, acceleration
    a. Be able to explain the difference between distance and displacement.
    b. Calculate an object's velocity given a displacement time graph.

   c. Calculate an object’s velocity given data and equations.
   d. Calculate an object’s acceleration given a velocity time graph.
   e. Calculate an object’s acceleration given data and equations.
3. Forces
   a. Explain the differences between inertia, mass, weight, and force and how this relates to Newton’s first law.
   b. Be able to perform calculations using Newton’s second law.
   c. Explain how motion is possible using Newton’s third law.
   d. Draw and interpret force diagrams.
   e. Explain how balanced forces interact with stationary objects or can cause constant velocity.
4. Momentum
   a. Be able to perform calculations with momentum equations.
   b. Be able to describe how force, velocity, momentum, and time interact.
   c. Explain how momentum and energy are conserved (or not) in both elastic and inelastic collisions.
5. Gravity
   a. Use the law of universal gravitation to explain the relationships among the force of gravity, mass, and distance of two objects.
   b. Explain the role gravity plays in the formation of stars and the universe.
6. Energy
   a. Be able to explain the relationship among mechanical, kinetic, thermal, and potential energy.
   b. Identify and calculate the amount of different types of energy in a closed system.
   c. Identify, explain, and calculate where and why energy is transformed and transferred within a system.
   d. Explain why work is done in a system and how work is related to energy.
7. Cyclic processes
   a. Explain the steps of the rock cycle.
   b. Identify geologic features and areas of geologic activity on a map.
   c. Explain and describe the stages of star formation.
   d. Describe the different types of stars.
   e. Create and interpret H-R diagrams.
8. Waves
   a. Explain the difference between mechanical and EM waves.
   b. Explain and calculate the relationships among velocity, wavelength, and frequency (or period) in a wave.
   c. Explain how energy is transferred via waves.
   d. Explain and describe how waves will behave in specific situations.
9. Wave applications
   a. Explain the theory behind the Big Bang and give evidence supporting it.
   b. Explain how waves are related to star formation/position/spectra.
   c. Describe P and S waves and how are they related to seismic activity.
   d. Explain the Doppler shift and why it is important to astronomy.

10. Atomic model
    a. Describe the three subatomic particles and their mass, charge, and location.
11. Static charge
    a. Explain why and how objects build up static charge.
    b. Use Coulomb's law to explain the relationships among electrical force, charge, and distance.
    c. Draw magnetic field lines around a magnetic object.
    d. Identify how like and unlike poles will interact.
12. Moving charges
    a. Be able to calculate voltage, current, and resistance using Ohm's law.
    b. Explain the relationship between moving charges and field forces.
    c. Create and interpret series circuit diagrams.
    d. Explain how moving charges can be used to create an electromagnet.