Physical Science Support Document

Standard PS-2 The student will demonstrate an understanding of the structure and properties of atoms.

Supporting Content Websites

jlab.org
http://education.jlab.org/atomtour/index.html
Website is a good interactive tour of the atom including protons, neutrons, and electrons and their masses and charges.
P.S.-2.1

jlab.org
http://education.jlab.org/elementmath/index.html
This game chooses an element randomly and asks the student to provide the number of protons, neutrons, or electrons from the information given.
P.S.-2.1 and P.S.-2.4

Colorado.edu
http://www.colorado.edu/physics/2000/isotopes/index.html
Good explanations of both stable and unstable isotopes.
P.S.-2.2

Schoolscience.com
http://www.schoolscience.co.uk/content/4/physics/atoms/partch5pg1.html
Site has good detail using lithium. It includes a question for students to work through.
P.S.-2.2

Chem4kids.com
http://www.chem4kids.com/files/elem_pertable.html
There a good descriptions of the periodic table and trends. The language used is easy for students to understand.
P.S.-2.3

Chemicalelements.com
http://www.chemicalelements.com
This is an interactive periodic table that displays information on elements as students click on them.
P.S.-2.3

jlab.org
http://education.jlab.org/qa/pen_number.html
This is a good demonstration of how to calculate number of protons and electrons for a given element.
P.S.-2.4

Chem4kids.com
http://www.chem4kids.com/files/atom_ions.html
Site describes ions and characteristics associated with them.
P.S.-2.5

Energyquest.Ca.gov
http://www.energyquest.ca.gov/story/chapter13.html
Good description of both fusion and fission.
P.S.-2.6

Radiochemistry.org
http://www.radiochemistry.org/nuclearmedicine/radioisotopes/01_isotopes.shtml
General information on isotopes and medical applications in nuclear medicine.
P.S.-2.7

Suggested Literature

Miller, R. (2005). *The elements: What you really want to know*. N.Y., N.Y.: Lerner Publishing Group.
ISBN # 0-7613-2794-0
Historical account of how scientists studied the elements from the early Greeks to present day. Excellent source of information about each of the naturally occurring transuranium elements
P.S.-2.3

Menuing, T. M. (2004). *Isotopes: Principles and applications*. Hoboken, N.J.: John Wiley & Sons Inc.
ISBN # 0-471-38437-2
This book covers radiogenic, radioactive, and stable isotopes. This volume consists of five units that present fundamentals of atomic physics.
P.S.-2.2

Woodford, C. (2004). *Atoms and molecules*. N.Y., N.Y.: Thomson/Gale.
ISBN #1-41030-295-4
Describes the history of the scientific process by which atoms and molecules were discovered, looks at subsequent research into the structure and behavior of atoms and molecules, and includes information about people who contributed to the field.
P.S.-2.1, P.S.-2.4., and P.S.-2.5

Whiting, J. (2004). *Otto Hahn and the story of nuclear fission*. N.Y., N.Y.: Mitchell Lane Publishers.
ISBN # 1-58415-2044
Profiles German chemist Otto Hahn, whose research into radioactivity led to the discovery of nuclear fission and, despite his opposition, to the development of the atomic bomb.
P.S.-2.6 and P.S.-2.7

Cobb, C. (2002). *Magick, mayhem, and mavericks*. N.Y., N.Y.: Prometheus Books.
ISBN # 1-57392-976-X
This book depicts the story of the eccentrics who made groundbreaking discoveries in chemistry and physics. This book depicts how one idea is built upon another.
P.S.-2.1

Newton, D. (1994). *The chemical elements*. N.Y., N.Y.: Instructional Horizons.
ISBN # 0-531-12501-7
This volume gives broad general introductions to the chemical elements and the periodic table. The author of this book assumes no prior knowledge in chemistry.
P.S.-2.1, P.S.-2.3, P.S.-2.4, and P.S.-2.5

Stwertka, A. (2002). *A guide to the elements*. N.Y., N.Y.: Oxford University Press Inc.
ISBN # 0-19-515027-9
The history and properties of the elements are discussed as well as practical uses.
P.S.-2.1, P.S.-2.4, and P.S.-2.5

Mackintosh, R.& Khalili, A. & Johnson, B. & Pena, T. (2001). *Nucleus: A trip into the heart of matter*. Baltimore, M.D.: John Hopkins University Press.
ISBN # 0-8018-6860-2
This book depicts the history of the nucleus from discovery to the nuclear devices and nuclear medicine applications today.
P.S.-2..1, P.S.-2.6, and P.S.-2.7

Gallant, R. (2000). *The ever changing atom*. N.Y., N.Y.: Benchmark Books.
ISBN # 0-7614-0961-0
Matter to atoms to quarks all described in simple terms in this book. Additionally, this books covers isotopes, the splitting of the atom, and nuclear waste.
P.S.-2.1, P.S.-2.2, P.S.-2.4, P.S.-2.5, P.S.-2.6. and P.S.-2.7

Rigden, J. S. (2002). *Hydrogen: The essential element*. Cambridge, M.A.: Harvard College Press.
ISBN # 0-674-00738-7
This is the biography of Hydrogen. The book begins with the “Big Bang” and ends with questions of what we have left to discover about this element.
P.S.-2.1 and P.S.-2.6

Suggested StreamlineVideo Resources

Energy and the Chemistry of Life
Atoms and Elements
ETV Streamline SC
This clip goes into the structure of the atom and the subatomic particles
Atoms and Elements 3:33
P.S.-2.1

Elements of Physics: Matter: Atoms and Molecules
The Elements
ETV Streamline SC
This video describes protons, electrons, and neutrons. Atomic number and atomic mass are also covered.
The Elements 4:53
P.S.-2.1 and P.S.-2.4

Elements of Physics: Matter: Atoms and Molecules
The Periodic Table
ETV Streamline SC
This clip describes the trends in the periodic table.
The Periodic Table 2:49
P.S.-2.3

Elements of Physics: Energy: Work and Power
Nuclear Energy
ETV Streamline SC
This clip discusses fission and fusion and nuclear energy.
Nuclear Energy 1:10
P.S.-2.6

Elements of Chemistry: Atoms: The Building Blocks of Matter
The Structure of Atoms
ETV Streamline SC
This video discusses the structure of atoms along with a little history. Protons, electrons, and neutrons are covered.
The Structure of Atoms 2:20
P.S.-2.1

Elements of Chemistry: Atoms: The Building Blocks of Matter
Elements and Isotopes
ETV Streamline SC
This clip discusses atomic numbers and protons as well as differing neutrons and isotopes.
Elements and Isotopes 3:58
P.S.-2.2 and P.S.-2.4

Elements of Chemistry: Atoms: The Building Blocks of Matter
Ions
ETV Streamline SC
This video describes both negative and positive ions and the properties of each. This clip has excellent graphics.
Ions 1:48
P.S.-2.5

Physical Science: Nuclear Energy
The Curies and Nuclear Medicine
ETV Streamline SC
This clip depicts the history of the discovery of radioactive molecules and then delves into its uses in medicine.
The Curies and Nuclear Medicine 2:56
P.S.-2.7

Physical Science: Nuclear Energy
Nuclear Submarines
ETV Streamline SC
This clip discusses fission and how the U.S. powers a submarine with nuclear power.
Nuclear Submarines 3:04
P.S.-2.7

Simply Science: Periodic Table
Using the Modern Periodic Table
ETV Streamline SC
This clip has good descriptions of how to read a periodic table. Trends due to valence electrons are also discussed.
Using the Modern Periodic Table 6:24
P.S.-2.3 and P.S.-2.5

Career Connections

Chemical Engineer
Chemical engineers design chemical plant equipment and devise processes for manufacturing chemicals and products such as gasoline, synthetic rubber, plastics, cement, paper, and pulp. (P.S.-2.3 and P.S.-2.5)

Chemist
Chemists involved in research and development investigate the composition, structure and properties of substances, and the transformation these substances undergo. Chemists play an important role is such diverse areas as medicine, the environment, agriculture, and industry. (P.S.-2.3 and P.S.-2.5)

Nuclear Engineer
Nuclear engineers participate in broad areas of analysis, design, management, and research using nuclear energy for power plants, transportation, space exploration, diagnostic health, and environmental control of pollution. Some specialize in the development of nuclear weapons; others develop industrial and medical uses for radioactive materials. (P.S.2.6 and P.S.-2.7)

Nuclear Medical Technologist
Nuclear medical technologists are paramedical specialists who are concerned with the use of radioactive material for diagnostic and therapeutic purposes. They use radioactive material to perform body function studies and organ imaging to analyze biological specimens and to treat disease. Nuclear medical technologists are usually supervised by a Nuclear Medical Physician. (P.S.-2.7)

Radiation Therapist
Radiation therapists operate specialized radioactive equipment in order to treat diseases such as cancer. They not only help to administer the radiation to the patient, but also monitor and record the radiation’s effect on the patient. (P.S.-2.7)

PS-2.1 Compare the subatomic particles (protons, neutrons, electrons) of an atom with regard to mass, location, and charge, and explain how these particles affect the properties of an atom (including identity, mass, volume, and reactivity).

Taxonomy Level: 2.6-B Understand/Compare Conceptual Knowledge
2.7-B Understand/Explain Conceptual Knowledge

Key Concepts

Sub-atomic particles: proton, neutron, electron
Energy level: electron cloud
Nucleus

Previous/future knowledge: In 7th grade, students recognize that matter is composed of tiny "particles called atoms" (7-5.1). Students have no prior knowledge about the structure of the atom.

In Physical Science, students identify and compare the *sub*atomic particles that compose atoms and develop a fundamental concept of the role that these three particles have in determining the properties of the atoms that they compose. The concepts addressed in this indicator are the foundation for the Atomic Theory, the idea that the physical and chemical properties of substances are functions of the particles of which they are composed, and are therefore prerequisite for PS-3 (properties of matter), PS-4 (chemical reactivity) and all subsequent study of chemistry.

This is an introduction so it is essential to emphasize a concrete, descriptive approach.

It is essential for students to compare subatomic particles by:

- Particle type:
  - Know that the atom is composed of *subatomic particles* (*protons, neutrons*, and *electrons*) that affect the properties of an atom.
- Particle mass:
  - Understand that protons and neutrons have about the same mass.
  - Understand that the mass of an electron is much less than the mass of protons and neutrons (It is not necessary for students to know the exact mass of the particles)
- Particle charge:
  - Understand that protons have a positive charge; know that neutrons have no charge.
  - Understand that the net charge of the nucleus is positive and equal to the number of protons.
  - Understand that electrons have a negative charge.
  - Understand that there is an attractive force between electrons and protons
  - Understand that there is a repulsive force between electrons and electrons, and between protons and protons.
  - Understand that atoms are neutrally charged because the number of electrons is the same as the number of protons.
- Particle location:
  - Understand that protons and neutrons are tightly bound in a tiny *nucleus*.

- Understand that the nucleus is located in the center of an electron cloud.
- Understand that the *electron cloud* is the space where electrons are moving erratically in areas of space called energy levels.
- Understand that *energy levels* are regions of space at increasing distances from the nucleus.
- Electrons with more energy occupy energy levels further from the nucleus.
  - There are a maximum number of electrons that can occupy each energy level and that number increases the further the energy level is from the nucleus.

It is not essential for students to:

- Know the exact number of electrons that can occupy each energy level.
- Know that the main energy level occupied by an electron is a description of the principal quantum number.
- Understand the nature of the other quantum numbers (angular momentum quantum number, magnetic quantum number, or spin quantum number).
- Understand the forces holding the nucleus together.

It is essential that students understand the role that subatomic particles have in determining the properties of atoms:

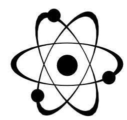
- Identity of the Atom:
  - Understand that the number of protons determines the identity of an atom (an element).
  - Understand that while atoms of the same element have the same number of protons, the number of neutrons may vary (PS-2.2)
  - Understand that an atom of a given element may lose or gain electrons yet it still remains the same element.
- Mass of the Atom:
  - Understand that only the total number of protons and neutrons within its nucleus determines the mass of the atom, because the mass of the atom's electrons is insignificant by comparison.
- Reactivity of the Atom:
  - The particles in the nucleus of the atom do not change in a chemical reaction.
  - Chemical reactions occur in the electron cloud.
  - The number of electrons in the outer energy level of the atom and the relative distance from the nucleus of these outer-energy level electrons determine how the atom will react chemically.
- Volume of the Atom:
  - The volume of the electron cloud determines the volume of the atom, as the volume of the nucleus of a typical atom is extremely small when compared to the volume of the entire atom.

It is not essential for students to

- Understand the contributions of shielding effect and nuclear attraction to atomic radius.

Misconception: (Teacher note)

Most students have the misconception that an atom is like the diagrams in their textbooks: a nucleus roughly half the size of the atom, electrons orbiting in perfect circles. Students need to understand that this is a convenient way to represent the parts an atom, but not a dimensionally accurate representation. A drawing such as the one below also gives students the incorrect impression that electrons orbit the nucleus in regular, circular paths.

X 

It is important that students can visualize the nucleus of an atom as a tiny speck in the center of an atom and the electron cloud as an area outside the nucleus where electrons are moving erratically like bees around a beehive. The electrons with more energy can move further from the nucleus, those with less energy stay closer. The space where the electrons are moving makes up the vast majority of the volume of the atom.
In order to visualize the perspective, if the nucleus of an atom is represented by a speck the size of the period at the end of this sentence, the first electrons would be located in a region at a distance away from the speck equal to the length of a football field.

Assessment Guidelines

The first objective of this portion of the indicator is to ***compare*** the three primary subatomic particles with regard to mass, charge and location; therefore the primary focus of assessment should be for students to detect correspondences between and among these particles with regard to these three properties. It is important that assessments go beyond recall of factual knowledge, as conceptual knowledge is an understanding of the interrelationships. Assessments should insure that students understand the relevance of the factual information to an overall conceptual model of an atom. For instance, with regard to charge, students should *identify* the charge of each particle, but by combining that knowledge with knowledge of particle location, students should have a concept of the nucleus as positive and the electron cloud as negative. With regard to particle location, while it is essential that students *recognize* that protons and neutrons are located in the nucleus and electrons in the electron cloud, conceptual understanding requires that students combine that *recall* with knowledge of particle mass and electron energy levels to understand the nucleus as a densely packed core, and the electron cloud as an area of vast space by comparison.
In addition to comparing, students should be able to

- *Illustrate* with drawings or diagrams that depict the charge, location, and mass of the three particles,
- *Classify* the three particles based on the characteristics of mass, location, and charge
- *Summarize* the characteristics of the subatomic particles.

The 2nd objective of this portion of the indicator is to *explain* the role that the three primary subatomic particles have in determining the mass of the atom, the volume of the atom, the identity of the atom and how the atom is likely to react chemically. As the verb "explain" means "to construct a cause-and-effect model of a system", the primary focus of assessment should be for students to indicate an understanding of the role that each sub-atomic particle plays in shaping the properties and characteristics of atoms. Assessments should insure that students understand the relevance of the factual information to an overall conceptual model of an atom. For instance, assessments should not only ask which particle determines the identity of the element, (factual knowledge) but in addition, assessment should test the student's understanding of why the identity of an atom does not change during a chemical reaction (cause-and-effect model of the interrelationships among basic elements).

In addition to explain, students should be able to:

- *Infer* - draw a logical conclusion about how each characteristic (identity, mass, volume, and or reactivity of an atom) would be affected if the number of particles changed;
- *Summarize* the significance of each subatomic particle in determining the atom's characteristics; or
- *Recognize* the role that each particle has in the characteristics of an atom.

PS-2.2 Illustrate the fact that the atoms of elements exist as stable or unstable isotopes.

Taxonomy Level: 2.2-B Understand/Exemplify Conceptual Knowledge

Key Concepts:

isotope	nuclear reaction
atomic number	nuclear decay
mass number	radiation
atomic mass	

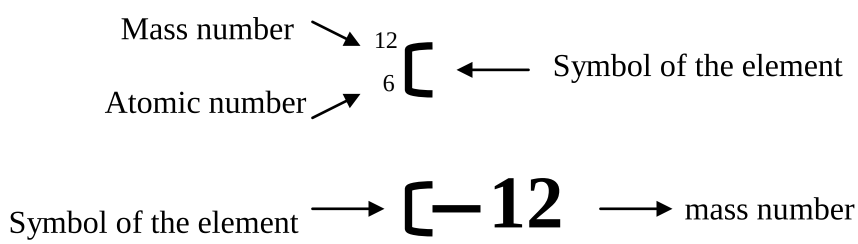
Previous/future knowledge: In 7th grade, students recognize that matter is composed of tiny "particles called atoms" (7-5.1). Students have no prior learning about isotopes or atoms being stable or unstable.
In Physical Science PS-2.1, students identify and compare the *sub*atomic particles that compose atoms and develop a fundamental concept of the role that these three particles have in determining the properties of the atoms that they compose. This indicator (PS-2.2) expands on how the number of neutrons affects the properties of an atom. Students are introduced to the concept of isotopes and to the idea that those isotopes can be stable or unstable. The concept of isotopes as stable or unstable is the basis for an understanding of nuclear reactions. Indicators PS-2.6 and PS-2.7 expand on nuclear reactions. Subsequent chemistry courses will further explore nuclear processes and reactions.

It is essential for students to understand:

- Atomic Number:
  - The *atomic number* of an element is equal to the number of protons. The atomic number is always the same for a given element.
  - The atomic number of an element can be found on the periodic table. Since it is the same for all atoms of that element, it is always a whole number.
- Mass Number:
  - Atoms of the same element may have different numbers of neutrons.
  - The *mass number* of a particular atom is the sum of that atom's protons and neutrons.
  - The mass number cannot be found on the periodic table. (The mass number is not the same as atomic mass and **cannot** be found by rounding off atomic mass.)
- Atomic Mass:
  - The *Atomic mass* of an element as seen is the weighted average of the masses of the naturally occurring isotopes of an element.
  - The atomic mass of an element can be found on the periodic table. Since it is an average, it is usually not a whole number.
- Isotopes:
  - Atoms of the same element with different numbers of neutrons will have different mass numbers.

- *Isotopes* are defined as two or more atoms of the same element having the same number of protons but different numbers of neutrons (and therefore different masses)
- Students must be able to ***illustrate*** isotopes (or recognize illustrations of isotopes) with diagrams, symbols, or with words; in each case, the illustration must indicate that isotopes are atoms with the same number of protons, but different numbers of neutrons.

The following are two widely accepted examples of symbols used to illustrate one isotope of carbon:



    - It is important that students are familiar enough with the meaning of each of these symbols that they can recognize each, not by position but by logic. (See PS-2.3)

- Unstable isotopes:
    - In order for a nucleus to be stable, there must be enough neutrons present to block the repulsive forces among the protons.
    - An unstable isotope of an element is radioactive.
    - Due to the unstable condition of the nucleus, radioactive isotopes undergo nuclear decay.
        - *Nuclear decay* is a nuclear reaction that involves emission of energy or particles from the nucleus, resulting in a more stable nuclear environment.
        - *Radiation* is the term used to describe the particles and/or energy that are emitted during nuclear decay. (Alpha, and beta particles, and gamma rays)
        - Nuclear decay occurs naturally in many elements that are common on earth and there is always some radiation present in every environment. (See indicator PS-2.7 for the effects of nuclear radiation.)
- Students must be able to use a periodic table to apply this concept to all elements. The periodic table that students will use on the end-of-course test should be downloaded from the following website (see PS-2.3):

http://ed.sc.gov/agency/offices/assessment/Programs/endofcourse/periodtable022304.pdf

Misconception: (Teacher note)
Students often confuse the mass number of a given isotope with the atomic mass of the element. It is important to emphasize that the mass number of a specific isotope of an element must be given to the student in order to calculate the number of neutrons. Students often have the misconception that the mass number of a given isotope of an element can be determined by rounding the atomic mass of the element (found on the periodic table).

It is not essential that students

- Memorize the mass number, atomic number or symbol of any element.
- Understand the reasons that some isotopes are unstable.
- Understand the types of nuclear radiation (alpha, beta, or gamma).
- Balance nuclear equations

- Understand half-life.
- Compare the strong nuclear force and electrostatic force.
- Determine whether a specific isotope is stable or unstable.

Assessment Guidelines

The objective of this indicator is to ***illustrate*** that atoms exist as isotopes; therefore the primary focus of assessment should be for students to give illustrations of these concepts or use illustrations to show understanding of isotopes. Illustrations may be in the form of verbal descriptions, diagrams or symbols but in each case, the illustration must indicate that isotopes are atoms with the same number of protons, but different numbers of neutrons. Because this is conceptual knowledge, assessments should test the student's ability to apply this concept to any element, not be restricted to memorized examples. Students should know that some isotopes are "unstable", but also should have an understanding of nuclear decay as a result of an unstable isotope, and understand that radiation is a result of nuclear decay.

In addition to illustrate, students should be able to:

- *Interpret* (change from one form of representation to another), for instance, read a written description of an isotope and produce an illustration in the form of a symbol or a diagram;
- *Compare* stable and unstable isotopes; or
- *Recognize* isotopes of the same element.

PS-2.3 Explain the trends of the periodic table based on the elements' valence electrons and atomic numbers.

Taxonomy Level: 2.7-B Understand/Explain Conceptual Knowledge

Key Concepts:

period	nonmetal
group or family	valence electron
metal	atomic mass

As periodic tables vary greatly both in format and in the information which they provide, it is very important that students are comfortable using the periodic table that will be available on the End-of-Course Test. Each student should receive a copy of this periodic table at the beginning of the physical science course and be encouraged to use it for all homework, class-work, and assessments. The periodic table can be downloaded from the following website:
http://ed.sc.gov/agency/offices/assessment/Programs/endofcourse/periodtable022304.pdf

Previous/future knowledge: Students were introduced to the basic organization of elements on the periodic table in the 7th grade (7-5.4). The concepts addressed in this Physical Science indicator will develop an understanding of how the periodic table can be used to discern an element's atomic structure as well as an understanding of how an element's position on the periodic table can be used to predict how it will bond, its chemical reactivity, and its chemical properties. (PS-2.5 and PS-4.1 through PS4.10). Students should understand the reasons for the trends and therefore use logic to describe them. The periodic table is a valuable tool used by chemistry students from high school through college. With each subsequent chemistry course, students will learn more information that can be determined by the element's position on the periodic table.

It is essential for student to:

- Understand the parts of the periodic table in order to understand trends
    - Know that *Period* is the term used to describe a horizontal row on the periodic table.
    - Know that *Group* and family are terms used to describe a vertical column on the periodic table.
    - Locate major categories of elements such as the *metals*, *metalloids*, and *nonmetals* (metals and nonmetals were introduced in 7th grade).
        - Metalloids should be identified as elements that have some characteristics of metals and some of nonmetals; they border the line between metals and nonmetals on the periodic table.
    - Locate referenced elements when prompted with a period number or group number.
    - Determine a given element's atomic number (number of protons).
    - Determine the number of electrons that an atom of a given element contains (the same as the number of protons-atomic number).

- Determine how many energy levels are occupied in a given element by recognizing that the period in which an element appears on the periodic table indicates the number of occupied energy levels.
    - For example, all elements in period 4 have four occupied energy levels.
    - This is an introduction to quantum theory that will be studied in chemistry.
- Recognize a given element's atomic mass (the weighted average of the masses of the naturally occurring isotopes of the element), by recognizing that the atomic mass of an element is a decimal number. It is always larger than the atomic number and generally increases erratically for each successive element
- Determine the number of *valence electrons* (electrons in the outer-most energy level), for selected groups of elements when given the element's group number or name.
    - Elements in groups 1-2, 13-18

Group or Family	**Name**	**# valence electrons**
1	Alkali metals	1
2	Alkaline Earth Metals	2
13		3
14		4
15		5
16	Oxygen group	6
17	Halogens	7
18	Nobel Gasses	8 (except He)

It is essential that students

- Understand some of the trends in the properties of the elements that the periodic table displays.
    - Periodic trends in the number of valence electrons:
        - From left to right ***across periods 1-3:*** (Not from left to right across periods 4-7 as a deeper understanding of quantum theory is prerequisite for understanding these trends.
            - Atoms of all these elements contain one more valence electron than the atoms of the previous element.
        - From top to bottom within any group:
            - Atoms of all of the elements in a given group contain the same number of valence electrons.
- Periodic trends in the number of energy levels:
    - From left to right across any period:
        - Atoms of all elements in a given period have the same number of energy levels.
    - From top to bottom within any group
        - Atoms of each subsequent element (from top to bottom) in any given group contain one more energy level than the atoms of the element above.

- Use knowledge of those trends to predict properties of elements relative to each other. (not specific values, but given two elements, determine which element will have the higher value for each of the trends listed above.)

It is not essential that students:

- Recall the history of the periodic table although the history of the periodic table highlights its purpose and therefore would serve as a definite aide in helping students comprehend the value and relevance of this concept.
- Understand the carbon-12 standard for atomic mass.
- Calculate a weighted average.
- Determine the number of valence electrons for the Transition Elements, elements in groups 3-12 (including the Lanthanide Series and the Actinide Series) as the transition elements have various numbers of valence electrons depending upon the stability of their "d" and "f" orbitals. .
- Understand reasons that there are exceptions to trends or be able to cite exceptions to trends. (Students should realize, however, that there are exceptions to some of the trends.)
- Understand periodic trends for atomic radius within a period, or other trends such as electronegativity, electron affinity, ionization energy, ionic radius or shielding effect.

Assessment Guidelines:

Most of the basic periodic table information, the basic elements that students must know to be acquainted with the periodic table, is prerequisite knowledge for the indicator. Assessment of this part of the indicator should focus on showing that students can recognize or recall this information.

The objective of this indicator is to explain trends in atomic structure that are revealed by the periodic table. As explain means to "construct a cause-and-effect model of a system", the primary focus of assessment should be for students to show that if an element is found at a particular location on the periodic table, then certain characteristics of that element's atomic structure can be described relative to the other elements on the table. The cause-and-effect for this indicator only refers to knowing that an element has a certain position on the table because of its atomic structure. The reasons for the trends are beyond the scope of this course. Because this is conceptual knowledge, assessments should test the students' ability to apply this concept to any element or set of elements (other than those noted in the instructional guidelines as not essential). Assessment should not be restricted to memorized examples.

In addition to explain, students should be able to

- *Exemplify* a trend (find a specific example of a trend);
- *Infer* some aspects of atomic structure of an element based on its position on the periodic table (draw a logical conclusion from presented information); or
- *Compare* some aspects of atomic structure of two or more elements based on their relative positions on the periodic table (detect correspondences between two elements)

PS-2.4 Use the atomic number and the mass number to calculate the number of protons, neutrons, and/or electrons for a given isotope of an element.

Taxonomy Level: 3.2-C Understand/Use Procedural Knowledge

Previous/future knowledge: Students have not been introduced to this concept prior to Physical Science. Indicators PS-2.1, PS-2.2 and PS-2.3 are prerequisite for this indicator. Students must have a firm grasp of atomic number, mass number and how each of the three subatomic particles contributes to these values. It is also essential that students can interpret the mass number and the atomic number from the symbol for an isotope of an element. When given the symbol of an element, students must be able to determine the element's number of protons and electrons from the periodic table (PS-2.3).

It is essential that students:

- Use the equation: mass number = number of protons + number of neutrons and a periodic table to perform the following calculations:
  - When given the symbol for an isotope of an element (which includes the element's symbol and the mass number of the isotope), determine the number of protons, neutrons, and electrons
    1. Determine the number of protons and the number of electrons from the periodic table
    2. Calculate the number of neutrons from the equation
  - When given the mass number and the number of neutrons for a particular isotope of an unknown element, write the symbol for the isotope
    1. Use the above equation to calculate the number of protons.
    2. Use the number of protons to determine the number of electrons, and the identity of the element
    3. Write the symbol for the isotope

$^{27}_{13}Al$ or Al-27 $^{238}_{92}U$ or U-238

Teacher note: The mass number cannot be determined by rounding off the atomic mass

Assessment Guidelines

The objective of this indicator is to ***use*** the correct procedure to mathematically determine the number of protons, neutrons, and/or electrons in an isotope of an element when given the mass number and the atomic number of the isotope. Use or implement means to apply a procedure to an unfamiliar task, therefore, students should be able to apply this procedure for any given element. In addition, students should be able to determine the identity of the element, the mass number, the atomic number, and the number of electrons when given the number of protons, and neutrons.

PS-2.5 Predict the charge that a representative element will acquire according to the arrangement of electrons in its outer energy level.

Taxonomy Level: 2.5-B Understand/Predict Conceptual Knowledge

Key Concepts: ion

Previous/future knowledge: Students have not studied subatomic particles prior to Physical Science, so this is the first experience students will have with the idea that the number of outer-level electrons determines the stability of an atom, and that atoms tend to gain, lose, or share electrons in order to stabilize the outer-level electron arrangement. Fundamental knowledge of how atoms achieve outer-level electron stability is essential for all of the study of chemistry. As this is an introduction to the concept of ionization, emphasis should be placed on those groups of elements that are likely to gain or lose 1 or 2 electrons, and on the Noble Gasses.

It is essential for students to

- Understand that a stable atom contains 8 valence electrons (or 2 for helium). Atoms that do not contain 8 valence electrons in the neutral state (when the number of electrons equals the number of protons) tend to gain, lose or share valence electrons in order to achieve stability.
- Understand that only electrons are involved in chemical reactions.
  - In chemical reactions, the number of protons and the number of neutrons remain constant.
- Determine (by using a periodic table) the number of protons and the number of electrons a neutral atom of a given element contains. (PS-2.3)
- Predict how many electrons an atom of a given element will gain or lose in order to most readily gain stability based on the following generalizations:
  - The elements in groups 1 and 2 tend to lose 1 and 2 electrons respectively.
  - The elements in group 18 are stable and do not readily gain nor lose electrons.
  - The elements in groups 16 and 17 tend to gain 2 and 1 electron respectively.
  - The elements in groups 13-15 are less likely than those listed above to either gain or lose electrons because they have 3, 4, and 5 valence electrons respectively. Students are **not** responsible for predicting the charges of elements from groups 13-15
  - Most of the transition elements (groups 3-12) tend to lose electrons.
- Reconcile the number of protons and electrons in the resulting stable *ion* and determine the excess positive or negative charge.
- Refine their definition of metals as elements that tend to lose electrons and non-metals as elements that tend to gain electrons. (Students distinguished metals from nonmetals by their position on the periodic table and their observable properties in 7th grade and in PS-2.3)
  - Students should be aware that some of the chemical properties of metals and nonmetals are due to their propensity to lose or gain electrons.

It is not essential that students

- Understand reasons that there are exceptions to ionization trends or be able to cite exceptions to trends. (Students should, however, realize that there are exceptions.)
- Understand how the size of some elements influences whether they gain or lose electrons. (Metalloids)

Assessment Guidelines

The objective of this indicator is for students to *predict* the charge that a representative element will acquire (draw a logical conclusion) based on the number of electrons the element has in its outer-most energy level (from presented information). As this is conceptual knowledge of relationships, the primary focus of assessment should be to show that students can use knowledge of chemical stability and the relationship between an element's position on the periodic table and outers-shell electron arrangement to predict whether an atom will gain or lose electrons, and how many electrons will be involved. In addition, students should have an understanding that many atomic properties are a result of an atoms tendency to gain or lose electrons. As this is conceptual knowledge, assessments should test the students' ability to infer the charge for any element or set of elements (elements not mentioned in the instructional guidelines as not essential).

In addition to predict, students should be able to:

- *Exemplify* elements with like charges;
- *Interpret* diagrams that depict outer-shell electron arrangement; or
- *Compare* charges within and between families of representative elements.

PS-2.6 Compare fission and fusion (including the basic processes and the fact that both fission and fusion convert a fraction of the mass of interacting particles into energy and release a great amount of energy).

Taxonomy Level: 2.6-B Understand/Compare Conceptual Knowledge

Key Concepts:
Nuclear fission: chain reaction, critical mass
Nuclear fusion

Previous/future knowledge: Students have not been introduced to fission and fusion prior to Physical Science. Students were introduced to nuclear decay in indicator PS-2.2. Fission and fusion are two very different nuclear reactions. Students often confuse chemical reactions with nuclear reactions. It is therefore essential that students understand the processes of nuclear reactions to the extent that they can differentiate them from chemical reactions, and also to understand the roles that nuclear processes have in global affairs (PS-2.7).

It is essential for students to

- Understand that nuclear reactions involve the particles in the nucleus of the atom (as opposed to chemical reactions, which involve the electrons in an atom and where the nucleus remains intact).
- Understand that there is a great deal more energy change involved in nuclear reactions than in chemical reactions.
- Understand the processes of *nuclear fission*
    - *Nuclear fission* occurs when a heavy nucleus, such as the U-235 nucleus, splits into two or more parts, a large amount of energy is released.
        - The penetration of a large nucleus (such as U-235) by a neutron is one way to initiate a fission reaction.
        - When an atom with a large nucleus undergoes fission, atoms that have smaller nuclei result. In the process smaller particles such as neutrons may be ejected from the splitting nucleus.
        - If one or more ejected neutron strikes another U-235 nucleus, another fission reaction may occur. The continuation of this process is called a *chain reaction*. There must be a certain critical mass of fissionable material in close proximity for a chain reaction to occur.
    - Understand that fission is the type of nuclear reaction that occurs in nuclear power plants, and other nuclear applications (weapons, submarines, etc.)
    - Understand that the mass of the products of a fission reaction is less than the mass of the reactants.
        - This lost mass (m) is converted into energy (E). The equation $E = mc^2$ shows the relationship of this "lost mass" to the energy released. The conversion of mass to energy during a nuclear reaction involves far more energy than the amount of energy involved in a chemical reaction. (It is **not** essential for students to use this equation.)
- Understand the processes of *nuclear fusion*

- *Nuclear fusion* occurs when light nuclei (such as hydrogen) fuse, or combine, to form a larger single nucleus (such as helium).
- As in fission reactions, in fusion reactions the mass of the products is less than the mass of the reactants and the "lost mass" is converted to energy.
- Fusion is the type of nuclear reaction that occurs on the sun (and other stars)
- Forcing small nuclei to fuse requires huge amounts of energy; however, when fusion reactions occur on the sun, more energy is released than the amount of energy required to produce the reaction.
- Using fusion for human applications is still in the developmental stage.

It is not essential that students

- Understand binding energy, or the dual nature of matter and energy.
- Use the equation $E = mc^2$ or explain the equation in any depth. Students are generally familiar with the equation so mentioning it brings relevance to the concept.
- Write or balance nuclear equations for fission or fusion.

Assessment Guidelines

The objective of this indicator is to *compare* (detect correspondences between two) fission and fusion. The major focus of the assessment should be for students to identify the similarities and differences in fission and fusion, the consequences, and the applications of the two processes.

In addition to compare, students should be able to:

- *Exemplify* (find a specific example of a trend) relevant examples of each process;
- *Classify* (determine that something belongs to a category) a process as either fission or fusion given a description of the steps;
- *Summarize* (abstract a general theme or major points) the steps in each process;
- *Illustrate* the process in a diagram format; or
- *Recognize* each process from an equation or diagram.

PS-2.7 Explain the consequences that the use of nuclear applications (including medical technologies, nuclear power plants, and nuclear weapons) can have.

Technology Level: 2.7-B Understand/Explain Conceptual Knowledge

Key Concepts:
Nuclear medicine
Nuclear power reactors
Nuclear weapons

Previous/future knowledge: Students were introduced to the process of nuclear decay in PS-2.2 and to fusion and fission in PS-2.6. PS-1.7 requires that students can evaluate technology on the basis of designated criteria. As South Carolina is a major player in the United States nuclear program, it is important that students can understand and evaluate nuclear applications.

It is essential that students understand that the term "consequences" refers to both those that are negative and those that are positive. They also need to understand that nuclear decay occurs naturally in many elements that are common on earth, and there is always some radiation present in every environment. The degree to which radiation is harmful to living organisms depends upon the type of radiation and the quantity of radiation to which the organism is exposed.

Students need to understand the identified nuclear applications in the indicator:
Nuclear medicine
Understand that radioactive materials are used in medical technologies.

- Examples of benefits might include:
  - Using radiation that results from the decay of certain isotopes to destroy targeted cells, such as cancer cells.
    - Cells are most susceptible to damage from radiation during the process of cell division. As cancer cells divide at a very fast rate, they are destroyed in greater numbers than normal cells, which divide less often.
  - Using the radiation that results from the decay of certain isotopes as a way of mapping the path of various substances through targeted organ systems.
    - Most substances that naturally pass through specific body systems can be "spiked" with radioactive samples of the same substances. The radioactivity can then be traced (using a Geiger counter or with photographic film) as the "spiked" substance naturally makes its way through the targeted body system thus revealing how the body system is functioning. In this manner, the natural functioning of the body system can be observed.
- Examples of drawbacks might include:
  - Waste from nuclear medicine must be stored in a special way until it is no longer radioactive, which can be a very long time.
  - Healthy tissue is always damaged to some degree by radiation.

Nuclear weapons

- Understand that nuclear reactions are used in weapons.
- Examples of benefits might include:
  - Some people believe that nuclear weapons are a deterrent to war
- Examples of drawbacks might include:
  - Specialized technology is required to refine the fuel and to produce the weapons.
  - Tremendous amounts of energy available from small amounts of fuel so it can be "smuggled easily."
  - Tremendous amount of destruction, both material and biological.
  - Contamination of the environment with fission-product isotopes, many of which are radioactive and remain so for very long periods of time.
  - Waste from nuclear weapons must be stored in a special way until it is no longer radioactive, which can be a very long time.
  - Improper handling of nuclear materials and possible leakage can cause radioactive isotopes to contaminate the environment, causing long-term radioactive decay problems.

Nuclear-power reactors

Understand how nuclear technology is used to produce electricity

- Energy from controlled nuclear fission is used to heat water into steam,
- The steam expand and spins a huge magnet
- The moving magnetic field forces electrons flow.
- The primary difference between a coal-powered electric generating plant and a nuclear-powered electric generating plant is the method of heating water.
- Examples of benefits might include:
  - Tremendous amounts of energy available from small amounts of fuel
  - No air pollution from the burning of fossil fuels,
  - Can be used anywhere (as opposed to wind power, solar power, hydroelectric power, etc)
  - Abundance of fuel
  - Non-reliance on fossil fuel
- Examples of drawbacks might include:
  - Requires specialized technology to refine the fuel
  - Can cause thermal pollution to water systems
  - Waste from nuclear fission reactors must be stored in a special way until it is no longer radioactive, which can be a very long time.
  - Improper handling of nuclear materials and possible leaks can cause radioactive isotopes to contaminate the environment, causing long-term radioactive decay problems.
  - Power plant failure – radioactive explosions

Assessment Guidelines

The objective of this indicator is to *explain* nuclear processes. As explain means to "construct a cause-and-effect model of a system", the primary focus of assessment should be for students to show both the beneficial effects that the nuclear reaction has in meeting a need or producing a product and the harmful effects that might result from the process.

It is important that students understand how the process results in both the beneficial and the harmful consequences inclusive of those applications stated in the indicator.
If assessments require that students explain nuclear applications other than the ones listed above, detailed descriptions of the application must be provided in the assessment item.
In addition to explain, students should be able to

- *Exemplify* (find a specific example of illustration of a nuclear application)
- *Summarize* (abstract the general theme or major points) one of the applications listed
- *Compare* (detect correspondences between two processes) a nuclear application to a non-nuclear application
- *Recognize* the benefits or detractors of nuclear power.

Standard PS-3: The student will demonstrate an understanding of various properties and classification of matter.

Supporting Content Web Sites

Density
www.nyu.edu/pages/mathmol/textbook/density.html
This site describes density using visuals and formulas. It also includes calculations for students to submit online.
PS-3.1

Physical and Chemical Properties and Changes
www.fordhamprep.org/gcurran/sho/sho/lessons/lesson15.htm
Physical and chemical properties are described. Worksheets and online quizzes are available.
PS-3.1

Review and Practice on Chemical vs. Physical Properties and Changes
www.teacherbridge.org/public/bhs/teachers/Dana/chemphys.html
This site contains reviews of the concepts of chemical and physical properties and changes. It also has an online practice activity.
PS-3.1

Soap and Detergent Chemistry
www.sdahq.org/cleaning/chemistry
This site gives information about how soap works, including a description of how nonpolar oils are used in soaps.
PS-3.2

What is the difference between a compound and a molecule?
http://education.jlab.org/qa/compound.html
This question and answer site answers questions relating to compounds and molecules.
PS-3.3

The Dissolving Process
www.geocities.com/capecanaveral/Lab/1643/solutions2.html
This site examines the process of a solid dissolving in a liquid as well as factors affecting the rate of dissolving.
PS-3.5

Elements, Mixtures, and Compounds
http://www.darvill.clara.net/hotpots/emc.htm
The site is comprised of a matching game that allows students to match types of mixtures and compounds to diagrams.
PS-3.4

Skool.co.uk Chemistry
http://lgfl.skoool.co.uk/keystage3.aspx?id=64
This site has a huge variety of chemistry topics including properties and states of matter, particle theory of matter, change in state, reactions of metals in acid, reactivity series of metals, acid and alkalis, acid base reactions and the pH scale.
PS-3.1, PS-3.6, PS-3.7, PS-3.8

GEMS Alien Juice Bar
http://sv.berkeley.edu/showcase/flash/juicebar.html
This site contains games that challenge students to learn about acids, bases, neutrals, and Ph.
PS-3.8

S-Cool Chemistry GCSE Acids and Alkalis
http://www.s-cool.co.uk/topic_principles.asp?loc=pr&topic_id=1&subject_id=21&ebt=212&ebn=&ebs=&ebl=&elc=4
This site provides review of the concepts of acid and alkali properties and explains the uses of neutralization. It also has sample questions for practice.
PS-3.8

Suggested Literature

Gardner, R. (2004). *Science Fair Projects About the Properties of Matter Using Marble, Water, Balloons, and More*. Berkeley Heights, NJ: Enslow Publishers, Inc.
ISBN: 0-7660-2128-9
Lexile Level: NA
This book includes descriptions of elastic properties, properties of solids and liquids, and density of solids, liquids, and gases.
PS-3.1

Newmark, A. (2005). *Eyewitness Books-Chemistry*. New York: DK Publishing, Inc.
ISBN: 0-7566-1385-X
Lexile Level: NA
This book investigates mixtures and how they are separated, discerns atoms from molecules, and investigates elements and compounds. It also examines acids and bases with using pH and a discussion of indicators.
PS-3.4 and PS-3.8

Baldwin, C. (2006). *States of Matter*. Chicago: Raintree
ISBN: 1-41091-678
Lexile Level: NA
This book includes discussions on the properties of solids, liquids, gases, and plasmas. It also examines how matter changes states.
PS-3.6

The Facts on File Dictionary of Inorganic Chemistry. (2004). New York: Facts on File
ISBN: 0-8160-4926-2
Lexile Level: NA
This book gives definitions as well as explanations of terms associated with inorganic chemistry. It also provides illustrations.
PS-3.2

The Facts on File Dictionary of Organic Chemistry. (2004). New York: Facts on File
ISBN: 0-8160-4928-9
Lexile Level: NA
This book includes alphabetized entries on common organic terms.
PS-3.2

Hayhurst, Chris. (2003). *Bifuel Power of the Future: New Ways to Turning Organic Matter into Energy*. Springfield, NJ: Rosen Publishing Group
ISBN: 0-8239-3659-7
Lexile Level: NA
This book examines the pros and cons of using plant and animal wastes (organic matter) to meet our growing energy needs.
PS-3.2

Suggested Streamline Video Resources

Physical Science Series: Properties of Matter
Characteristics of Matter
ETV Streamline SC
Describes properties as chemical and physical properties and gives examples.
1:26-5:19
PS-3.1

Physical Science Series: Properties of Matter
Density
ETV Streamline SC
This video shows application and formula of density. Also includes problem solving exercise.
8:20- 10:02
PS-3.1

Physical Science Series: Mixtures and Solutions
Solubility
ETV Streamline SC
This video describes solubility in terms of mass and temperature. Graphs are used to describe saturated and unsaturated solutions.
11:29 – 15:44
PS-3.1

Physical Science Series: Phases of Matter
Melting and Vaporization and Condensation, Freezing, and Sublimation
ETV Streamline SC
These two video segments explain the physical properties of freezing, condensation, melting, evaporation and sublimation.
5:12 -9:12
PS-3.1

Elements of Chemistry: Carbon: The Element of Life

Polymers and Plastics
ETV Streamline SC
Demonstrates applications of synthetic organic polymers and describes their properties.
13:08 – 15:26
PS- 3.2

Energy and the Chemistry of Life

Atoms and Elements and Molecules, Compounds, and Chemical Bonds
ETV Streamline SC
These segments explain the parts of the atom and compares sizes of atoms of different elements. It also explains bonding of molecules as a result of chemical reactions and gives a good description of chemical formulas.
22:54 – 29:15
PS- 3.3

Physical Science Series: Mixtures and Solutions
Classification of Matter and Mixtures
ETV Streamline SC
This video explains differences in heterogeneous and homogeneous mixtures and classifies these mixtures as colloids, suspensions, and solutions. It also explains the terms solute and solvent.
0:00 -7:29
PS-3.4

Physical Science Series: Mixtures and Solutions
Solubility
ETV Streamline SC
Agitation, particle size, and temperature are all examined as they relate to the rate of dissolving.
7:29-9:29
PS-3.5

Elements of Chemistry: Gases, Liquids, and Solids
Different States of Matter
ETV Streamline SC
This segment distinguishes among the attraction of particles in solids, liquids, and gases. It also describes how temperature is related to change of state.
8:30-12:10
PS-3.6

Physical Science Series: Phases of Matter
Phase Changes
ETV Streamline SC
This segment defines changes in matter due to heat transfer and temperature.
8:11-13:50
PS-3.7

Chemistry Connections: Kinetic and Potential Energy Changes during Changes to States of Matter
Phase Changes and Temperature-Time Graphs
ETV Streamline SC
This segment shows the use of probes to measure temperature changes throughout an experiment. Graphing using computers is also described.
1:04-12:43
PS-3.7

Elements of Chemistry: Acids, Bases and Salts
Properties of Acids and Bases
ETV Streamline SC
This segment gives several good examples of the properties of acids and bases.
0:00- 3:14
PS-3.8

Elements of Chemistry: Acids, Bases, and Salts
Strong and Weak Acids and Bases
ETV Streamline SC
The leveling of pH and water's ability to act in neutralization are described in this segment.
8:15-10:46
PS-3.8

Chemistry Connections: Acids and Bases Defined
Empirical Definition of Acid and Base Solutions
ETV Streamline SC
The properties and chemical activity of acids and bases are described in this segment. Also included are the uses of litmus, pH probes, and reactions with metals.
7:03-21:02
PS-3.8

Career Connections

Chemistry Professor/Teacher
Chemistry educators work using educational methods to teach students to appreciate how matter is composed and how it behaves. They also use mathematics to solve problems related to chemistry concepts. University professors will also do research and publish their findings.

Chemical Engineer
Chemical engineers use chemical laboratory processes in an industrial setting in order to produce products such as fertilizers, pharmaceuticals, plastics, and food preservatives.

Inorganic Chemist
An inorganic chemist primarily works with metals. They are especially important in the electronics industry where they have used their knowledge of materials chemistry to build components such as integrated circuits.

Organic Chemist
An organic chemist often works with petroleum, wood products, plastics, textiles, as well as in the food industry. They may design new production processes for older materials as well as the development of synthetic materials.

Physical Chemist
A physical chemist will study the physical properties of matter. Some topics they may study include the statistics on molecular interactions, combustion of plasma, and nuclear reactions.

PS-3.1 Distinguish chemical properties of matter (including reactivity) from physical properties of matter (including boiling point, freezing/melting point, density [with density calculations], solubility, viscosity, and conductivity).

Taxonomy Level: 4.1-B Analyze/Distinguish Conceptual Knowledge

Key Concepts
Physical property: boiling point, freezing/melting point, density, solubility, viscosity, conductivity
Chemical property: the capacity to oxidize, combustibility, the capacity to corrode

Previous/future knowledge: Students were introduced to this topic in 7th grade (7-5.9).
A more in-depth understanding of the actual processes is expected for Physical Science. Distinguishing between physical and chemical properties is the foundation for an understanding of the distinction between chemical reactions and physical change (PS-4.6), and therefore vital to an understanding of chemical reactions in PS-4.7 through PS-4.11, and all future chemistry courses.

It is essential for students to:

- Know the criteria for distinguishing chemical from physical properties
  - A physical property of a substance is a characteristic of the substance that can be observed directly or measured with a tool without changing the composition of the substance.
  - A chemical property is a description the capacity of a substance to undergo a change that will alter the composition of the substance.

It is essential for students to:

- Understand <u>physical properties.</u>
  ***Boiling point, freezing/melting point* –** students should
  - ♦ Know that the terms boiling point and melting/freezing point do not refer to the phase change itself, but to a measurement: the temperature at which these changes occur.
  - ♦ Understand that the composition of a substance does not change during phase change nor does it change when one measures temperature in order to determine the boiling point, and freezing point/ melting point, therefore, boiling point and melting/freezing point are physical properties.

  Misconception: As the physical appearance of a substance changes during a phase change, students often mistakenly assume that boiling and freezing/melting are chemical changes (see PS-4.6), especially with boiling where students confuse vaporization with gas formation.

  It is not essential for students to
  - ♦ Understand the effect of pressure on the boiling point or the freezing/melting point of a substance.

Density **–** students should

- ♦ Understand the concept of density as the mass of a substance per unit volume. A conceptual understanding of density ensures that students understand why the density of a particular substance (under constant conditions) is always the same, regardless of the sample size.
- ♦ Understand why the density of a substance changes with phase change. PS-3.7 addresses the difference in the particle arrangement in solids, liquids and gasses. Students should understand that because the volume of a particular substance is dependent upon phase, the density of a particular substance is as well.
- ♦ Understand that density can not be measured directly, but is the ratio of two measurements: mass and volume.
    - * Students must have a strong conceptual understanding of mass and volume. In addition, it is essential that students understand and are proficient at carrying out the procedures for accurately measuring the mass and volume of solids (regularly and irregularly shaped), liquids, and gases. (PS-1.3)
- ♦ Understand and are proficient at carrying out the procedures for calculating density using the formula: density = mass/volume.
- ♦ Understand that the composition of a substance does not change when one measures mass, and volume in order to calculate density, therefore, density is a physical property.

It is not essential for students to

- ♦ Understand the effect that temperature change (apart from phase change) has on volume (and therefore the density) of solids, liquids, or gasses.

Misconception: Students can often manipulate and solve the density equation without a grasp of the proportional thinking required to truly understand the concept. Understanding a ratio requires that students think abstractly, a cognitive skill that many physical science students have not yet acquired. It is therefore essential that this concept be introduced in a concrete manner.

Solubility **–** students should

- ♦ Understand that a substance is soluble in a solvent if it will dissolve in that solvent. The term solubility is defined as the maximum amount of a solute (substance being dissolved) that can dissolve in a given volume of solvent (the dissolving medium) at a particular temperature and pressure.
- ♦ Understand that a saturated solution is one in which the maximum mass of the solute is dissolved in the solvent at a particular temperature.
- ♦ Be able to give examples of solids, liquids, and gasses that readily dissolve in water.
- ♦ Understand that the components of solutions (and therefore mixtures) do not chemically combine to form a new substance and therefore, solutions are composed of two substances which each retain their own properties. Therefore solubility is a physical property.
- ♦ **Note** to teachers:

* In physical science, solubility is defined as a physical property because solutions are defined as homogeneous mixtures. However, as students study chemistry in future courses, they will find that the dissolving process varies with the characteristics of the solute and the solvent respectively. The attraction of various solute particles to water molecules varies and if this force is strong, the dissolving process is considered a chemical reaction. It is not essential for physical science students to be aware of this, but if they find conflicting information in texts, an explanation should follow.

Misconceptions:

- Students often confuse solubility with the rate of dissolving (see PS-3.5).
- As the physical appearance of a substance changes when it dissolves (the solute often disappears) students often mistakenly assume that dissolving is a chemical change. (PS-3.6) In a solution, the solute and solvent do not chemically combine, they form a homogenous mixture. (PS-3.4)

It is not essential for students to

- Consider solubility of substances in solvents other than water.
- Consider the effect of pressure on solubility.
- Predict the effect that temperature has on the solubility of a given substance (see above concerning reading temperature vs. solubility graphs) (It is interesting but not essential to contrast the effect that temperature has on the solubility of gasses verses most solids and to consider the many results and applications of temperature dependent solubility in our world.)
- Understand how to read temperature vs. solubility graphs

***Viscosity* –** students should

- Understand that viscosity is a property of fluids (focus on liquids).
- Understand that viscosity is a measure of the material's resistance to flow. High-viscosity fluids take longer to pour than low-viscosity fluids.
- Understand that viscosity may change with temperature.
- Understand that the composition of a fluid does not change when it is poured and therefore, viscosity is a physical property.

It is not essential for students to

- Know the normal laboratory method and accepted units for measuring viscosity.

***Electrical Conductivity* –** students should

- Understand that solid as an electrical conductor or insulator based on the solids ability to complete an electric circuit. (see indicator PS-6.9 for electric circuits)
- Understand that materials (such as metals) with high conductivity are called electrical conductors because they allow current to flow easily.
- Understand that materials with low conductivity block current from flowing and are called electrical insulators. Most non-metals are insulators.

- ♦ Understand that some solutions can conduct electric current, depending on the nature of the solute. Solutes that allow electric current to flow are called electrolytes. Electrolyte solutions contain ions.

It is not essential for students to

- ♦ Know the relationship among the terms electrical conductor, electrical resistivity, and electrical resistance.

It is essential for students to:

- Understand <u>chemical properties.</u>

The capacity to oxidize **–** students should

- ♦ Understand that when oxidation occurs, a substance combines with oxygen to form a new substance with new properties.
- ♦ Understand that the new substance formed is a combination of the atoms of the original substance and oxygen.
- ♦ Understand that the properties of a substance change during the process of oxidation

It is not essential for students to

- ♦ Understand oxidation in terms of loss of electrons,
- ♦ Understand oxidation numbers

Combustibility **–** students should

- ♦ Understand that combustion is a special type of oxidation.
- ♦ Understand that when combustion occurs, a substance combines with oxygen to form a new substance with new properties in a process which releases heat and light. As in all cases of oxidation, the new substance which is formed is a combination of the original substance and oxygen.
- ♦ Understand that the properties of a substance change during the process of combustion

The capacity to corrode **–** students should

- ♦ Understand that corrosion is the process by which metals naturally combine with oxygen, sulfur, or other nonmetals.
- ♦ Understand that when corrosion occurs, the new substance that is formed is a combination of a metal and a nonmetal.
- ♦ Understand that the properties of a substance change during the process of corrosion.

Assessment Guidelines

In order to insure that students can <u>*distinguish*</u> solubility, viscosity, conductivity, density, boiling and freezing point, as physical properties, assessments should require that students identify the relevant or important aspects of the property necessary for classification. In this case, the composition of the substance does not change when the property is measured. In order to do this, students must have a conceptual understanding of the property as well as an understanding of the distinction between chemical and physical properties. Assessments may require that students understand the reason for classifying a property as a physical property.

In order to insure that students can *distinguish* the capacity to oxidize, combust, or corrode as a chemical property, students must have a conceptual understanding of these properties, as well as an understanding of the distinction between chemical and physical properties. Assessments may require that students understand the reason for classifying a property as a chemical property

In addition to distinguishing solubility as a physical property, assessments may require that students:

- *Use* the mathematical formula for density to solve for one of the variables when given the other two.
- *Use* appropriate laboratory techniques required to measure mass and volume, including the correct procedure for measuring the mass and volume, including the correct procedure for measuring the volume of a liquid and the volume of a solid (by water displacement), and the correct method of measuring the volume of a regularly-shaped solid.
- *Classify* substances based on their physical and chemical properties.
- *Identify* a property as physical or chemical.
- *Exemplify* (give examples) chemical and physical properties.
- *Differentiate* physical and chemical properties of a substance.

PS-3.2 Infer the practical applications of organic and inorganic substances on the basis of their chemical and physical properties.

Taxonomy Level: 2.5-B Understand/Infer Conceptual Knowledge

Key Concepts
Organic substances: hydrocarbon, protein, carbohydrate, lipid
Inorganic substances

Previous/future knowledge: Students have not been introduced to this topic in any previous grade. Distinguishing between organic and inorganic substances is a foundation for an understanding of two major areas of chemistry.

It is essential for students to

- Select the best substance for a particular function when given a list of the substance's chemical and physical properties.
- Distinguish between organic and inorganic substances.
- Understand how the function of selected organic substances are dictated by their properties
  - Recall the name of selected biological molecules and summarize how their anatomical functions in organisms are dictated by their chemical properties.
    - *Protein* molecules are long chains of small units (amino acid monomers) that are arranged in various configurations so they can form a wide variety of molecules. Proteins serve many functions in living organisms such as catalysts (enzymes) and tissue building.
    - *Carbohydrate* molecules (sugars and starches), provide organisms with energy when they break down into smaller molecules.
    - *Lipid* molecules (fats and oils) are well suited for long term energy storage because lipids are harder to break into smaller particles than carbohydrates and therefore provide more energy.
  - Recall that hydrocarbons are a class of organic particles composed of various combinations of the elements, carbon and hydrogen.
    - Recognize that many hydrocarbons are combustible so they are used for fuel, including gasoline, kerosene, jet fuel, and diesel oil.
    - Recognize that many hydrocarbons form long chain molecules called polymers so they are used to make plastics and synthetic fibers.
- Recognize potential uses of inorganic substances when given the properties of the substance.
  - Copper is ductile and conducts electricity, so it is used in wiring.
  - Aluminum has a low density compared to substances with similar strength so it is used in making airplanes.
  - Water is a good solvent, so it is used to wash clothes.
  - Argon is will emit light when energized with electricity but it is inert so it is used in light bulbs.

It is not essential for students to

- Recall the chemical formula of organic or in organic compounds.
- Recall organic nomenclature.

Assessment Guidelines

The verb ***infer*** means to draw a logical conclusion from presented information, so assessment will focus on the student's ability to choose an appropriate substance for a particular practical application when presented with the chemical and physical characteristics of several substances, or to describe the chemical and physical properties that a substance would need to have in order to be used for a particular practical application. It is not appropriate for students to memorize examples, as assessments should present students with novel substances and applications to ensure that students can infer the relationship, not recall previously given examples.

In addition to inferring an appropriate practical application for a given substance, assessments may require students to:

- *Classify* substances as organic or inorganic when given a description of the components of the compound. (based on the presence or absence of carbon)
- *Exemplify* (find specific examples) of organic and inorganic substances.
- *Summarize* how the practical applications of hydrocarbons and biological compounds are determined by their properties.
- *Recognize* organic compounds by components-chemical formula

PS-3.3 Illustrate the difference between a molecule and an atom.

Taxonomy Level: 2.2-B Understand/Illustrate Conceptual Knowledge

Key Concepts
Molecule
Atom

Previous/future knowledge: In 7th grade, students recognize the atom as the basic building block of matter (7-5.1)
In Physical Science indicators PS-2.1 through 2.4 addressed the parts and properties of atoms. This indicator is meant to introduce students to the concept of chemical bonding. PS-3.4 will require that students classify matter as pure substance or mixture. In preparation for this skill, students must understand the implications of atoms bonding to form molecules. This standard lays the foundation for chemical bonding (PS-4.1 through PS-4.5)

It is essential for students to
- Understand that elemental substances (elements) are composed of only one type of atom.
- Understand that an atom is the smallest particle of matter that retains the properties of an elemental substance.
- Understand that all of the elements are listed on the periodic table.
- Understand that molecular substances are composed of two or more atoms covalently bonded together.
- Understand that a molecule is the smallest particle of a molecular substance that can exist and still have the composition and chemical properties of the substance.
    - *Teacher note: This indicator is an introduction to bonding; illustrating shared electrons and bonding will be addressed in PS-4.1 through PS-4.5.
- Understand the chemical and physical properties of a molecular substance are different from the chemical and physical properties of the component elements.
- Can give examples (illustrations) of substances composed of molecules and examples of substances composed of atoms (as indicated by the verb illustrate). Illustrations may be in the form of chemical names, chemical symbols/formulas, verbal descriptions, or pictorial diagram

It is not essential for students to
- Remember the chemical formula for substances, or be familiar with chemical nomenclature (for example, it is not essential that students know that CO_2 is carbon dioxide, or that Sulfur trioxide contains one sulfur atom and three oxygen atoms.
- Understand that the atoms in metallic substances such as copper are held together by metallic bonds.

Assessment Guidelines

The verb *illustrate* means to find or use an illustration of a concept or principle, therefore the major focus of assessment will be for students to give or use illustrations that show that they understand the differences between atoms and molecules on a conceptual level. Conceptual knowledge requires that students understand that atoms can exist individually or bonded to one another in discrete groups as molecules that may consist of two or more of the same type of atom or different atoms. When a substance consists of different types of atoms chemically bonded together, the substance has identifying properties that are different from those of the component elements.

In addition to illustrate, assessments may require students to

- *Classify* substances as atoms or molecules when given the chemical names, chemical formula/symbols, verbal descriptions, or pictorial diagrams of substances, and give the reason the category chosen.
- *Summarize* the differences between atoms and molecules in terms of structure and properties.
- *Compare* atoms to molecules, in terms of structure and properties.

PS-3.4 Classify matter as a pure substance (either an element or a compound) or as a mixture (either homogeneous or heterogeneous) on the basis of its structure and/or composition.

Taxonomy Level: 2.3-B Understand/Classify Conceptual Knowledge

Key Concepts
Pure substance: element, compound
Mixture: homogenous mixture, heterogeneous mixture

Previous/future knowledge: In 7th grade (7-5.2), students classify matter as element, compound, or mixture on the basis of composition.
In Physical Science PS-2.1, students developed and understanding of elements as composed of only one type of atom. PS-3.3 added that molecular substances are composed of two or more types of atoms that are bonded together as molecules and that molecular substances do not retain the properties of their components but have their own identifying properties. (PS-3.3)
Building on this knowledge, students will classify elements and compounds as pure substances due to the fact that each of these types of matter have unique, identifying properties.
Students will learn how mixtures differ from pure substances and how to differentiate different types of mixtures. This indicator lays the foundation for an understanding of chemical reactions (PS-4.8).

It is essential for students to

- Understand that substances which have unique, identifying properties are called pure substances, there are two types of pure substances, elements and compounds.
  - Understand that an *element* is a pure substance which is composed of only one type of atom. All of the elements are listed on the periodic table
  - Understand that a *compound* is a pure substance which is composed of more that one type of element.
    - ♦ Compounds all have identifying properties which are different from the properties of the elements which compose them.
    - ♦ Compounds can be decomposed into elements only by chemical reactions; they can not be physically separated.
    - ♦ Compounds have a definite chemical composition identified within a chemical formula. For example, the ratio of the number of oxygen atoms to hydrogen atoms in any sample of water is always 1 to 2.
    - ♦ Molecular substances are one type of compound and ionic substances are another type (this is addressed further in PS-4.1 through PA-4.5.
  - Understand that when matter is composed of two or more component substances which retain their own identifying properties, the matter is classified as a *mixture.*
    - ♦ A mixture can be separated physically because the components of the mixture have different physical properties. (PS-3.1) examples of separating mixtures based on differing properties include but are not limited to:

        - ♦ Mixtures do not have definite composition; the components of a mixture may be in any ratio.
        - ♦ Procedures for separating mixtures include: dissolving, filtering, evaporating, decanting, magnetic separation, separating by particle size (screening), or chromatography
        - ♦ Mixtures can be classified into two groups, heterogeneous and homogeneous.
            - *Heterogeneous mixtures* do not have the components distributed evenly throughout. The different components are easy to see in a heterogeneous mixture.
            - *Homogeneous mixtures* have components evenly distributed. The components are small that they can not be seen with the naked eye.
                - ∗ A *solution* is a homogeneous mixture in which the components are close to the size of individual particles of the substance (atoms, molecules, or ions) and therefore, too tiny to be seen with a microscope. (Ions will be addressed in PS-4.2)
    - ○ Understand that mixtures can occur between and among all phases of matter:
        - ♦ Gas/gas (air)
        - ♦ Gas/liquid (oxygen in water)
        - ♦ Liquid/liquid (alcohol in water)
        - ♦ Liquid/solid (sugar in water)
        - ♦ Solid/solid (alloy such as steel)

It is not essential for students to

- Understand colloids or suspensions
- Understand ionic or covalent bonding (this will be addressed in standard PS-4)
- Understand colligative properties

Assessment Guidelines

As the indicator states, the major focus of assessment is to *classify* given examples of matter first as pure substances or a mixtures. Secondarily, if a matter sample is classified as a pure substance, it will be further classified as an element or a compound. If the matter sample is classified as a mixture, it will be further classified as a homogeneous mixture or a heterogeneous mixture.
As the indicator is classified as conceptual knowledge, assessment items will require that students understand the criteria for each of these category. Memorizing that certain examples of matter belong to specific categories will not be sufficient. Assessments will require that students can classify any given sample of matter when given the relevant information.

In addition to classifying, assessments may require that students:

- *Exemplify* (find a specific example) of a pure substance, mixture, element, compound, heterogeneous mixture, homogeneous mixture or solution, and justify the example
- *Compare* one of the given categories to another as to relevant characteristics which define each category.
- *Summarize* the major points which define each category.

- *Infer* from laboratory data the correct classification (element, compound, homogeneous mixture, heterogeneous mixture) for a given sample of matter.

PS-3.5 Explain the effects of temperature, particle size, and agitation on the rate at which a solid dissolves in a liquid

Taxonomy Level: 2.7-B Understand/Explain Conceptual Knowledge

Key Concepts
Kinetic Theory
Temperature (effect on particle motion)
Particle size (effect on surface area)
Agitation (effect on solute/solvent collisions)

Previous/future knowledge: In 5th grade (5-4.6) students "explain how temperature change and stirring affect the rate of dissolving", but at this point students are only required to understand that these factors do have an affect on the rate of dissolving, not why. 5th grade students have not yet been introduced to the particulate nature of matter. In 7th grade students "recognize that matter is composed of extremely small particles called atoms".
Physical Science students are cognitively capable of comprehending matter as composed of various types of particles and to beginning to develop a model of how those particles behave. Indicator PS-3.4 introduced students to a solution as a homogeneous mixture in which the components are close to the size of individual particles of the substance (atoms, molecules, or ions) and therefore, too tiny to be seen with a microscope. The essential learning in this indicator is not just to discover how each of the variables (temperature, particle size, and agitation) influences the rate of dissolving, but to understand each variable in terms of the particles that compose the solution. The verb "explain" was chosen for this indicator because students must develop a mental model of how the particles of the substances in a solution are affected by each of the variables during the process of dissolving. This is an abstract concept and must be approached in a concrete manner.

It is essential for students to
- Understand the Kinetic Theory
  - The Kinetic theory has three basic assumptions
    - All matter is composed of small particles (molecules, atoms, and ions).
    - The particles are in constant, random motion.
    - The particles are colliding with each other and the wall of their container
- Understand the process of dissolving in terms of the kinetic theory
  - The solute (in this case water) is composed of individual water molecules (H_2O), all close enough to touch, but in constant motion, moving over, under, and past one another. (see liquids PS-3.6)
  - The solute (such as table sugar) is composed of crystals.
    - Each crystal is composed of billions of individual sugar molecules. The individual molecules are attracted to each other (not chemically bonded) together. The sugar molecules in the crystal are also moving but because sugar is a solid (See PS-3.6) the molecules do not move past each other, they move back and forth in all directions

        - ♦ Because sugar is a molecule (a compound) the individual sugar molecules can not be decomposed by a physical process such as dissolving so the sugar molecules do not dissolve into carbon, hydrogen and oxygen atoms during the dissolving process.
        - ♦ The dissolving process involves the sugar molecules being pulled <u>away from each other</u> (but each molecule remains intact) by the water molecules.
        - ♦ The sugar molecules on the surface of the crystal are the only ones to dissolve because they are the ones in contact with the water molecules. As surface sugar molecules dissolve, they expose the ones beneath to the water.
        - ♦ Because the dissolved sugar molecules are surrounded by water molecules, they are not attracted together (the water molecules block the attractive force)
        - ♦ In the resulting solution, the sugar molecules are distributed throughout the water. (you can taste the sugar in any sample of the water)
        - ♦ The water can be removed by boiling the water or allowing it to evaporate. When the water boils or evaporates away, the sugar molecules will once again be attracted, one to another. Sugar crystals will reform.
- Understand how temperature affects the rate at which substances dissolve
    - The higher the temperature, the faster the rate of dissolving for a solid in a liquid.
    - At higher temperatures the water molecules move faster and collide with the surface of the solute more often carrying off particles of the solute so dissolving occurs more rapidly.
    - At higher temperatures the sugar molecules are also vibrating faster allowing them to overcome their attraction for one another easier
- Understand how particle size affects the rate at which substances dissolve
    - The smaller the size of the particles, the faster they dissolve
    - The smaller the particle size the more surface area the sample will have to be in contact with the water molecules. With more surface area to contact the water molecules will have more opportunities to pull the molecules away from the solute's surface dissolving it faster.
- Understand how agitation affects the rate at which substances dissolve
    - The more the solution is agitated, the faster the rate of dissolving for a solid in a liquid.
    - When a solution is agitated, the water particles collide with the surface of the solute more frequently and the dissolving process occurs faster.
- Understand that if a substance is soluble in water, it will eventually dissolve even if the particle size is large, the temperature is low and there is no agitation.

Misconception: Students often confuse rate of dissolving (how fast a substance dissolves) with solubility (what quantity of a substance can dissolve) (see PS-3.1).

It is not essential for students to
- Understand the intermolecular forces within a molecular crystal
- Understand the energy of solution
- Understand the polar nature of the water molecule
- Differentiate polar and non-polar solvents

Assessment Guidelines

As the verb for this indicator is *explain* the major focus of assessment will be for students to not only show that they know the effect each variable has on the rate of dissolving, but that they can "construct a cause and effect model" based on the Kinetic Theory.
Because the indicator is written as conceptual knowledge, assessments must show that students can construct a cause and effect statement relating how each variable affects the rate of dissolving.
The cause and effect here is not "the solute dissolves faster because the particle size is smaller" but rather "smaller particle size increases the rate of dissolving because when a substance is in smaller pieces, there is more surface area exposed to the solute molecules to collide with."

In addition to *explaining*, assessments may require that students:
- *Compare* the dissolving rate of two solutions that differ according to one of the indicator variables;
- *Summarize* the effect of the factors influencing the rate of dissolving; or
- *Recall* the effect of the indicator variables on the dissolving process.

PS-3.6 Compare the properties of the four states of matter—solid, liquid, gas, and plasma—in terms of the arrangement and movement of particles.

Taxonomy Level: 2.6-B Understand/Compare Conceptual Knowledge

Key Concepts:
Kinetic theory
States of Matter: solid, liquid, gas, plasma

Previous/future knowledge: In 5th grade (5-4.2) students "compare the physical properties of the states of matter (including volume, shape, and the movement and spacing of particles)." This concept has not been revisited since that time.
Although the 5th grade and physical science indicators appear to be similar, physical science students develop a mental image of atoms and molecules and are cognitively prepared for a deeper understanding of the phases of matter in terms of the Kinetic Theory.

It is essential for students to

- Understand The Kinetic theory (see PS-3.5)
- Understand the characteristics of solids, liquids, and plasma in terms of the Kinetic Theory

Solids	• The particles of solids are closely packed together because there is an attractive force holding them together • The particles of solids are constantly vibrating but they do not slip past one another. • Because the particles can't slip past one another, a solid cannot be poured, and a solid has a definite shape.
Liquids	• The particles of liquids are in contact with each other because there is an attractive force holding them together. • The particles of liquids are moving fast enough to partially overcome the attractive force of the surrounding particles. Liquid particles can slip past surrounding particles, and slide over one another. Because the particles slip past one another, a liquid can be poured.
Gases	• The particles of gasses are not in contact with each other because they are moving fast enough to completely overcome the attractive force between or among the particles. • The particles of gasses are moving randomly, in straight lines until they bump into other particles or into the wall of the container. When a particle hits another particle or the container, it bounces off and continues to move. • Because gas particles move independently, a gas takes the shape of the container. The forces between the particles are not strong enough to prevent the particles from spreading into different shapes.
Plasma	• Plasma is matter consisting of positively and negatively charged particles • A substance is converted to the plasma phase at very high temperatures, such as those on stars (such as the sun). High temperature means that the particles of a substance are moving at high speeds. At these speeds, collisions between particles result in the electrons being stripped from the atom • Plasma is the most common state of matter in the universe, found not only on stars, but also in lightning bolts, neon and fluorescent light tubes and auroras.

It is not essential for students to

- Differentiate crystalline from amorphous solids (Addressed in subsequent chemistry classes)
- Understand various crystalline structures or types of packing (Addressed in subsequent chemistry classes)
- Understand various intermolecular forces (Addressed in subsequent chemistry classes)
- Convert Celsius temperature to Fahrenheit

Misconceptions: Students often believe that at a given temperature the particles of all liquid substances are moving faster than the particles of all solid substances, and that the particles of gaseous particles are moving fastest of all. It is important that students understand that at a given temperature, all matter has approximately the same kinetic energy. The reason that various types of matter are in various phases at a given temperature is primarily due to the variation in the strength of the forces between the particles of various substances.

Assessment Guidelines

As the indicator states, the major focus of assessment is to *compare* (detect correspondences) in the properties of the phases of matter with regard to the arrangement and motion of particles.

As the indicator has a cognitive dimension of conceptual knowledge, assessment items will require that students understand each of the phases in terms of the "interrelationships among the basic elements within the category". These interrelationships include both an understanding of the distinguishing characteristics of each phase with regard to the motion and arrangement of particles. And an understanding of the reasons that the particles of each phase are arranged and move as they do in each phase of matter in terms of the kinetic theory.

In addition to comparing, assessments may require that students:

- *Exemplify* (give a specific example) of particle motion and arrangement in a solid, liquid, gas, or plasma;
- *Classify* a substance as a solid, liquid, gas, or plasma based on a description of the particle arrangement and motion;
- *Explain* how the forces between the particles of a substance and the temperature of the substance effect the motion of the particles of the substance;
- *Summarize* the characteristics of the particle motion in solids, liquids, gas, and plasma; or
- *Recognize* the four states of matter by their characteristics.

PS-3.7 Explain the processes of phase change in terms of temperature, heat transfer, and particle arrangement.

Taxonomy Level: 2.7-B Understand/Explain Conceptual Knowledge

Key Concepts:
Phase change (in terms of energy)
Temperature change (in terms of energy)
Boiling point
Freezing/Melting point
Heat Energy

Previous/future knowledge: The process of phase change is addressed in third grade (3-4.2) "Explain how water and other substances change from one state to another (including melting, freezing, condensing, boiling, and evaporation." In 7th grade students revisited changing states of matter as a physical change along with melting and boiling points as properties.

The Physical Science indicators appear to be very similar to 3rd grade but Physical Science students have developed a mental image of atoms and molecules and are more cognitively prepared for a deeper understanding of phase change in terms of the Kinetic Theory and energy changes.

It is essential for students to

- Understand that *temperature* is a term used to describe the average kinetic energy of the particles in a substance. The faster particles are moving the higher the temperature.
- Explain *phase change* in terms of The Kinetic Theory
  - Phase change is due to *changing* the movement (energy) of the particles.
  - The freezing or melting point is the temperature where a phase change occurs between a liquid and a solid. If heat is being added at this temperature bonds between particles will break and a solid will melt. If heat is being taken away bonds will form between particles and a liquid will freeze at this temperature.
  - The boiling point is the temperature where a liquid is changing to a gas throughout the liquid. This phase change can occur at any temperature. Boiling occurs when bubbles of the vapor are formed.
- Understand that when energy (such as heat) is added to a substance, the energy of the particles of the substance increases. Evidence of this would be that the temperature of the substance increases or a phase change.
- Understand that when heat is added to a solid the particles will move faster and the temperature will increase until the temperature of the solid reaches its melting point.
  - When the temperature of a solid is equal to the *melting point* and more heat is added to the substance the temperature will not change. The extra heat will be used to break some of the bonds between the molecules of the solid and change the phase to a liquid.

- Understand that when heat is added to a liquid the particles will move faster and the temperature will increase until the temperature of the liquid reaches its boiling point.
  - When the temperature of a liquid is equal to the *boiling point* and more heat is added to the substance the temperature will not change. The extra heat will be used to break the bonds between the molecules of the liquid and change the phase to a gas. When a substance boils it forms bubbles of the gas. (For example when water boils the bubbles are water vapor)
- Understand that liquids may evaporate at any temperature. This is because some of the molecules at the surface are moving fast enough to escape the attraction of the other molecules.
- Understand that many solids may undergo the process of sublimation, a process that involves particles changing directly from the solid phase to the gaseous phase. This is a process similar to evaporation that takes place at the surface of the solid.
  - Sublimation may occur in some substances, such as dry ice – solid carbon dioxide, because the melting point and boiling point of a substance are virtually the same temperature.
- Understand the changes shown on a temperature versus time graph that shows boiling point and melting/freezing point
  - The line of the graph has a positive slope until a phase change occurs.
  - At the melting point or boiling point the temperature does not change as more heat is added over time. The slope of the line will be flat during the time that the phase is changing.
  - After the phase change the slope of the line becomes positive again.

Misconceptions:
- Students often confuse heat with temperature,
- Sometimes it is helpful to point out that a huge pot of very hot water, and a coffee cup of very hot water can both have the same temperature but the pot of water contains much more heat energy than the water in the cup.
- This concrete example helps students to understand that there is a distinction in the two concepts, even though it is beyond the scope of this course for students to fully explore the distinction in the two.
- The only distinction that is essential for Physical Science students to make is that heat is a form of energy and temperature is an indication of the kinetic energy (and therefore the speed) of the particles

It is not essential for students to
- Understand the effect that pressure has on phase change
- Differentiate heat and temperature in quantitative terms. (Addressed in subsequent chemistry/physics classes)
- Understand how the mass of the particles of a substance affect the energy of the particles

Assessment Guidelines

As the verb for this indicator is *explain* the major focus of assessment will be for students to "construct a cause and effect model" of phase change. In this case, the model should be based on the Kinetic theory of matter.

- The cause and effect required by assessment is not a statement such as "the solid melts because heat is added when it is at a temperature equal to its melting point"; the cause and effect required by assessment is a model of the system such as "A solid will only melt if heat is added when it is at a temperature equal to it the melting point of the substance because that is when the particles of the substance have almost enough kinetic energy to overcome the attractive force between the particles, so added energy will allow the molecules to have enough energy to overcome the forces."

Because the indicator is written as *conceptual knowledge*, assessments should require that students show that they understand the "interrelationships among the basic elements within a larger structure that enable them to function together." These interrelationships include:

- the processes of energy flow into and out of a substance
- An understanding of the interrelationships of the roles of temperature, heat transfer, and particle arrangement (in terms of The Kinetic Theory) in shaping the process of each phase change (melting, freezing, boiling, condensing).

In addition to explaining, assessments may require that students:

- *Exemplify* (give a specific example) of phase change in terms temperature, heat transfer, and particle arrangement
- *Summarize* the changes resulting from energy flow into a substance
- *Compare* internal kinetic energy to internal potential energy
- *Interpret* a temperature vs. time graph to determine the boiling point or freezing/melting point
- *Infer* the phase change temperature for a substance from a graph showing temperature over time as the substance was heated through the phase change.

PS-3.8 Classify various solutions as acids or bases according to their physical properties, chemical properties (including neutralization and reaction with metals), generalized formulas, and pH (using pH meters, pH paper, and litmus paper)

Taxonomy Level: 2.3-B Understand/Classify Conceptual Knowledge

Key Concepts

Acid	pH
Base	Neutralization reactions
Neutral solution	

Previous/future knowledge: In 7th grade (7-5.6) students "Distinguish between acids and bases and use indicators (including litmus paper, pH paper, and phenolphthalein) to determine their relative pH.

It is essential for students to

- Understand that an *acid* is a chemical that releases hydrogen ions (H^+) in solution and that a *base* is a chemical which releases hydroxide ions (OH^-) in solution.
- Understand that the *pH scale* is a way to measure the concentration of hydrogen ions in solution. It measures how acidic or how basic a solution is.
  - The pH of a solution can be measured using pH paper, litmus paper, or pH meters.
  - The pH range of a solution is between 0 and 14.
  - The pH of pure water is 7. Any solution with a pH of 7 contains equal concentrations of H^+ and OH^- and is considered a *neutral solution*. It is not an acid or a base.
  - The pH of an acid solution is less than 7. It contains more H^+ than OH^-. A lower number indicates more hydrogen ions. The lower the number the more acidic the solution.
  - The pH of a base solution is greater than 7. It contains less H^+ than OH^-. A higher number indicates more OH^- ions. The higher the number the more basic the solution is.
- Understand the physical and chemical properties of *acids*.
  - Acid solutions conduct electricity (are electrolytes)
  - Acid solutions have a tart or sour taste (caution! students should never taste anything in science lab)
  - Acids turn litmus paper red; other indicators will turn a specific color for each pH value
  - Acid solutions have a pH less than 7
  - Acids react with active metals such as zinc and magnesium.
  - For the purposes of Physical Science, the formula of an acid can be recognized because the first element in the formula is hydrogen except for water.
  - Examples might include.
    - ♦ HCl Hydrochloric acid (stomach acid)
    - ♦ H_2SO_4 Sulfuric Acid (common industrial acid)
- Understand the physical and chemical properties of *bases*.
  - Basic solutions have a slippery feel

- Basic solutions conduct electricity (are electrolytes)
- Basic solutions have a pH greater than 7
- Red litmus paper turns blue in the presence of a basic solution; other indicators will turn a specific color for each pH value
- For the purposes of Physical Science, the formula of a base can be recognized because the formula ends in OH.
- Examples might include.
  - NaOH Sodium Hydroxide (drain cleaner)
  - $Ca(OH)_2$ Calcium Hydroxide (hydrated lime - fertilizer)

- Understand the process of *Neutralization*:
  - Acids react with bases to form water and a salt. This type of reaction is called a *neutralization reaction* because in forming water, both hydrogen ions and hydroxide ions are equal in solution.
  - Bases react with acids to form water and a salt. This type of reaction is called a *neutralization reaction* because in forming water, both hydrogen ions and hydroxide ions are equal in solution.
- Understand and be proficient at carrying out laboratory procedures for determining the pH of an unknown solution using pH paper or a pH meter, as well as, for determining whether an unknown substance is an acid or a base using litmus paper.

It is not essential for students to

- Understand the different theories of acids and bases (Arrhenius, Bronsted-Lowry, and Lewis)
- Understand or be familiar with the nomenclature for acids
- Understand or be familiar with pH or pOH calculations
- Remember the specific pH of common acids or bases
- Differentiate between strong/weak acids and concentrated/dilute acids

Assessment Guidelines

As the indicator states, the major focus of assessment is to *classify* various solutions as acids or bases. As the taxonomy verb is classify as opposed to distinguish, the assessment item should include all of the relevant information that is needed to make the distinction between categories.

As the indicator has a cognitive dimension of *conceptual knowledge*, assessment items will require that students show that they understand the criteria for each category. Memorizing that certain examples of solutions are acids or bases will not be sufficient. Assessments will require that students can classify any given solution when given the relevant information.

In addition to classifying, assessments may require that students:

- *Exemplify* (find a specific example) of an acid and a base and justify the classification of the example based on the given information
- *Compare* acids to bases with reference to relevant characteristics which define each category.
- *Summarize* the major points which define each category.

- ***Infer*** from laboratory data the correct classification (acid or base) of an unknown solution.

Standard PS-4: **The student will demonstrate an understanding of chemical reactions and the classifications, structures, and properties of chemical compounds.**

Supporting Content Web Sites

The University of Sheffield and WebElements Ltd, UK
http://www.webelements.com/
This is the ultimate site for information on the periodic table and the elements.
PS-4.1-4.3, 4.5

Harmsy
http://www.harmsy.freeuk.com/jigsaw.html
This site has printable puzzle pieces that students can use to construct formulas.
PS-4.5

FunBased Learning
Http://funbasedlearning.com/chemistry/default.htm
This site is for learning to write formulas and balancing equations. Do it all in one hour- even with remedial students! This is a fun site!!!
PS 4.6, 4.8, 4.10, 4.11

Vision Learning – National Science Foundation
http://www.visionlearning.com/library/
This site explains the role of bonding in achieving chemical stability in both ionic and molecular substances. It illustrates the fact that ions attract ions of opposite charge and form crystal lattices. Many other topics are explained on this site!!
PS-4.1- 3, 4.9 - 10

Chem4kids
http://www.chem4kids.comT
This site addresses atom basics, elements, chemical reactions and other chemistry topics.
PS- 4.6, 4.8

Cavalcade O' Chemistry
www.chemfiesta.com
This site has many lab activities and worksheets for chemical reactions, ionic and molecular compounds, and many other teacher help.
PS-4.4, 4.5, 4.7, 4.9, 4.10.

Associated Chemistry Teachers of Texas
http://www.statweb.org/ACT2/labs_demos.htm
This site is a great source for Physical Science labs and demos. Use! Use! Use!
PS-4.3 -4.5

QuiaWeb
http://www.quia.com/jq/19617.html
This site has much information about bonding as well as an interactive quiz that assesses knowledge of the principles behind chemical bonding. It also contains many other sources of help for teachers of chemistry.
PS-4.1, 4.3-5

General Chemistry Online
http://antoine.frostburg.edu/chem/senese/101/
This is a rich source for activities and it is an interactive site.
PS-4.7, 4.9 -10

Science Help Online – Fordham Preparatory School
http://www.fordhamprep.org/gcurran
This is a chemistry lessons site but there are many worksheets and much information that is appropriate for Physical Science.
PS-4.1 – 4.11

Suggested Literature

Sachs, Oliver (2001). **Uncle Tungsten.** New York: Alfred A Knopf
ISBN 0-375-40448-1
Lexile: NA
The book weaves together the wonders of chemistry and the boyhood experiences of Oliver Sachs. Follow his experiments of "stinks and bangs" under the tutelage of his "chemical" uncle. Numerous reactions are featured as well as his heroes, Humphrey Davy and Marie Curie.
PS-4.7 - 4.9.

Platt, Richard (2005). **Forensics (Kingfisher Knowledge).** Kingfisher/Houghton Mifflin Company
ISBN 0-7534-5862-4
Lexile: NA
This book presents the real information behind TV shows like CSI. The author condensed the topic of forensics into three major areas: Signs of the Crime, Who Is It?, and Crime Lab. The aspiring forensic scientist can gain a wealth of information on such topics as evidence collection, DNA analysis, and fingerprinting.
PS-4.9

Holden, Alan (1982). **Crystals and Crystal Growing.** Cambridge: MIT Press
ISBN: 0-262-58050-0
Lexile: NA
This book gives step-by-step instructions for growing crystals.
PS-4.3

Rohrig, Brian (2002)**. 150 Captivating Chemistry Experiments Using Household Substances.** Columbus, OH: Fizzbang Science
ISBN: 0-9718480-2-5
Lexile: NA
This book uses common household substance to teach students about chemical reactions and changes.
PS-4.7 - 4.12

Rohrig, Brian (2002). **150 More Captivating Chemistry Experiments Using Household Substances.** Columbus, OH: Fizzbang Science
ISBN: 0-9718480-1-7
Lexile: NA
This book uses common household substance to teach students about chemical reactions and changes.
PS-4.7 - 4.12

Gardner, Robert. (2000). **Science projects About the Science Behind Magic**. Berkeley Heights, NJ:Enslow Publishers, Inc.
ISBN: 0-7660-1164-X
Lexile: NA
Five groups of suggested experiments that can be performed as magic demonstations are included. One of these groups is related to fundamental chemical effects. Young readers with inquisitive minds will be motivated to dig deeper.
PS- 4.7 - 4.9

Taylor, C. and Pople, S. (1995). **The Oxford Children's Books of Science.** New York: Oxford University Press
ISBN: 0-19-52153535-4
Lexile: NA
This book is divided into 22 sections covering the worlds of chemistry, physics and biology. The emphasis is on the "what and why" and is visually captivating.
PS-4.4, 4.7 – 4.9

Lister,T. (2005). **Kitchen Chemistry.** London: The Royal Society of Chemistry
ISBN: 0854043896
Lexile: NA
All food is made of chemicals so cooking can be thought of as a series of chemical reactions. This book consists of a variety of activities including class practical, demonstrations, paper-based activities. The approach can be stimulating for many students.

PS-4.7 - 4.9, 4.12

Greenberg,B. (1998). **Art in Chemistry.** Ontario: Teachers Ideas Press.
ISBN: 1-56308-487-2
Lexile: NA
The disciplines of art and chemistry may seem worlds apart but this excellent book brings them together - resulting in a meaningful, relevant and interesting new way of helping students grasp basic chemistry concepts. The abstract nature of chemistry can be explored in a way that helps students better visualize these concepts and thus better understand them.
PS-4.7 – 4.9

Gonick, L. (20005). **The Cartoon Guide to Chemistry**. New York: Harper Collins
ISBN: 0-06-093677-0
Lexile: NA
You don't need to be a scientist to grasp these and many other complex ideas, because this work explains them all: the history and basics of chemistry, atomic theory, combustion, solubility, reaction stoichiometry, the mole, entropy, and much more -- all explained in simple, clear, and yes, funny illustrations. Chemistry will never be the same!
PS-4.8 - 4.12

Suggested Streamline Video Resources

Physical Science: Elements, Compounds, and Atoms
ETV Streamline SC
Students will learn about elements and the chemical symbols used to represent them. They will also learn how elements combine to form compounds, as well as the difference between atoms and molecules.
Compounds (3:59)
PS-4.5

Physical Science Series: Chemical Bonding
ETV Streamline SC
Students will be introduced to the nature of chemical bonding and the characteristics of atoms that allow them to form bonds.
Introduction (1:15)
Atoms and Bonding (1:40)
Electrons and Energy Levels (1:01)
Stability and Chemical Bonds (1:37)
Common Types of Atomic Bonds (7:22)
Ionic Bonds (2:18)
Structure of Ionic Bonds (0:54)
Covalent Bonds (1:23)
PS-4.1 - 4.4

Elements of Chemistry: Compounds and Reactions
ETV Streamline SC
Elements bond together into compounds and it is these compounds that make up the great variety of substances. Students explore how different types of compounds are formed, and examine the chemical reactions of elements when they bond into other substances.
Ionic Bonds (3:21)
Covalent Bonding (4:07)
Chemical Reactions (3:29)
PS- 4.1-4.3 and 4.6-4.9

Physical Science Series: Chemical Reactions
ETV Streamline SC
This program introduces chemical equations and shows students how to balance chemical equations via colorful animation. Synthesis, decomposition, and replacement reactions are described. The energy dynamics and rates of reactions are explored.
Introduction to Chemical Reactions (0:49)
Traits of Chemical Reactions (1:48)
Chemical Equations (1:53)
Four Types of Chemical Reactions (3:12)
Exothermic and Endothermic Reactions (0:55)
Rates of Chemical Reactions (1:50)
PS – 4.6-4.11

Changes in the Properties of Matter: Physical and Chemical
ETV Streamline SC
This program has segments on chemical and physical changes.
Chemical Properties (1:16)
Physical Changes (6:43)
Chemical Changes (6:10)
PS - 4.6

Chemistry Connections: Corrosion Reactions
ETV Streamline SC
This program is excellent for explaining rusting of iron.
Suggested Segments:
Rust, the Corrosion of Iron (9:59)
Galvanizing (6:02) PS - 4.6

Simply Science: Reaction Equations
ETV Streamline SC
This program discusses formation and decomposition reactions; how to predict and test compound classification as ionic, molecular, acid or base; how to name the compounds involved; the law of conservation of mass; and how to balance equations.
Evidence of Reactions (2:44)
Formation Reactions (4:06)

Classifying Compounds (9:07)
Naming Compounds and Balancing Equations (5:33)
Decomposition Reactions (2:17)
PS - 4.4. - 4.10

Career Connections

Agricultural Chemists focus on chemical compositions and changes involved in the production, protection, and use of crops and livestock. Agricultural chemists study the causes and effects of biochemical reactions related to plant and animal growth, seek ways to control these reactions and develop chemical products. PS-4 requires a beginning understanding of basic composition and chemical changes as well as rates of reactions.

Analytical Chemists perform qualitative and quantitative analysis. They use their knowledge of chemistry, instrumentation, computers, and statistics to solve problems in almost all areas of chemistry. The basic ideas incorporated in PS-4 are extended to all aspects of research in industry, academia, and government.

Chemical Technicians play a vital role in a variety of industries, working with chemists and chemical engineers to develop, test, and manufacture chemical products. Their opportunities are diverse, depending on where they work, and their education, skills and experience. They operate standard laboratory equipment; set up apparatus for chemical reactions; perform chemical tests and experiments that involve various procedures; test for quality, performance or composition; and conduct a variety of laboratory procedures. The skill of technicians begins with the understanding of the chemistry concepts in PS-4.

Chemical Education is a challenging and rewarding job. Helping students grow, develop, and seek their potential is a tremendously inspiring job where one is always engaged in the practice and process of chemistry on a daily basis. PS-4 requires explanations for the way substances interact and is good beginning preparatory work for future teachers.

Chemical Engineers apply the principles of chemistry, math, and physics to the design and operation of large-scale chemical manufacturing processes. They translate processes developed in the lab into practical applications for the production of products such as plastics, medicines, detergents, and fuels; design plants and evaluate plant operations. The concepts of PS-4 are essential for such a career.

Chemical Information Specialists manage technical information in a variety of ways. Reading and analyzing data as in the PS-4 standard is good training for such a job. Presentation and organization of information is also a component. Opportunities in chemical information include being a scientific librarian, a technical publisher, a software developer, or market researcher.
http://mail.sci.ccny.cuny.edu/~phibarn/careers.html This site has numerous links

Chemical Sales is a synergy of scientific and business expertise. This field combines business and technical expertise. Two-thirds of marketers in the chemical industry have a technical degree. Today, scientific inquiry is more geared toward product development. Those who understand the properties and uses of materials as in PS-4 but who are well-suited to the more social aspects of marketing would enjoy a career in chemical sales.

Forensic Chemists apply knowledge from diverse disciplines such as chemistry, biology, materials science, and genetics to the analysis of evidence found at crime science or on/in the bodies of crime suspects. The results of their work are used in police investigations and court trials, at which they may be called upon to provide expert testimony and explain their findings to a jury. The concepts in PS-4 are embedded in such work.

Materials Scientists are concerned with the relationship between the structure and properties of materials such as PS-4 addresses. They are generally employed by industry or in laboratories where the focus is on developing product-related technologies. Persistence is highly desired in this field. Companies whose products include metals, ceramics, rubber, coatings, superconducting materials, and implants employ material scientists.

Science Writers and editors spend most of their time writing or reviewing articles and article proposals. They must keep up-to-date on major scientific and technical developments by reading press releases, articles, and original research papers. They attend science and technology conferences to report on discoveries presented there. They interview scientists and engineers and conduct literature searches. The ability to write imaginative and organized lab reports of PS-4 activities would be helpful when considering such a career.

www.chemistry.org.
Chemical Careers in Brief - Students can explore 30 different careers in chemistry. Each brief includes information on educational requirements, employment outlook, salaries, and the skills needed to pursue a career in each field. This is the website of the American Chemical Society.

http://www.southwestern.edu/academic/chemistry.dept/chem-careers.html
This site is an excellent one for careers. There are lists of careers, links and books listed.

Kahn, Jetty.(2000). **Women in Chemistry Careers.** Capstone This work describes the careers of five women working in the field of chemistry.
ISBN: 0-7368-0315-7   Lexile: 720

PS-4.1 Explain the role of bonding in achieving chemical stability.

Taxonomy Level: 2.7-B Understand/Explain Conceptual Knowledge

Previous/future knowledge: In the 7th grade students recognize that matter is composed of extremely small particles called atoms (7.1); classify matter as element, compound, or mixture on the basis of its composition (7.2); compare the physical properties of metals and nonmetals (7.3); and use the periodic table to identify the basic organization of elements and groups of elements (including metals, nonmetals, and families) (7.2).
In Physical Science students will expand their concepts of atoms and how they bond with other atoms to form compounds. A key concept will be the formation of chemical bonds to make the atoms more stable.

Key Concepts:
Stability: bond, noble gas configuration, helium structure
Ion
Nonmetals, Metals

It is essential for students to

- Understand that a noble gas electron configuration is *stable* and that all atoms would be more stable if they had this electron configuration.
  - Two electrons in the outside energy level compose a stable *helium structure*.
  - Eight electrons in the outside energy level is a stable structure for the other noble gases.
- Understand that when atoms bond chemically they do so to become more stable.
  - Group 1 and Group 2 metals tend to transfer electrons to Group 16 or Group 17 nonmetals to form ionic bonds.
    - Metals lose electrons to achieve a stable noble gas structure and nonmetals gain electrons to achieve a noble gas structure. When metals lose electrons and nonmetals gain electrons, they bond and become stable through ionic bonding.
  - Nonmetals bond with each other by sharing electrons to become stable through covalent bonding.

It is not essential for students to

- Understand hybridization of orbitals or exceptions to the octet rule. At this point students only need to know that atoms achieve stability through bonding to achieve a stable configuration of two or eight in the outside energy level.

Assessment Guidelines
The verb, *explain*, implies a cause and effect relationship. Since the verb for this indicator is explain the major focus of assessment will be for students to construct cause and effect models about how elements form bonds to attain two or eight electrons in the outer energy level.

In addition to explain, assessments may require that students

- *Summarize* the major points about elements bonding to achieve stability;
- *Compare* the number of electrons in a stable configuration and a less stable configuration;
- *Infer* whether bonded or unbonded atoms are more stable; or
- *Exemplify* elements that transfer electrons or share electrons.

PS-4.2 Explain how the process of covalent bonding provides chemical stability through the sharing of electrons.

Taxonomy Level: 2.7-B Understand/Explain Conceptual Knowledge

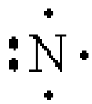
Previous/future knowledge: In the 7th grade students were introduced to atoms as summarized in indicator 7-4.1. In Physical Science students will explain the concept of covalent bonding and sharing electrons to become more chemically stable.

Key Concepts:
Covalent bond: sharing electrons, electron pair
Group

It is essential for students to

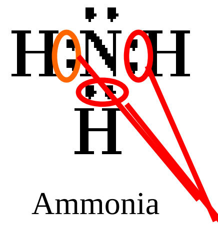
- Understand that nonmetals have less than the number of electrons that they need in order to have a stable outer-shell arrangement.
  - Nonmetals tend to gain electrons in order to become more stable.
  - In addition to gaining electrons two nonmetals can share electrons in order to become more stable
    - For example group 17 atoms can bond with other group 17 atoms by sharing one electron from each atom. Sharing electrons in this manner results in both atoms attaining eight electrons in their outer energy level.
    - The atoms would form one covalent bond consisting of two shared electrons.
    - The molecule formed is more stable than the individual atoms.
  - In water, oxygen shares two pairs of electrons, one pair with each of two hydrogen atoms, forming one covalent bond with each. This gives the oxygen atom eight outer energy level electrons and each hydrogen atom, two outer energy level electrons. All of the atoms in the molecule are stable.
  - There are many other combinations of nonmetals that achieve electron stability by sharing different numbers of electrons (2 or 8 electrons in the outer energy level).
- Show examples of covalent bonding or recognize examples of covalent bonding.
  - Examples may be in the form of "dot" diagrams, pictorial diagrams, or verbal descriptions.
    - Atomic illustrations must indicate which element the illustration represents and the number of electrons in the outer-most energy level of the atom (see PS-2.5).
    - Molecular illustrations must indicate the identity of the elements that compose the molecule and show all atoms sharing electrons in the outer-most energy levels such that each atom in the molecule has a complete outer-most energy level.
      - The shared pairs of electrons in the molecular illustration should be labeled as "covalent bonds"

Example of Electron Dot Diagrams



nitrogen atom

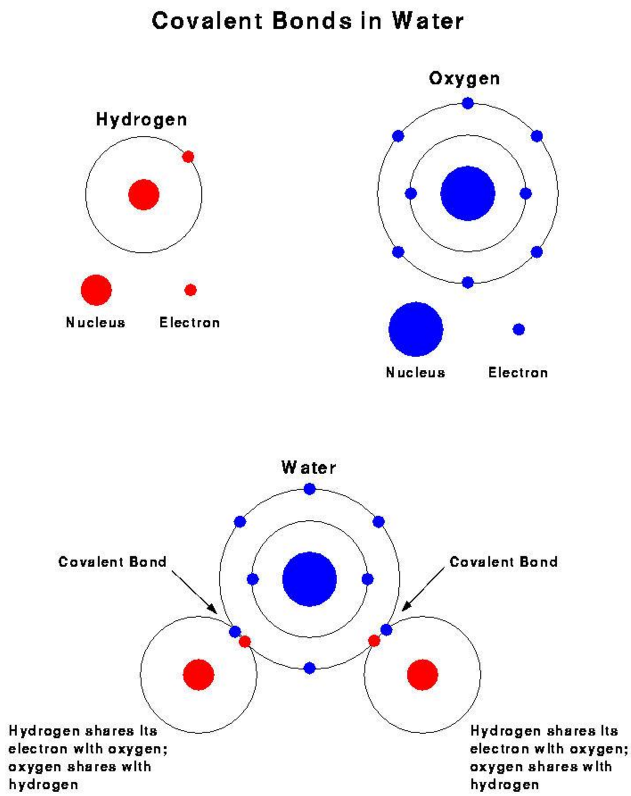
hydrogen atom



Ammonia molecule

Covalent bonds

Example of Pictorial Diagrams



Example of a Written Description

- An atom of Hydrogen has one electron in its outer-most energy level. Two electrons are required for hydrogen to have a stable outer-most energy level.
- An atom of Chlorine has seven electrons in its outer most-energy level. Eight electrons are required for chlorine to have a stable outer-most energy level.

- A molecule of Hydrogen Chloride forms when the one electron in the outer-most energy level of a hydrogen atom, and one of the electrons in the outer-most energy level of the chlorine atom are shared.
- The shared electrons occupy both the outer energy level of the chlorine atom and the outer energy level of the hydrogen atom. In the resulting molecule, the hydrogen atom has two electrons in its outer most energy level, (the original hydrogen electron and the electron it is now sharing from the chlorine atom) and the chlorine atom has eight electrons in its outer most energy level, (the original seven chlorine electrons and the electron it is now sharing from the hydrogen atom).
- The sharing of two electrons (one from each atom) is called a covalent bond.

It is not essential for students to:

- Understand double or triple covalent bonds.
- Understand molecular shapes.
- Understand resonance.
- Understand hybridization of orbitals

Assessment Guidelines

The verb, *explain*, implies a cause and effect relationship. Since the verb for this indicator is explain, the major focus of assessment will be for students to show not only that they know the effect - covalent bonds are formed – but also that they can "construct a cause and effect model". In this case, the atoms share electrons to achieve stability by having two or eight electrons in the outer energy level.

Because the indicator is written as conceptual knowledge, assessments must show that students can construct a cause and effect statement relating covalent bonds to sharing electrons and to achieving stability. Assessments will not only test the student's knowledge that covalent bonds are shared electrons but why they are formed.

In addition to explain, assessments may require that students to

- *Compare* covalently bonded atoms to unbonded atoms;
- *Summarize* covalent bonding and stable configurations;
- *Infer* that particular elements will form covalent bonds;
- *Represent* covalent bonds in dot diagrams, pictorial diagram or word descriptions;
- *Exemplify* covalently bonded compounds; or
- *Classify* bonds as covalent or not covalent.

PS-4.3 Illustrate the fact that ions attract ions of opposite charge from all directions and form crystal lattices.

Taxonomy Level: 2.2-B Understand/Illustrate Conceptual Knowledge

Previous/future knowledge: In the 7th grade students were introduced to atoms as summarized in indicator 7-4.1.
In Physical Science students will explain the concept of ionic bonding and transfer of electrons to become more chemically stable. Ions with opposite electrical charges attract and stick together to form a crystal lattice.

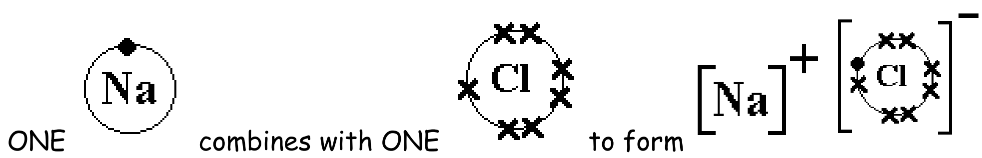
Key Concepts:
Ionic bonds: ions, electron transfer, crystal lattice
Stability: noble gas configuration
Groups

It is essential for students to

- Understand that metals tend to lose electrons to become stable, and that metals in groups 1 and 2 can most easily achieve a stable electron configuration by losing electrons. For example:
  - Group 1 metals have one electron in the outer energy level; Group 1 metals will tend to lose one electron and become an ion with a 1+ charge because the number of electrons is now one less that the number of positive protons.
  - Group 2 metals have two electrons in the outer energy level; Group 2 metals will tend to lose two electrons and become an ion with a 2+ charge because the number of electrons is now two less than the number of positive protons.
- Understand that nonmetals tend to gain electrons. For example:
  - Group 16 atoms have 6 electrons in the outside energy level; Group 16 atoms such as oxygen become stable by gaining two electrons and become an ion with a 2- charge because they now have two more negative electrons than positive protons.
  - Group 17 atoms have seven electrons in the outside energy level; Group 17 atoms such as chlorine can become stable most easily by gaining one electron to become an ion with a 1- charge because they now have one more negative electron than positive protons.
- Understand that ionic bonds form when positively charged metal ions attract negatively charged nonmetal ions due to the attraction between oppositely charged particles.
  - Positively and negatively charged ions surround each other and pack together as closely as possible to form an ionic crystal.
  - The ions cluster in a ratio that will cancel the net charge of the ions
- Show examples of ionic crystals or recognize examples of ionic crystals.
  - Examples may be in the form of pictorial diagrams, or verbal descriptions or electron dot formulas.
  - Illustrations of ions should indicate the name and the charge of the ion the illustration represents.

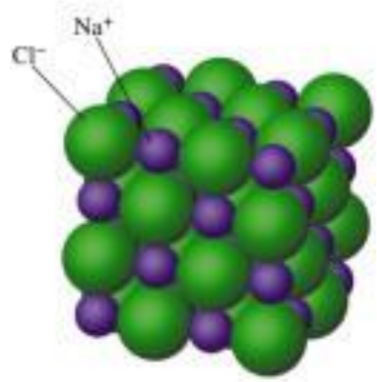
- Illustrations of crystals must indicate the identity of the ions that compose the crystal and show the ions in a crystal lattice. (PS-2.5)

For example



or

Pictorial diagram



It is not essential for students to:

- Predict the types of crystals that ions will form.
- Predict or explain ionic bonding for ionic crystals other than those formed by Groups 1,2,16, and 17 elements unless the charge of the ion is given.

Assessment Guidelines

The verb ***illustrate*** means to find a produce an illustration or use an illustration of a concept or principle; therefore, the major focus of assessment will be for students make or use diagrams, pictures, or word models that show they understand that positive metal ions and negative nonmetal ions attract each other to form crystals, understand that some of the elements form positive metal ions and some form negative nonmetal ions, and that crystals that form because the positive and negative ions stick together.

In addition to illustrate, assessments may require students to

- *Classify* substances as ionic crystals;
- *Summarize* ionic crystals and ions;
- *Compare* positive and negative ions;
- *Represent* ionically bonded compounds with diagrams or word descriptions; or
- *Exemplify* positive and negative ions.

PS-4.4 Classify compounds as crystalline (containing ionic bonds) or molecular (containing covalent bonds) based on whether their outer electrons are transferred or shared

Taxonomy Level: 2.3-B Understand/Classify Conceptual Knowledge

Previous/future knowledge: In the 7th grade students "translated chemical symbols and the chemical formulas of common substances to show the component parts of the substances (including NaCl [table salt], H_2O [water], $C_6H_{12}O_6$ [simple sugar], O_2 [oxygen gas], CO_2 [carbon dioxide], and N_2 [nitrogen gas])." (7-5.2)
In Physical Science students will expand their concepts of chemical compounds and elements by classifying the bonds as ionic or covalent and the combination as molecular or crystalline compounds.

Key Concepts:
Ionic bonds: electron transfer, ions
Covalent bonds: shared electrons

It is essential for students to

- Understand that generally, when metals react with nonmetals, they form compounds that are crystalline and have ionic bonds.
  - Understand that metals tend to gain electrons. For example:
    - Group 1 metals have one electron in the outer energy level; Group 1 metals will tend to lose one electron and become an ion with a 1+ charge in order to form noble gas electron configuration
    - Group 2 metals have two electrons in the outer energy level; Group 2 metals will tend to lose two electrons and become an ion with a 2+ charge in order to form noble gas electron configuration.
  - Understand that nonmetals tend to gain electrons. For example:
    - Group 16 atoms have 6 electrons in the outside energy level; Group 16 atoms such as oxygen become stable by gaining two electrons and becoming an ion with a 2- charge.
    - Group 17 atoms have seven electrons in the outside energy level; Group 17 atoms such as chlorine can become stable most easily by gaining one electron and become an ion with a 1- charge. Group 1 or Group 2 metals react with Group 16 or Group 17 nonmetals
- Understand that in general when metals react with nonmetals, electrons are transferred from the metals to the nonmetals.
  - The metals form positive ions and the nonmetals form negative ions.
  - Positively charged metal ions attract negatively charged nonmetal ions.
  - These positive and negatively charged ions pack together as closely as possible in a crystal lattice to form an ionic crystal.
- Understand that when nonmetals form compounds with other nonmetals, they form covalent bonds.
  - Nonmetals will share electrons with each other to become stable.
  - Bonds formed by sharing electrons are covalent bonds.
  - Compounds that have covalent bonds are molecules.

It is not essential for students to:

- Classify covalently bonded molecules other than combinations of nonmetals unless they are told that the electrons are shared.
- Understand percent ionic character.

Assessment Guidelines

As the indicator states, the major focus of assessment is to *classify* given examples of crystalline (ionic bonding) or molecular (covalent bonds). As the taxonomy verb is classify, as opposed to distinguish, the assessment item should expect students to classify ionic compounds or covalent molecules based on their position on the periodic table or valence electrons. Students may need to use the periodic table to classify.

As conceptual knowledge, assessment items will require that students understand the criteria for each category. Memorizing that certain compounds belong to specific categories will not be sufficient.

In addition to classify, assessments may require that students

- *Exemplify* (find a specific example) of an ionic or covalent compound;
- *Compare* ionic and covalent bonds molecular or crystalline compounds;
- *Summarize* the major points that define each category;
- *Summarize* ionic and covalent bonding; or
- *Infer* that bonds are ionic or covalent.

PS-4.5 Predict the ratio by which the representative elements combine to form binary ionic compounds, and represent that ratio in a chemical formula.

Taxonomy Level: 2.5-B Understand/Predict Conceptual Knowledge

Previous/future knowledge: In the 7th grade students "translated chemical symbols and the chemical formulas of common substances to show the component parts of the substances (including NaCl [table salt], H_2O [water], $C_6H_{12}O_6$ [simple sugar], O_2 [oxygen gas], CO_2 [carbon dioxide], and N_2 [nitrogen gas])." (7-5.2)
In Physical Science students will predict the ratio and write formulas for binary ionic compounds.

Key Concepts:
Binary ionic compounds
Chemical formula
Balanced charge

It is essential for students to
- Predict the charge of the ions that the atoms in Groups 1, 2, 16, and 17 will attain.
  - Group 1 metals form 1+ ions,
  - Group 2 metals form 2+ ion,
  - Group 16 nonmetals form 2- ions,
  - Group 17 nonmetals form 1- ions.
- Understand the meaning of symbols and subscripts in chemical formulas.
- Understand that compounds do not have a net charge.
- Write balanced formulas for ionic compounds.
  - Balance the charges in chemical formulas of compounds that contain ions of the elements in Groups 1,2,16, and, 17 without being given the charges on the ions
  - Balance the charges on binary ionic compounds for any elements that form ionic compounds when the charges on the ions are given, thereby predicting the ratio of the ions in the formula of the resulting ionic compound.

It is not essential for the students to:
- Balance formulas for ionic compounds other than Group 1, 2, 16, and 17 unless charges are given
- Understand percent ionic character.

Assessment Guidelines
The first objective of this indicator is to ***predict*** the ratio of ions in binary ionic compounds. Predict means to draw a logical conclusion from presented information. Students can predict the charges for Groups 1,2,16, and 17 ions based on the periodic table and predict that they will form ionic bonds when the metals react with the nonmetals. If other *metal* elements are used, the ionic charges of these ions must be given. Another objective is to ***represent*** this ratio in the form of a chemical formula; therefore students must balance the formula. Conceptual knowledge involves the interrelationship among the basic elements within a larger structure the enable them to function together. Students will understand that ions will form ionic compounds in ratios that produce no net charge.

In addition to predict, assessment may require students to

- *Infer* charges of Groups 1, 2, 16, and 17 ions;
- *Recognize* balanced ionic formulas;
- *Exemplify* ions with 1+, 2+, 1-, or 2- charges; or
- *Classify* elements that will form 1+, 2+, 1-, or 2- charges.

PS-4.6 Distinguish between chemical changes (including the formation of gas or reactivity with acids) and physical changes (including changes in size, shape, color, and/or phase)

Taxonomy Level: 4.1 B Analyze/Distinguish Conceptual Knowledge

Previous/future knowledge: In the 7th grade students compared physical properties of matter (including melting or boiling point, density, and color) to the chemical property of reactivity with a certain substance (including the ability to burn or to rust) (7-5.9); and compared physical changes (including changes in size, shape, and state) to chemical changes that are the result of chemical reactions (including changes in color or temperature and formation of a precipitate or gas) (7-5.10). The 7th grade students were also introduced to acids (7-5.6).
In Physical Science the students will expand the concept for evidences of chemical changes that include the formation of a gas and reactivity with acids. They will expand their concept for evidences of physical changes to include changes in phase, size, shape, and color. Students will look at these evidences and determine the relevance of the evidence to distinguish changes that are physical from those that are chemical.

Key Concepts:
Chemical changes: gas formation
Acids
Physical changes: phase change

It is essential for the student to

- *Understand Chemical Changes*
  - ***When a chemical change occurs there is a change in the arrangement of the atoms involved so a different substance with different properties is produced. When a chemical reaction takes place some type of evidence can be observed.***
    - ***One type of evidence might the formation of a gas. This gas is not a phase change but is a new molecule formed by a chemical reaction. An example of this type of reaction would be the reaction of baking soda with vinegar. Carbon dioxide gas is formed which is evidence that a chemical reaction has occurred. The atoms are rearranged and a new substance (carbon dioxide) is formed.***
  - The reaction of a substance with an acid is another chemical change
    - Active metals react with acids. The metal will replace the hydrogen in the acid and form a salt and hydrogen gas. The atoms are rearranged and new substances are formed with different properties so this is a chemical change.
    - Acids react with bases to form water and a salt. The atoms are rearranged and new substances are formed with different properties so this is a chemical change.
  - Color change may be evidence that chemical change has occurred. Metal tarnishing and changing color is a chemical change because in this case atoms are rearranged and a new substance is formed. The tarnish is a compound formed when the metal and another substance (such as oxygen) combine.

- ***Understand physical changes***
  - When physical changes occur a new substance is not produced.
    - A substance may change size, such as being broken into smaller pieces,
    - A substance may change in shape, such as being bent or stretched,
    - A substance may expand or contract due to a temperature change.
  - Color may indicate a physical change.
    - When different colors of paint, crayon, or food coloring are mixed together a mixture is formed and the color changes. No rearrangement of the atoms occurs. You still have the same substances that you started with they are just mixed together. This is a physical change.
  - Phase changes (freezing, melting, evaporation, sublimation, etc.) are physical changes.

It is not essential for students to write chemical equations to show that chemical changes (reactions) have occurred for this indicator.

Assessment Guidelines
In order to insure that students can *distinguish* chemical changes, like gas formation, from physical changes, such as boiling, assessments should require that students identify the relevant or important aspects of the change necessary for classification, in this case, that the composition of the substance undergoes a change when a gas is formed. The composition of the substance does not change when a liquid boils. In order to do this, students must have a conceptual understanding of gas formation and boiling as well as an understanding of the distinction between chemical and physical changes. Assessments may require that students be able to recognize what is relevant information for classifying boiling or evaporation as a physical change and formation of a different gas as a chemical change. With all of these examples of changes in the indicator, the students should be able to determine the reason it is classified as that type of change.

In addition to distinguish, assessments may require that students
- *Classify* these changes as chemical or physical changes;
- *Exemplify* chemical and physical changes;
- *Recognize* or *recall* changes as chemical or physical;
- *Infer* from a description of a change whether it is a chemical change or not; or
- *Compare* physical and chemical changes.

PS-4.7 Summarize characteristics of balanced chemical equations (including conservation of mass and changes in energy in the form of heat—that is, exothermic or endothermic reactions)

Taxonomy Level: 2.4-B Understand/Summarize Conceptual Knowledge

Previous/future knowledge: Students in the 7th grade "explained how a balanced chemical equation supports the law of conservation of matter." (7-5.8)

Key Concepts:
Chemical equation: balanced equation, conservation of mass
Energy change: exothermic, endothermic

It is essential for the student to

- Understand that a balanced equation represents the process of a chemical reaction where atoms are rearranged but not created or destroyed.
  - The equation shows that the same atoms that existed before the chemical reaction are still there after the reaction. Mass is conserved.
- Understand that there is always an energy change when a chemical reaction occurs.
  - If heat is given off it is called an *exothermic* reaction. This type of reaction adds heat to the area around the reaction, so this area will become warmer.
  - If heat is absorbed it is called an *endothermic* reaction. This type of reaction takes heat from the area surrounding it, so the area around the reaction will become cooler.

If is not essential for the student to:

- Predict whether a reaction will be endothermic or exothermic or give reasons why.
- Calculate heat released or absorbed.

Assessment Guidelines

The objective of this indicator is to *summarize* the concepts involved in balanced chemical equations including conservation of mass and endothermic or exothermic reactions. When students summarize this concept, they abstract a general theme or major points about balanced equations in the context of conservation of mass and changes in energy. It is important that assessments go beyond recall of factual knowledge since conceptual knowledge is an understanding of the interrelationships in the model of mass conservation. Students should also summarize the major points in the concepts of exothermic and endothermic reactions.

In addition to summarize, assessments may require that students

- *Compare* endothermic and exothermic reactions;
- *Infer* that endothermic or exothermic reactions have occurred given evidence (Such as the beaker the reaction occurs in becomes cold.); or
- *Exemplify* characteristics of reactions.

PS-4.8 Summarize evidence (including the evolution of gas; the formation of a precipitate; and/or changes in temperature, color, and/or odor) that a chemical reaction has occurred.

Taxonomy Level: 2.4-B Understand/Summarize Conceptual Knowledge

Previous/future knowledge: Students in the 7^{th} grade "Compared physical properties of matter (including melting or boiling point, density, and color) to the chemical property of reactivity with a certain substance (including the ability to burn or to rust) (7-5.9); and "Compared physical changes (including changes in size, shape, and state) to chemical changes that are the result of chemical reactions (including changes in color or temperature and formation of a precipitate or gas)" (7-5.10).

Key Concepts:
Evolution of a gas
Precipitate
Chemical reaction

It is essential for students to

- Understand that when a chemical reaction occurs, there is some observable evidence, but evidence that a chemical reaction has occurred should be weighed carefully. Evidence is not proof. It is the combination of evidences that give validation for a chemical or physical change.
  - When bubbles form, it may be evidence that a chemical reaction has occurred and that a gas has been formed.
    - An example of this is adding an active metal such as zinc to a hydrochloric acid solution. Hydrogen gas will evolve. This is evidence that a chemical reaction has occurred.
    - Bubbles could also be evidence that boiling, which is a physical change, is occurring.
  - When a precipitate forms, it could be evidence that an insoluble solid has formed and fallen out of solution. This is a chemical reaction.
    - An example of this is adding a solution of silver nitrate to a solution of sodium chloride, a white precipitate of silver chloride is formed.
    - It could also be true that some of a substance that was dissolved has fallen out of solution because of a change in conditions. This is a physical change.
  - In all chemical reactions there is an energy change.
    - When paper burns, heat and light are given off. This would be evidence that a chemical reaction has occurred.
    - Many physical changes also involve an energy change. For instance, melting is an endothermic change.
  - Color change can be an evidence for a chemical change.
    - When silver tarnishes it changes color. This is a chemical change.
    - It can also be change due to physical factors such as a change in the way light is shining on an object or the mixing of different colors of paint. This is not a chemical change.

- An odor being given off is often evidence that a chemical reaction has occurred.
    - When ammonium carbonate is heated the odor of ammonia gas can be detected. This is a chemical reaction.
    - Odor can also occur because molecules are evaporating from the surface of a substance, which is a physical change.

It is not essential for the student to provide the reasons for the exceptions to the evidence. (When a gas evolves, the student should reason that this is evidence, not proof, that a chemical reaction has occurred).

Assessment Guidelines

The objective of this indicator is to *summarize* the concepts involved in finding evidence of a chemical reaction. When students summarize this concept they abstract a general theme or major points about evidences for chemical and physical changes. It is important that assessments go beyond recall of factual knowledge since conceptual knowledge is an understanding of the interrelationships in a model of a chemical reaction.

In addition to summarize, assessments may require that students

- *Infer* that reactions occur when certain evidence is presented or
- *Exemplify* or *illustrate* chemical reactions.

PS-4.9 Apply a procedure to balance equations for a simple synthesis or decomposition reaction.

Taxonomy Level: 3.2-C Apply Procedural Knowledge

Previous/future knowledge: Students in the 7th grade "explained how a balanced chemical equation supports the law of conservation of matter." (7-5.8)
In Physical Science students will expand concept of balanced chemical equations. Students will write balanced formulas for some ionic compounds. Students will apply a procedure to manipulate coefficients to balance some chemical equations.

Key Concepts:
Balanced equation: coefficients, subscripts
Synthesis equation
Decomposition equation

It is essential for students to

- Understand that a *balanced equation* represents a chemical reaction that rearranges atoms but does not create or destroy them.
  - The same number of every atom on the reactant side must also be on the product side.
  - C*oefficients* and *subscripts* are used in specific ways to show the number of atoms represented.
- Manipulate the coefficients to balance the atoms in the equation for a simple *synthesis* or *decomposition* reaction.

  Example of a synthesis reaction equation:

  $4Al + 3O_2 \rightarrow 2Al_2O_3$

  Example of a decomposition reaction equation:

  $2 NaCl \rightarrow 2Na + Cl_2$

It is not essential for students to:

- Write balanced formulas for molecular compounds.
- Balance equations other than for simple synthesis or decomposition reactions.

Assessment Guideline:
The objective of this indicator is to *apply* the procedure for balancing a chemical equation. Apply means to carry out a procedure. The students will know the procedure for balancing the equations and can apply it to the situations of balancing simple synthesis and decomposition reactions.

In addition to applying procedural knowledge to balance equations the student should be able to

- *Recognize* balanced equations;
- *Summarize* the number of each type of atom on each side;
- *Infer* that the number of each type of atom will remain the same; or
- *Exemplify* synthesis and decomposition equations.

PS-4.10 Recognize simple chemical equations (including single replacement and double replacement) as being balanced or not balanced.

Taxonomy Level: 1.1-B Remember/Recognize Conceptual Knowledge

Previous/future knowledge: Students in the 7th grade "explained how a balanced chemical equation supports the law of conservation of matter" (7-5.8).
In Physical Science students expand the concept of balanced chemical equations by recognizing when certain equations are balanced or not balanced.

It is essential for students to

- Understand that a balanced equation represents a chemical reaction that rearranges atoms but does not create or destroy them. The same number of every atom on the reactant side must also be on the product side.
- Understand the meaning of the coefficients and subscripts with respect to how many atoms are represented.

It is not essential for students to balance single replacement or double replacement (ion exchange) reactions, only recognize that they are balanced.

Assessment Guidelines

The objective of this indicator is to *recognize* that chemical reactions are balanced. Recognize means retrieving relevant knowledge from long-term memory. Students need to *recall* what makes an equation balanced and should *recognize* or *identify* it as balanced but are not required to balance single and double replacement reactions for this indicator.

PS-4.11 Explain the effects of temperature, concentration, surface area, and the presence of a catalyst on reaction rates.

Taxonomy Level: 2.7-B Understand/Explain Conceptual Knowledge

Previous/future knowledge: In the 7th grade students "compared physical changes (including changes in size, shape, and state) to chemical changes that are the result of chemical reactions (including changes in color or temperature and formation of a precipitate or gas)." (7-5.10)
In Physical Science students will expand their concept of chemical reactions. For the first time students will explain factors that affect the rate of reaction. Students will explain the affect that changes in temperature, concentration, surface area, and the presence of a catalyst have on reaction rate.

Key Concepts:
Reaction rate factors: temperature, concentration, surface area, catalyst
Particle collisions

It is essential for students to

- Understand that chemical reactions occur when reactants collide with sufficient energy to react. Factors that affect reaction rate are as follows:
  - *Temperature:* When the temperature increases, the rate of a chemical reaction increases.
    - ♦ The average kinetic energy of the molecules of reactants increases with increased temperatures.
    - ♦ There will be more reactant particles with enough energy to react producing more successful collisions and the reaction will proceed faster.
  - *Concentration:* When reactants are more concentrated, the rate of a chemical reaction will increase.
    - ♦ There is a greater chance that reactant particles will collide when they are more concentrated.
    - ♦ More collisions mean a faster reaction rate.
  - *Surface Area:* When the surface area of reactants increases, the reaction rate increases.
    - ♦ Chemical reactions occur when reactants collide at the surface of other reactants.
    - ♦ If the particle size is smaller (with the same mass of reactants) there is a greater surface area and there is a greater chance for collisions to occur and the chemical reaction will proceed faster.
  - *Catalyst:* The presence of a catalyst will speed up a chemical reaction.
    - ♦ A catalyst lowers the amount of energy needed to start a reaction (activation energy).
    - ♦ Since the energy needed for successful collisions is less, there will be more successful collisions and the chemical reaction will proceed faster.

It is not essential for students to
Understand why a catalyst lowers activation energy or define activation energy.

Assessment Guidelines
The verb, *explain*, implies a cause and effect relationship. Since the verb for this indicator is explain, the major focus of assessment will be for students to show not only that they know the effect of temperature, surface area, concentration, and presence of a catalyst, on reaction rate but also that they can "construct a cause and effect model". In this case, these changes affect the rate of successful collisions and, thus, the rate of the reactions. Because the indicator is written as conceptual knowledge, assessments should require that students understand interrelationships. Assessments will not only test the student's knowledge that these factors affect the rate of reaction but also why they affect the rates.

In addition to explain, assessments may require that students
- *Compare* reaction rates under different conditions;
- *Summarize* the effects of changes in temperature, surface area, concentration and presence of a catalyst on reaction rates;
- *Infer* the effects of changes in temperature, surface area, concentration and presence of a catalyst on reaction rates; or
- *Exemplify* factors that affect reaction rates.

Standard PS-5: The student will demonstrate an understanding of the nature of forces and motion.

Supporting Content Websites

Teachers Domain – Galileo: His Experiments
http://www.teachersdomain.org/9-12/sci/phys/mfw/galileoexp/index.html
Simulates dropping of two different masses.
PS-5.5

Teachers Domain – Galileo on the Moon
http://www.teachersdomain.org/9-12/sci/phys/mfw/galmoon/index.html
Shows video of a hammer and a falcon feather being dropped on the moon.
PS-5.5

Teachers Domain – Galileo's Incline Plane
http://www.teachersdomain.org/9-12/sci/phys/mfw/galileoplane/index.html
Shows video of a replica of Galileo's incline plane and his discover that the velocity is equal to the acceleration multiplied times the time elapsed and that the distance traveled is proportional to the square of the time elapsed. Interesting science research work by Galileo (even though the mathematics is more than what is needed for Physical Science).
PS-5.5

Montana State University, Bozeman – Conceptual Astronomy and Physics Education Research Team – Welcome to the Student Difficulties in Physics Information Center
http://www.physics.montana.edu/physed/misconceptions/index.html
Discusses common misconceptions students have in physics, describes specific misconceptions and cites research. Good teacher reference.
PS-5.1,6

Glenbrook, IL Public Schools, The Physics Classroom – Describing Motion with Position vs. Time Graphs
http://www.glenbrook.k12.il.us/gbssci/phys/Class/1DKin/U1L3a.html
Gives summaries on interpreting one dimensional position vs. time graphs.
PS-5.6

The Physics Classroom – One Dimensional Kinematics
http://www.physicsclassroom.com/mmedia/kinema/cnv.html
Observe an object moving to the left while graphs are created that show Position-Time, Velocity-Time, and Acceleration-Time.
PS-5.6

Suggested Literature

William Robertson, Ph.D, *Stop Faking It! Force & Motion*, NSTA press, 2002.

Book guides the teacher (and/or student) to common understandings about the basics of force and motion. There are easy-to-understand explanations with activities using commonly found equipment. The book will lead the reader through Newton's laws and gravity explanations with concrete examples, clear language, and diagrams.

Robert Gardner. *Experiments with Motion,* Enslow, 1995.
Easy-to-do experiments better illustrate the text and allow a student to understand Newton's Laws of Motion and their application to space flight as well as to the movement of animals and vehicles. Diagrams, explicit lists of materials needed, answers to puzzles, and a bibliography contribute to the usefulness of this work.

Robert W. Wood. *Mechanics Fundamentals*, Learning Triangle Press/McGraw-Hill, 1996.
Important principles of physics, specifically relating to the effect of forces on objects at rest or in motion, are explained through the simple-to-perform experiments in this book. Line drawings illustrate all experiments and a glossary explains new terms.

Suggested Data Streaming Video

Science Investigations Physical Science: Investigating Motion, Forces and Energy
2004 Discovery Channel School
Several segments focus on the ways different forces affect motion.

Speed and Acceleration
9:05
PS-5.1-4

Physics of Roller Coaster Forces
4:37
PS-5.7, PS-5.5

Basics of Physics: Exploring Laws of Motion
Program focuses on Newtons Three Laws – examples help the understanding of inertia, force/mass/acceleration, and actions/reactions.
21:16
PS-5.7

Basics of Physics: Exploring Gravity
1993 United Learning
Program explores gravity through demonstration and activities.
16:20
PS-5.5, PS-5.10

Career Connections

Road Traffic Accident Investigator
Mechanical Engineer
Civil Engineer

PS-5.1 Explain the relationship among distance, time, direction, and the velocity of an object

Taxonomy Level: 2.7-B Understand/Explain Conceptual Knowledge

Key Concepts

Distance, displacement
Speed: average speed, instantaneous speed, initial speed, final speed
Velocity: average velocity, instantaneous velocity, initial velocity, final velocity
Rate

Previous/future knowledge: In 5th grade, students "summarize the motion of an object in terms of position, direction, and speed". In 8th grade, students "use measurement and time-distance graphs to represent the motion of an object in terms of its position, direction, or speed" and also "Use the formula for average speed, v = d/t to solve real-world problems."
Physical Science requires that students expand on the idea that direction is an important aspect of the motion of an object. Students will compare the concepts of distance and displacement. The term "velocity" is used for the first time, and students will differentiate speed and velocity. The concept of how direction is an important aspect of motion is the basis for the study of vector motion in subsequent physics classes. Also, an understanding of the duel nature of velocity (speed and direction) is essential before students can understand how forces affect the motion of objects (Newton's laws of motion).

It is essential for students to:

- Understand ***Distance and Displacement****:*
  - *Distance* is a measure of "how far an object has moved" and is independent of direction.
    - ♦ If a person travels 40m due east, turns and travels 30m due west, the *distance* traveled is 70m
  - *Displacement* has both magnitude and direction. It is a change of position in a particular direction. For example: 40m east is a displacement.
  - *Total* or *final displacement* refers to both the distance and direction of an object's change in position from the starting point or origin.
    - ♦ If a person travels 40m due east, turns and travels 30m due west, the *total displacement* of the person is 10m east.
    - ♦ If a person travels 40m east and then travels another 50m east the *total displacement* is 90m east.
- Understand ***Speed****:*
  - *Speed* is how fast something is going. It is a measure of the distance covered per unit of time and is always measured in units of distance divided by units of time. (The term "per" means "divided by")
  - Speed is a *rate* as it is a change (change in distance) over a certain period of time
  - Speed is independent of direction.
  - The speed of an object can be described two ways

- *Instantaneous speed* is "the speed at a specific instant". *Initial speed* and *final speed* are examples of instantaneous speed. A speedometer measures instantaneous speed.
- *Average speed* is "the total distance covered in a particular time period"
    - If an object is traveling at a constant speed, the instantaneous speed at each point will be equal to the average speed.
    - If an object is traveling with varying speeds, the average speed is the total distance covered divided by the total time.

- Understand ***Velocity****:*
    - *Velocity* refers to both the speed of an object and the direction of its motion.
    - A velocity value should have both speed units and direction units, such as: m/sec north, km/hr south, cm/sec left, or km/minute down.
    - Velocity is a rate because it is a change in displacement over a certain period of time.
    - The velocity of an object can be changed in two ways:
        - The speed of the object can change (it can slow down or speed up).
        - The direction of an object can change. (A racecar on a circular track moving at a constant speed of 100 km/hr has a constantly changing velocity because of a changing direction of travel.)
    - The velocity of an object can be described two ways:
        - *Instantaneous velocity* is "the velocity at a specific instant". *Initial velocity* and *final velocity* are examples of instantaneous velocity.
        - *Average velocity* is "the total (final) displacement in a particular time".

Assessment Guidelines
As the verb for this indicator is *explain* the major focus of assessment will be for students to "construct a cause and effect model". In this case, assessments will ensure that students can model the effects of distance and time on the speed of an object and know that the velocity of an object is a description of the effects of speed and direction. The applicable model of velocity involves the effects of displacement and time.

Because the indicator is written as conceptual knowledge, assessments must show that students can construct a cause and effect statement relating how each variable affects the motion of the object, as well as the effect of combinations of variables on motion.

In addition to *explain*, assessments may require that students:
- *exemplify* how each variable influences the motion of an object;
- *compare* distance to displacement and velocity to speed;
- *summarize* the effect of each variable on the motion of an object;
- *infer* from experimental data the relative speed or velocity of an object (faster vs. slower)

PS-5.2 Use the formula v = d/t to solve problems related to average speed or velocity.

Taxonomy Level: 3.2-C Apply/Use Procedural Knowledge

Key Concepts:
v: average speed, average velocity
d: distance, displacement
t: elapsed time

Previous/future knowledge: 8th grade students "Use the formula for average speed, v = d/t to solve real-world problems." (In 8th grade the term is "speed" even though the variable is a "v") In PS-5.1 students develop a conceptual understanding of the idea that direction is an important aspect of the motion of an object and compare the concepts of distance and displacement. The term "velocity" is used for the first time and students differentiate speed and velocity (PS-5.1). This indicator addresses the mathematical dimension of motion solving for average velocity or speed.
Physical Science students will need to rearrange the equation v = d/t to solve for any of the variables.

It is essential for students to

- Understand the correct context for the variables in the word problem when using the equation v = d/t.
  - In the equation, "v" can represent either velocity or speed and "d" can represent either displacement or distance, depending on the context of the problem. The differences are addressed in PS-5.1
  - The term "speed" or "velocity" refers to average speed or velocity.
  - Students must determine the "given" information in a problem using the correct units. See sample table:

Variable	Abbreviation	Units	Direction required?	Examples	
Speed	v	distance/time	No direction	m/sec	22 cm/yr
Velocity	v	distance/time	With direction	m/sec north,	36 km/hr west
Distance	d	distance	No direction	15m	30.0 km
Displacement	d	distance	With direction	546 km down	24.9 m west
Time	t	Time	NA	15 sec	32 days

- Use the formula, v = d/t.
  - Students must be able to calculate average speed.
    - ♦ When calculating *average speed* using v = d/t: The average speed for the trip equals the total distance divided by the total time. Ignore the direction of the motion.
  - Students must be able to calculate average velocity.
    - ♦ When calculating *average velocity* using v = d/t: the average velocity is equals the total displacement divided by the total time.
      - ∗ The total displacement may be different from the total distance.

        * When indicating the average velocity, direction must be given and the average velocity will have the same direction as the total displacement.
        * The total displacement is the distance and direction from the starting point.
        * If the direction of the motion is changing, the velocity will not be constant even if the speed is constant.
    - Students must be able to rearrange the equation to solve for any of the variables. Example: d = vt, or t = d/v
    - The instantaneous velocity at any point will not necessarily be the same as the average velocity.

Teacher note:
The students are only responsible for velocity problems in which the total or final displacement is given.

<u>It is not essential for students to</u>

- Solve problems in standard English units nor convert Standard English units to metric units
- Solve problems involving scientific notation.
- Calculate average velocity using displacement when total displacement is not given. (They do not need to solve for total displacement first.)
- Solve velocity problems involving vector addition.

Assessment Guidelines
As the verb for this indicator is <u>*use*</u>, the major focus of assessment will be for students to show that they can "apply a procedure to an unfamiliar task". The knowledge dimension of the indicator is <u>procedural knowledge</u>. In this case the procedure is the application of the velocity equation. The unfamiliar task is a novel word problem or set of laboratory data. A key part of the assessment will be for students to show that they can apply the knowledge to a new situation, not just repeat problems that are familiar. This requires that students have a conceptual understanding of each of the variables (see PS-5.1), as well as mastery of the skills required to implement the mathematical equation in order to solve for any of the variables when given the other two.

PS-5.3 Explain how changes in velocity and time affect the acceleration of an object.

Taxonomy Level 2.7-B Understand/Explain Conceptual Knowledge

Key Concepts
Acceleration

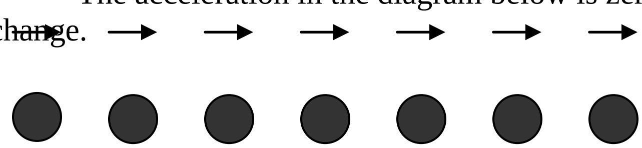
Previous/future knowledge: In 8th grade, students "Use measurement and time-distance graphs to represent motion of an object in terms of its position, direction, or speed." (8-5.1); "Analyze the effects of forces (including gravity and friction) on the speed and direction of an object" (8-5.3) and "Analyze the effect of balanced and unbalanced forces on an object's motion in terms of magnitude and direction" (8-5.5). These indicators address how forces influence the motion of an object, and in each case the answer is that a force can cause the speed of an object to increase or decrease or the direction of the object's motion to change. However, 8th grade students do not consider the concept of acceleration.

With an understanding of velocity in terms of speed and direction (PS-5.1 and PS-5.2), Physical Science students have the foundation necessary to develop an understanding of the concept of acceleration as the rate of change in the velocity of an object, in terms of either speed or direction.

It is essential for students to understand:

- Motion diagrams for:
  - *Constant Velocity*: The first motion diagram, shown is for an object moving at a constant speed toward the right. The motion diagram might represent the changing position of a car moving at constant speed along a straight highway. Each dot indicates the position of the object at a different time. The dots are separated by equal time intervals. Because the object moves at a constant speed, the displacements from one dot to the next are of equal length. The velocity of the object at each position is represented by an arrow. The velocity arrows are of equal length (the velocity is constant).

The acceleration in the diagram below is zero because the velocity does not change.

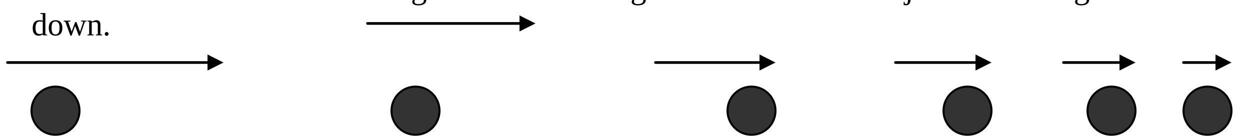


  - *Constant Positive Acceleration* (speeding up): This motion diagram represents an object that undergoes constant acceleration toward the right in the same direction as the initial velocity. This occurs when your car speeds up to pass another car. Once again the dots represent schematically the positions of the object at times separated by equal time intervals. Because the object accelerates toward the right, its velocity arrows increase in length toward the right as time passes. . The displacement between adjacent positions increases as the object moves right because the object moves faster as it travels right.

The acceleration in the diagram below is positive because the object is speeding up.

- *Constant Negative Acceleration* (slowing down): This type of motion occurs when a car slows down. The dots represent schematically the positions of the object at equal time intervals. Because the acceleration is opposite the motion, the object's velocity arrows decrease by the same amount from one position to the next. Because the object moves slower as it travels right, the displacement between adjacent positions decreases as the object moves right.

The acceleration in the diagram below is negative because the object is slowing down.



It is essential for the students to understand:

- That *acceleration* is a measure of the change in velocity (final velocity - initial velocity) per unit of time. When the velocity of an object is changing, it is accelerating.
- That if the object slows down, the change in velocity ($v_f - v_i$) is negative so the acceleration is negative and conversely when the object is speeding up the acceleration is positive.
- That both the change in velocity and the time it takes for that change to occur are important when considering the acceleration of an object.
  - When comparing the acceleration of two objects that have the same change in velocity, the one that undergoes the change in the least amount of time has the greatest acceleration.
  - When comparing the acceleration of two objects that accelerate over the same interval of time, the one that undergoes the greatest change in velocity accelerates the most.
- That acceleration is always measured in velocity (distance/time) units divided by time units.

Example: Acceleration is change velocity divided by time. The unit for velocity is m/s and the unit for time is second so the unit for acceleration is m/s/s. This is derived from velocity (m/s) divided by time (s).

- Students should understand acceleration units conceptually as "change in velocity over time" rather than "distance over time squared".
  - Students should understand that the time units may be the same for the velocity part of acceleration as they are for the time part, but they do not have to be.
  - Students should understand the meaning of time units that are different in the velocity part of the equation and denominator such as km/hr per second.
  - The most common acceleration units in the metric system are m/s/s or m/s^2.
- The velocity of an object can change two ways, so an object can accelerate in two ways:
  - The speed can increase or decrease
  - The direction can change.
    - Students need only recognize that the object is accelerating because the direction (and therefore the velocity) of the object is changing.

It is not essential for students to solve mathematical problems involving acceleration for an object that is changing direction.

Assessment Guidelines

As the verb for this indicator is *explain* the major focus of assessment will be for students to "construct a cause and effect model". In this case, assessments will ensure that students can model the effect of changes in velocity and/or time on the motion of an object and understand that the acceleration of an object is a description of the effect of those variables.

In addition to *explain*, assessments may require that students

- *exemplify* how each variable influences the motion of an object;
- *compare* negative and positive acceleration;
- *summarize* the effect of each variable on the motion of an object; *infer* from experimental data the relative acceleration (greater rate of acceleration vs. lesser rate of acceleration) of two objects.
- *recognize* accelerated motion on a motion diagram.

PS-5.4 Use the formula $a = (v_f - v_i)/t$ to determine the acceleration of an object.

Taxonomy Level: 3.2-C Apply/Use Procedural Knowledge

Key Concepts:
Acceleration: initial velocity, final velocity
Elapsed time

Previous/future knowledge: In 8th grade, students "Analyze the effects of forces (including gravity and friction) on the speed and direction of an object" and "Predict how varying the amount of force or mass will affect the motion of an object." So 8th grade students are familiar with the idea that the speed and direction of an object can change, however, not until the previous indicator in physical science are students introduced to the concept of acceleration. The concept of acceleration has many dimensions and the mathematics involved in analyzing accelerated motion is vast. In Physics students will derive equations to analyze circular motion, trajectory motion, and complex vector problems, all of which begin with a fundamental understanding of an understanding of the equation introduced here: $a = (v_f - v_i)/t$

The purpose of this indicator is to introduce Physical Science students to the mathematical aspects of acceleration. By calculating, using dimensional analysis in the calculation of acceleration, students will see that the final units for acceleration are m/sec^2 or m/s/s.

It is essential for students to:
- Interpret a word problem, or laboratory data involving the motion of an object that is accelerating in one direction and determine the "given" information:
- Differentiate velocity from speed if the direction is given. If velocity is given, students should record the direction.
- Differentiate initial velocity (speed) from final velocity (speed) from the context of the problem.

Teacher note: As this is an introduction to the mathematical application of the concept of acceleration, the units given to students should be consistent. (The units for initial and final velocity should be the same.)

Students need to list the given variables using the correct units:

Variable	Abbreviation	Units	Examples	
Initial velocity (or speed)	v_i	distance/time (direction)	5.0 m/sec east	22km/hr
Final velocity (or speed)	v_f	distance/time (direction)	2.0 m/sec east	36 km/hr
Elapsed time	t	Time	15 sec	32 hrs

It is essential for student to:
- Use the equation $a = (v_f - v_i)/t$ solve for acceleration (only)
- Substitute the correct values into the equation, including the correct units.

- Mathematically solve the problem, using dimensional analysis to derive the units of the answer. (see dimensional analysis PS-1.5)
- Check to make sure that the units calculated from the dimensional analysis match the appropriate units for the acceleration (distance/time divided by time or distance divided by time-squared).
- Understand that negative acceleration means that velocity is decreasing.

It is not essential for students to

- Solve problems to convert Standard English units to metric units.
- Solve problems involving scientific notation.
- Solve the equation for initial velocity, final velocity, change in velocity, or elapsed time.

Assessment Guidelines

As the verb for this indicator is *use*, the major focus of assessment will be for students to show that they can "apply a procedure to an unfamiliar task". In this case the procedure is the application of the acceleration equation to an unfamiliar word problem or set of experimental data. Students will apply the formula to new situations, not just problems that are familiar. This requires that students have a conceptual understanding of each of the variables (see PS-5.1), as well as mastery of the skills required to implement the mathematical equation in order to solve for acceleration.

In addition assessments should require students to:

- *recognize* when the formula should be applied; or
- *compare data* using the formula.

PS-5.5 Explain how acceleration due to gravity affects the velocity of an object as it falls.

Taxonomy Level: 2.7-B Understand/Explain Conceptual Knowledge

Key Concepts
Acceleration due to gravity: a_g

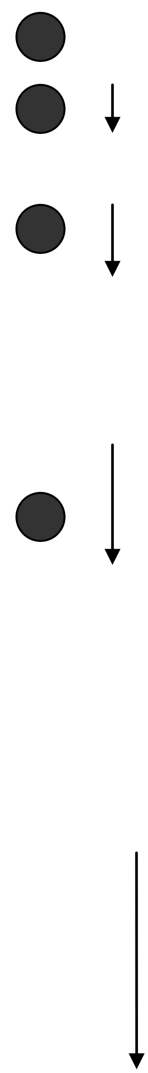
Previous/future knowledge: In 8th grade, students were introduced to gravitation as a force and the effect that gravitational force has on the speed of objects as they "Analyzed the effects of forces (including gravity and friction) on the speed and direction of an object" (8-5.3).

In Physical Science PS-5.6 will address the relationship between force and acceleration in more detail. The major emphasis of this indicator (PS-5.5) is the behavior of objects as they accelerate during free fall, not the reason that they accelerate.

It is essential for students to understand:

- That all objects accelerate as they fall because Earth continually exerts a force (gravitational force) on them.

  The diagram depicts the position of a freefalling object at regular time intervals. The fact that the distance which the ball travels every interval of time is increasing is a sure sign that the ball is speeding up as it falls downward. If an object travels downward and speeds up, then it accelerates downward.



- That when an object is released it accelerates.
- That the direction of the force is always downward.
- That the acceleration is in the direction of the force so the direction of the acceleration is downward as well.
- That when an object is dropped it has an initial velocity of 0.0 m/sec.
- The object will accelerate at a constant rate of $9.8 m/s^2$ or m/s/s.
  - This means that the object will speed up at a constant rate of 9.8 m/sec every second it is falling in the absence of air resistance.
- The value, 9.8m/sec per sec., is called the *acceleration of gravity* and has the symbol a_g.
- That since the object is accelerating because of Earth's gravity, the velocity of the object continues to increase in speed and continue in a downward direction until it hits the ground.

Students must understand the meaning of the values on the chart in terms changing velocity.

	v_i	v_f
1st sec	0.0 m/sec	9.8 m/sec

2nd sec	9.8 m/sec	19.6 m/sec
3rd sec	19.6 m/sec	29.4 m/sec
4th sec	29.4 m/sec	39.2 m/sec
5th sec	39.2 m/sec	49.0 m/sec

It is not essential for students to

- Consider the motion of free-falling objects influenced by other forces such as
  - Air resistance
  - Exerted forces such as rocket boosters
- Consider the motion of objects which have been projected upward
- Consider trajectory motion
- Calculate values such as distance fallen, elapsed time, final velocity, or other values.

Assessment Guidelines

As the verb for this indicator is *explain* the major focus of assessment will be for students to "construct a cause and effect model" of the concept of acceleration of gravity. Students should model how the velocity and the displacement of an object varies with time as the object falls. Because the indicator is written as conceptual knowledge, assessments must show that students can construct a cause and effect statement relating how the velocity and the displacement of an object vary with time as the object falls.

For general assessment purposes acceleration due to gravity may be given as 10 m/s/s (10 m/s^2).

In addition to *explain*, assessments may require that students:

- *illustrate* how velocity and displacement change as an object falls, or
- *summarize* how velocity and displacement change as an object falls.
- *interpret* diagrams of objects in freefall.

PS-5.6 Represent the linear motion of objects on distance-time graphs.

Taxonomy Level: 2.1-B Understand/Represent Conceptual Knowledge

Key Concepts

Previous/future knowledge: In 5th grade students, "use a graph to illustrate the motion of an object". In 8th grade, students "use measurement and time-distance graphs to represent the motion of an object in terms of its position, direction, or speed".

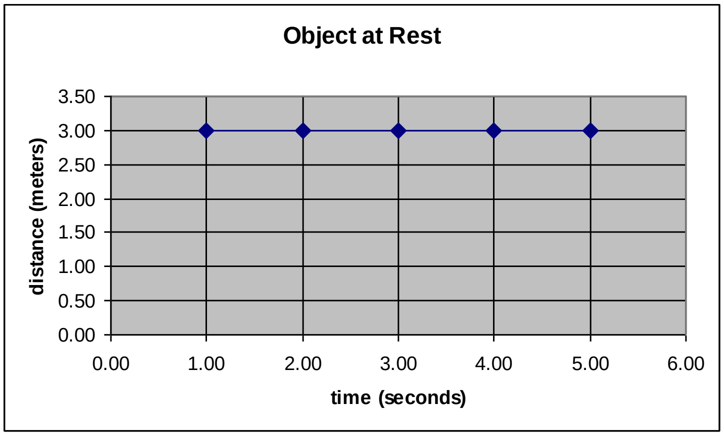
In Physical Science, students will again focus only on graphs of distance vs. time, but the focus here will be for students to understand and compare the shape of distance-time graphs for a variety of different types of motion.

It is essential for students to:

- Construct distance/time graphs from data showing the distance traveled over time for selected types of motion (rest, constant velocity, acceleration).
- Compare the shape of these three types of graphs and recognize the type of motion from the shape of the graph.
- Discuss in words the significance of the shapes of the graphs in terms of the motion of the objects.

(1) ***An object at rest***
Example:

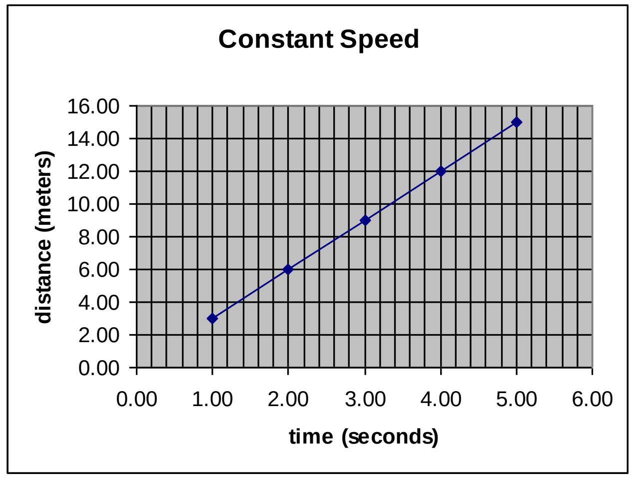
Elapsed Time (sec)	Total Distance Traveled (meters)
1.00	3.00
2.00	3.00
3.00	3.00
4.00	3.00
5.00	3.00



The shape of the graph is flat, because between the 1st and 6th second no distance is covered.

(2) ***An object with constant speed***
Example:

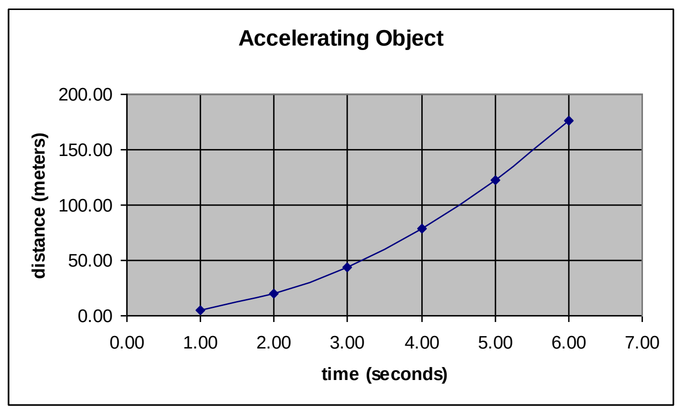
Elapsed Time (sec)	Total Distance Traveled (meters)
1.00	3.00
2.00	6.00
3.00	9.00
4.00	12.00
5.00	15.00



The shape of the graph is a diagonal straight line. The object covers the same amount of distance in each time period. As the time increases, the distance increases at a constant rate.

Elapsed Time (sec)	Total Distance Traveled (meters)
1.00	4.90
2.00	19.60
3.00	44.10
4.00	78.40
5.00	122.50
6.00	176.40

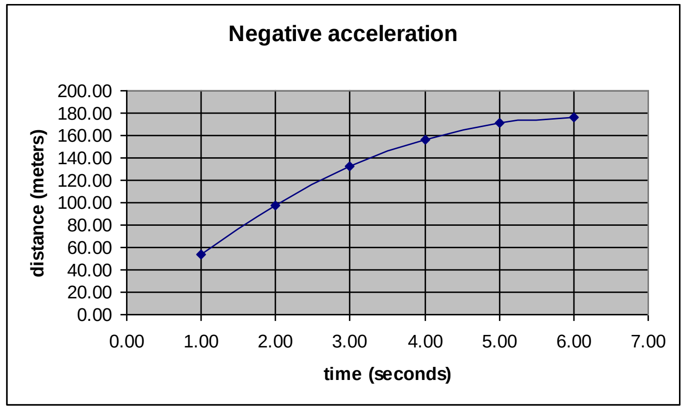
(3a) ***An accelerating object*** (the example below is a falling object) – positive acceleration
Example:



The shape of the graph is a curve getting steeper because as time goes by, the object covers more distance each second than it did in the previous second so the amount that the graph goes up each second gets more and more.

(3b) ***A negatively accelerating object*** (an object slowing down)
Example:

Elapsed Time (sec)	Total Distance Traveled (meters)
1.00	53.90
2.00	98.00
3.00	132.80
4.00	156.80
5.00	171.50
6.00	176.40



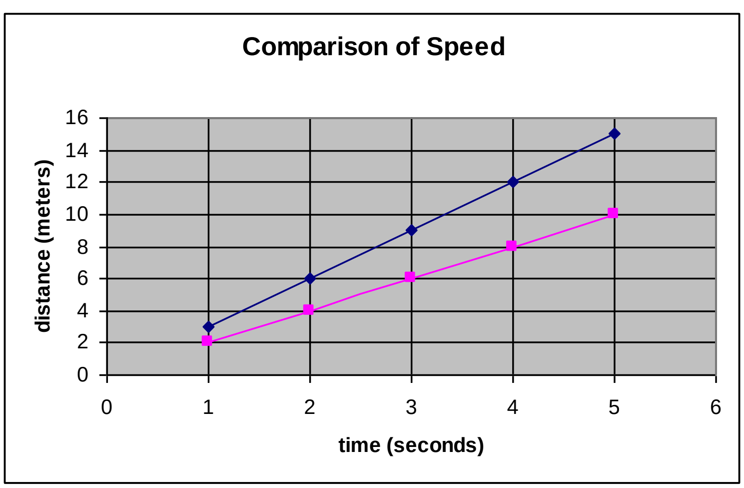
The shape of the graph is a curve getting flatter because as time goes by, the object covers less distance each second than it did in the previous second, so the amount that the graph goes up each second gets less and less.

It is essential for students to:

- **C**onstruct distance time graphs from data that compare the motion of objects.
- Discuss the significance of the shapes of the graphs in terms of the relative motion of the objects.

(1) ***A comparison of two objects traveling at different speeds***
Example:

Elapsed Time (sec)	Total Distance Traveled (meters) Object 1	Total Distance Traveled (meters) Object 2
1.00	3.00	2.00
2.00	6.00	4.00
3.00	9.00	6.00
4.00	12.00	8.00
5.00	15.00	10.00

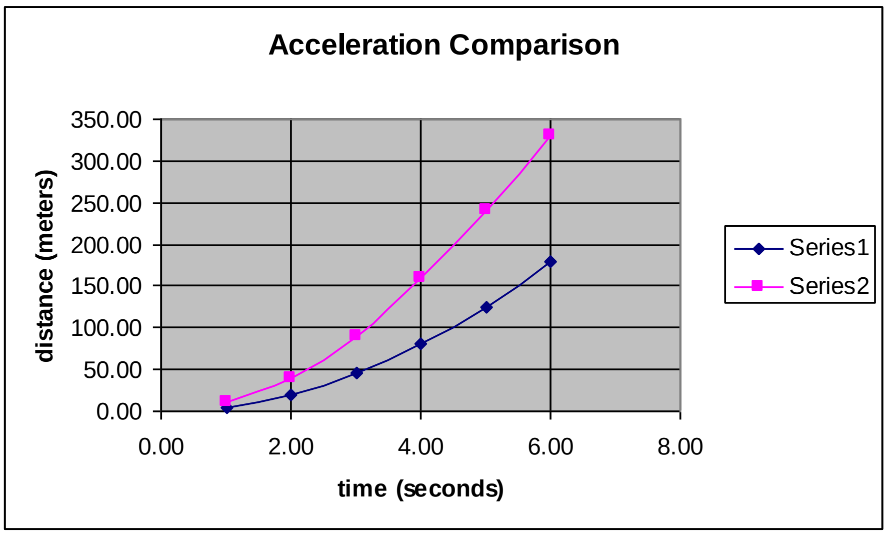


Both objects are traveling at a constant speed but the object represented by the top line is traveling faster than the lower one. You can tell this because the amount that the graph goes up each second (which represents the amount of distance traveled) is more for the top line than for the bottom one.

(2) ***A comparison of two objects accelerating at different rates***

Example:

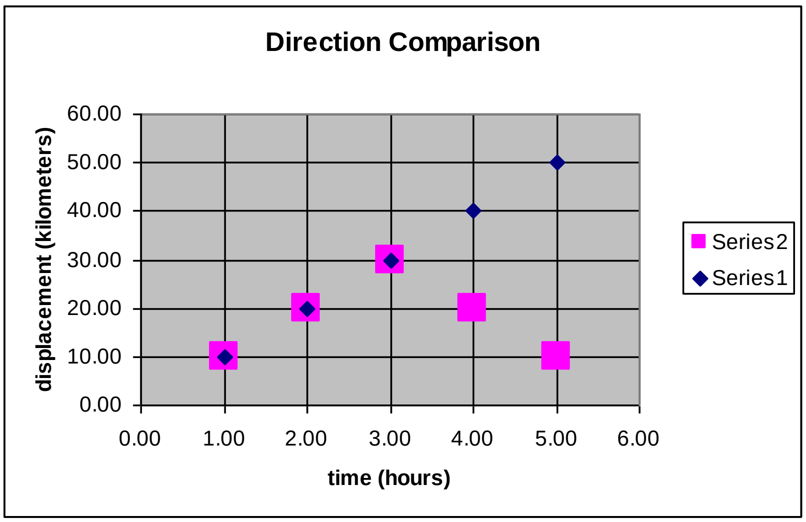
Total elapsed Time (seconds)	Total distance traveled (meters) Object 1	Total distance traveled (meters) Object 2
1.00	5.00 M	10.00 m
2.00	20.00 M	40.00 m
3.00	45.00 M	90.00 m
4.00	80.00 M	160.00 m
5.00	125.00 M	240.00 m
6.00	180.00 M	330.00 m



Both of the objects are accelerating but the Series 2 object (bottom curve) is accelerating at a greater rate than the Series 1 object. Both objects cover more distance each second than they did during the previous second, but the amount of increase for the pink object is more than the amount of increase for the blue object.

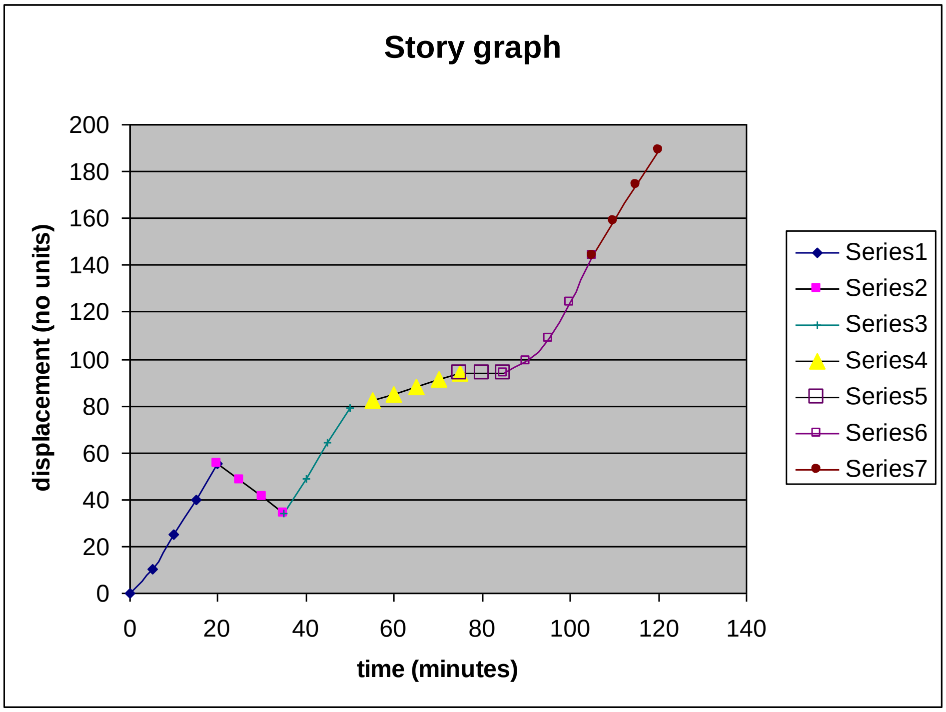
(3) A comparison of two objects traveling in different directions at a constant speed, (to show this, a displacement-time graph is required)

Elapsed Time (sec)	Total Displacement (meters) Object 1	Total Displacement (meters) Object 2
1.00	10.00 km W	10.00 km W
2.00	20.00 km W	20.00 km W
3.00	30.00 km W	30.00 km W
4.00	40.00 km W	20.00 km W
5.00	50.00 km W	10.00 km W



This is a displacement-time graph (displacement/location is distance and direction) so it shows how far each object is from the starting point after each second. The series 1 object gets farther and farther away. At the 3rd hour, the series 2 object turns around and comes back toward the start. The speed of each object is the same.

It is essential for a student to infer a possible story given a graph like this one.



Possible explanation.

- ♦ At first the object is traveling at a fairly constant velocity, away from the starting point.
  (Series 1)
- ♦ Then it turns and goes at a constant velocity back towards the starting position. (Series 2)
- ♦ It changes directions again and goes away from the starting point at about the original constant velocity. (Series 3)
- ♦ From about 55 minutes to 75 minutes it moves at a slower constant velocity. (Series 4)
- ♦ From about 75 minutes to about 85 minutes the object does not move. (Series 5)
- ♦ From about 85 to 110 minutes it accelerates in a positive direction. (Series 6)
- ♦ From about 95 minutes until about 110 minutes its velocity is about the same as the original velocity and fairly constant. (Series 7)

It is not essential for students to

- Construct or analyze velocity-time or acceleration-time graphs
- Determine velocity by mathematically calculating the slope of the graphs. Students should be able to interpret the meaning of the "steepness" of a graph.
- Graph any motion other than that which has been addressed.

Assessment Guidelines

As the verb for this indicator is *represent* the major focus of assessment will be for students to "change from one form of representation to another", in this case, the motion of an object is presented as graphical representation. The type of graph is restricted to distance/time or displacement/time graph, the type of motion is restricted to rest, constant velocity, or constant acceleration. The samples of graphs given above are only examples. It is not important that students know those specific graphs, but it is vital that students can apply their knowledge of graphical analysis of motion to any novel set of data, verbal description, or graphical analysis of motion.

In addition to *represent*, assessments may require that students:

- *exemplify* by finding a specific example of a type of graph which is appropriate for a given data set or verbal description of motion;
- *classify* the type of motion (rest, constant speed, or acceleration) by the shape of a distance time graph;
- *summarize* the shapes of graphs which represent specific types of motion;
- *infer* by extrapolating, interpolating, predicting the motion of an object based on a given graph of the object's motion; or
- *compare* the motion of two objects from graphical representations of their motion.

PS-5.7 Explain the motion of objects on the basis of Newton's three laws of motion: inertia; the relationship among force, mass, and acceleration; and action and reaction forces.

Taxonomy Level: 2.7-B Understand/Explain Conceptual Knowledge

Key Concepts
1st Law: Inertia, Law of Inertia, net force, newton
2nd Law: applied force, friction, air resistance
3rd Law: action force, reaction force

Previous/future knowledge: In 5th grade students are introduced to net force as they "explain how unbalanced forces affect the rate and direction of the motion in objects". In 8th grade, as foundation for Newton's first law, students "summarize and illustrate the concept of inertia". Also in 8th grade, as foundation for Newton's second law, students "predict how varying the amount of force or mass will affect the motion of an object."
In Physical Science, students have an understanding of the difference between constant velocity and accelerated motion. Students can now use Newton's first law of motion to explain how an object's inertia affects its motion in terms of speed and direction.
Students can use Newton's second law to explain how applied forces can affect the motion of an object in terms of speed and direction.
Newton's third law is an entirely new concept for Physical Science students.

Newton's First Law of Motion
It is essential for students to understand:

- That a force is a push or a pull that one object exerts on another object and that in the metric system, force is measured in units called *newtons* (N).
- That a *net force* is an unbalanced force. It is necessary to find the net force when one object has more than one force exerted on it.
- *Newton's First Law* states, "The velocity of an object will remain constant unless a net force acts on it." It is often called the *Law of Inertia*.
  - If an object is moving, it will continue moving with a constant velocity (in a straight line and with a constant speed) unless a net force acts on it.
  - If an object is at rest, it will stay at rest unless a net force acts on it.
  - *Inertia* is the tendency of the motion of an object to remain constant in terms of both speed and direction.
- That the amount of inertia that an object has is dependent on the object's mass. The more mass an object has the more inertia it has.
- That if an object has a large amount of inertia (due to a large mass)
  - It will be hard to slow it down or speed it up if it is moving
  - It will be hard to make it start moving if it is at rest
  - It will be hard to make it change direction.
- That inertia does not depend on gravitational force. Objects would still have inertia even if there were no gravitational force acting on them. (Far out in the middle of empty space)

- The behavior of moving objects in terms of the effect of inertia. Examples might include:
  - The fact that it is harder to turn a battleship than a rowboat or
  - People involved in a car stopping suddenly.
    - ♦ If a net force (braking force) is exerted on the car in a direction opposite to the motion, the car will slow down or stop.
    - ♦ If the people in the car are not wearing their set belts, because of their inertia, they keep going forward until something exerts an opposite force on them.
    - ♦ The people will continue to move until the windshield (or other object) exerts a force on them.
    - ♦ If the people have their seatbelts on when the braking occurs, the seatbelt can exert a force to stop the forward motion of the person.
- The reason that objects do not keep moving in our experience is always because there is a net force acting on them.
  - Students need to explain how friction as a net force slows or stops a variety of every-day objects.

Newton's Second Law of Motion

It is essential for students to understand:

- *Newton's Second Law* states, "When a net force acts on an object the object will accelerate in the direction of the net force".
  - The larger the net force, the greater the rate of acceleration.
  - The larger the mass of the object, the smaller the rate of acceleration
- Acceleration can mean speeding up, slowing down, or changing direction;
- The role that friction and air resistance have in determining the net force (friction and air resistance will often be ignored in discussions and problems, but students should be aware of its role in determining the net force).

It is essential that students understand:

- The motion of objects in terms of force, mass and acceleration.
- *The effects of force***:**
  - *Force magnitude*: If the mass of an object remains constant, the greater the net force the greater the rate of acceleration.
  - *Force direction:*
    - ♦ If the force is applied to an object at rest, the object will accelerate from rest to some speed (depending upon the magnitude of the force) in the direction of the force.
    - ♦ If the force is applied to a moving object in the same direction that the object is moving, the object will accelerate from its speed before the force to a greater speed and continue to travel in the same direction
    - ♦ If the force is applied to a moving object in a direction opposite to the direction that the object is moving, the object will have negative acceleration and slow down from its speed before the force was applied to a slower speed. It will either continue at the slower speed, stop, or begin to move in the opposite direction, depending on the magnitude of the force.

- *The effect of mass:*
  - If the same net force is applied to two objects, the object with the smaller mass will accelerate at the greater rate, in the direction of the applied force.

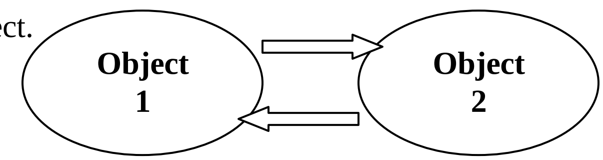
It is not essential for students to:

- Address forces in directions other than the same or opposite. (Vectors are not addressed)
- Understand the factors that affect friction.
- Differentiate sliding and rolling friction

Newton's Third Law of Motion

It is essential for students to understand

- *Newton's Third Law* states, "When one object exerts a force on a second object, the second one exerts a force on the first that is equal in magnitude and opposite in direction."
  - This law is called the "*Law of Action and Reaction*".
  - Even though the forces are equal in magnitude and opposite in direction, they do not cancel each other. This law addresses <u>two</u> objects, each with only <u>one</u> force exerted <u>on</u> it.
    - Each object is exerting one force on the other object.
    - Each object is experiencing only one force.



It is essential that for students to

Describe the motion of familiar objects in terms of action and reaction forces.
Examples may include:

- A swimmer is accelerating forward
  - The swimmer pushes against the water (action force) the water pushes back on the swimmer (reaction force) and pushes her forward.
- A ball is thrown against a wall
  - The ball puts a force on the wall (action force) and the wall puts a force on the ball (reaction force) so the ball bounces off.
- A person diving off a raft
  - The person puts a force on the raft (action force) pushing it and the raft puts a force on the diver (reaction force) pushing her in the opposite direction.
- A person pushes against a wall (action force) and the wall exerts an equal and opposite force against the person (reaction force).

It is not essential for students to understand or work problems involving momentum.

Assessment Guidelines

As the verb for this indicator is <u>*explain*</u> the major focus of assessment will be for students to "construct a cause and effect model" regarding the laws of motion. In this case, students will model the motion of objects in terms of each of Newton's Three Laws of Motion. Because the indicator is written as <u>conceptual knowledge,</u> assessments must show that students can construct cause and effect models that explain the familiar motion of objects in terms of the effect of applied forces and the mass of the objects on their speed and direction. The models may be in the form of verbal descriptions or diagrams.

In addition to *explain*, assessments may require that students:

- *exemplify* how mass and net force influence the rate of acceleration of an object;
- *compare* the rate of acceleration of objects with different masses or the rate of acceleration of an object when subjected to different forces (in terms of magnitude and direction);
- *compare* action and reaction forces in terms of magnitude, direction, source of force (which object) and recipient of the force (which object);
- *summarize* the effect of the mass of the object and relative magnitude or direction of force on the rate of acceleration of an object;
- *infer* from data the relative acceleration (greater rate of acceleration vs. lesser rate of acceleration) of two objects

PS-5.8 Use the formula F = ma to solve problems related to force.

Taxonomy Level: 3.2-C Apply/Use Procedural Knowledge

Key Concepts:
Applied force
Frictional force
Net force

Previous/future knowledge: 8^{th} grade students "Analyze the effects of forces (including gravity and friction) on the speed and direction of an object."
This indicator for Physical Science addresses the mathematical dimension of force by solving problems related to force, mass, and acceleration.

It is essential for students to
- Understand the correct context for the variables in a word problem.
- Understand that a *newton* is defined as the amount of force necessary to accelerate a 1.0 kg object at a rate of 1 meter/second/second. force = (mass)(acceleration)
  - The newton is a *derived* unit so when you multiply mass times acceleration, if mass is in kilograms and acceleration is in m/s/s you have the proper units for newtons (Kg·m/s/s or Kg·m/s^2).
- Mathematically solve problems for force, mass, or acceleration, using dimensional analysis to identify the units of the answer. (See dimensional analysis PS-1.5)
- Determine the "given" information using the correct units,
  - Mass should be given in kilograms, acceleration in m/s/s, or m/s^2, and force in newtons.
- Solve problems for any of the variable in the formula, F = ma. For example, the problem may give net force and mass and the student must find the acceleration (a = F/m).

It is not essential for students to
- Solve problems in Standard English units or convert Standard English units to metric units
- Solve problems involving scientific notation.
- Solve two-step problems that require first finding acceleration from initial velocity, final velocity and time
- Solve problems involving friction.

Assessment Guidelines
As the verb for this indicator is *use*, the major focus of assessment will be for students to show that they can "apply a procedure to an unfamiliar task" involving the mathematical formula, F = ma. In this case the procedure is the application of the equation for Newton's Second Law of Motion for an unfamiliar word problem or a set of data. This requires that students *recognize* each of the variables and can *summarize* the effect they have on one another (see PS-5.1), as well as mastery of the skills required to implement

the mathematical equation in order to solve for any of the variables when given the other two.

PS-5.9 Explain the relationship between mass and weight by using the formula $F_W = ma_g$

Taxonomy Level: 2.7-B Understand/Explain Conceptual Knowledge

Key Concepts
Force-weight (F_w)

It is essential for students to understand:

- That objects accelerate as they fall and that the only way that an object can accelerate is for a net force to act on it.
- For objects in freefall, neglecting air resistance, the net force acting on falling objects is the *gravitational force* exerted by Earth.
- The amount of force that the earth exerts on an object depends on the mass of the object.
  - The greater the mass, the greater the gravitational force.
- The amount of gravitational force that the earth exerts on an object is called *weight.*
  - As $9.8 m/sec^2$ is the acceleration of gravity for all objects (a_g), the weight of any object (F_w) can be calculated by multiplying the mass of the object times the acceleration of gravity. $F_w = ma_g$

It is essential for students to:
Solve problems involving the relationship among the weight and mass of objects and the acceleration of gravity using the formula $F_w = ma_g$. (This formula is sometimes written, $w = mg$.)

It is not essential for students to

- Solve problems in standard English units or convert Standard English units to metric units
- Solve problems involving scientific notation.
- Solve multi-step problems for this indicator that involve:
  - Determining the mass of an object from an applied net force and subsequent acceleration
  - Determining the acceleration of an object from the initial velocity, final velocity and the time
  - Determining the mass of an object from its weight in order to use the mass in another context.
- Solve problems that require considering opposing forces such as wind resistance or considering the forces on objects moving upward.

Assessment Guidelines
As the verb for this indicator is ***explain*** the major focus of assessment will be for students to "construct a cause and effect model" of the determination of and relationships between mass and weight.
This indicator also instructs students to "*use*" the equation as a tool for explaining. Therefore, a second focus of assessment will be for students to show that they can "apply

a procedure to an unfamiliar task". In this case the procedure is the application of the equation finding weight from mass using an unfamiliar word problem or set of data. Students should have a conceptual understanding of the relationship between weight and mass as well as mastery of the skills required to implement the mathematical equation in order to solve for any of the variables when given the other two.

In addition to ***explain***, assessments may require that students:

- ***summarize*** the relationship between the mass and the weight of an object; or
- ***compare*** the quantities of mass and weight in terms of the value each is measuring, the units for each, and the relationship between the two.

PS-5.10 Explain how the gravitational force between two objects is affected by the mass of each object and the distance between them.

Taxonomy Level: 2.7-B Understand/Explain Conceptual Knowledge

Key Concepts
Newton's Law of Universal Gravitation

Previous/future knowledge: Although students have been studying the concept of weight as a force, the concept of a force as something that exists equally between two objects is a new idea. In addition, until this point students have thought of gravity as a phenomenon peculiar to the earth or other planets. The idea that all objects exert forces on all other objects is a new concept.

It is essential for students to understand:

- *Newton's Law of Universal Gravitation* states that there is a force of attraction between all objects in the universe.
- The Law of Universal Gravitation applies to all objects.
- When considering the force of attraction between any two objects:
  - The force is greater when the mass of either of the two objects is greater.
    - Earth, with its huge mass has a relatively large attractive force with all of the objects near its surface.
    - The moon has less mass than Earth, so the moon has less attraction for objects on its surface than Earth does. (Objects on the surface of the moon weigh less than on Earth because the gravitational force of the moon is less than the gravitational force of Earth.)
  - The reason we do not notice the attraction between ordinary sized objects when we are on earth is that the force that the earth exerts on objects is so great; the force of attraction between other objects is very small.
    - The closer the two objects are, the greater the force
    - When an object such as a space vehicle moves away from Earth, the gravitational attraction between Earth and the vehicle becomes less and less.
- That if the force acting on a falling object is the same as the force acting on the earth, the object accelerates toward the earth while Earth doesn't seem to accelerate at all. This is because the mass of the earth is so huge, a small force causes only a very tiny acceleration, one that is undetectable by humans.

It is not essential for students to

- Understand the equation that represents Newton's Law of Universal Gravitation.
- Use Newton's Law of Universal Gravitation to solve any problems quantitatively.
- Understand the "inverse square" relationship of force and distance.
- Understand the significance of the Gravitation constant.

Assessment Guidelines
As the verb for this indicator is ***explain*** the major focus of assessment will be for students to "construct a cause and effect model" about gravitational force. In this case, assessments will ensure that students can model the gravitation force as a force between any two objects, rather than the force that the earth exerts on an object. The model should further reflect (conceptually) the effect that the mass of the objects and the distance between the objects has on the force. Students should construct cause and effect models that explain the behavior of familiar objects (falling objects, weight on the moon) in terms of the gravitational model. The models may be in the form of verbal descriptions or diagrams.

In addition to *explain*, assessments may require that students:
- *exemplify* how mass and distance influence the magnitude of gravitational force; or
- *compare* the relative gravitational force of two sets of objects with different masses (qualitatively, not quantitatively - the objects in both sets should be the same distance apart) or the relative gravitational force of sets of objects with different distances between them (qualitatively, not quantitatively - the objects in both sets should have the same masses).
- *Identify* which object would exert the greatest force dependent on its mass or proximity to other objects.
- *Summarize* the factors that affect gravitational force.

Standard PS-6: The student will demonstrate an understanding of the nature, conservation, and transformation of energy.

Supporting Content Web Sites

The Kavli Operating Institute, NSF
http://www.colorado.edu/physics/phet/web-pages/index.html
This site has fun, interactive simulations of physical phenomena that make bridges to the real world, from the Physics Education Technology project at the University of Colorado.
PS-6.6-6.8

The Physics Classroom
http://www.physicsclassroom.com/
The tutorial on work, power and energy is excellent. Contents are well covered.
PS-6.1-6.4

The School for Champions
http://www.school-for-champions.com/science.htm
The site offers much on PS-6 and is very good for 6.5-6.11. There is much content on electricity as well as experiments.
PS-6.5-6.11

Associated Chemistry Teachers of Texas
http://www.statweb.org/ACT2/labs_demos.htm
In the Doing Science: Introduction to Physical Science, Chapters 5 and 6 are excellent for static electricity.
PS-6.5

Experiments by Exploration, Arizona State University
http://acept.la.asu.edu/courses/phs110/expmts/toc.html
The site is good for physics activities. There are energy stations as well as electricity and magnetism activities. There are many simple activities.
PS6.1 and 6.6-6.9

Exploratorium
http://www.exploratorium.edu/snacks/iconelectricity.html
This site has some neat activities on electricity including making an electroscope and a motor. PS 6.5 and 6.11.

bbc.co.uk
http://www.bbc.co.uk/scotland/education/bitesize/standard/physics/electricity/index.shtml
The site is interactive, can be easily printed and has many problems on a variety of topics. It is great for electricity and also for work and energy. Indicators, PS-6.1-6-4 as well as 6.6-6.11, are covered.
PS-6.1-6-4, 6.6-6.11

DCMST Dearborn Public Schools
www.physicslessons.com
The site has superb graphics and offers an on-line stopwatch, calculator, graph paper and much more!!! See Demos, MicroLabs and Q Physics.
PS-6.5-6.11

The Science Spot Kids Zone
http://www.sciencespot.net/Pages/kdzphysics3.html
This excellent site covers electricity and magnetism. It uses Shockwave and is very interactive.
PS-6.5-6.11

North Carolina State University
http://www.physics.ncsu.edu/pira/demosite.html
This site gives a list of online Physics Demonstration Manuals and related physics resources with more than 30 college site links. All of PS-6 demos is somewhere on this site.
PS-6.1-6.10

Suggested Literature

Gunderson P. Erik (1999) The Handy Physics Answer Book Visible Ink Press
ISBN 0.7808.0723-5
Lexile Level - NA
A useful resource for all sorts of questions about gravity, magnetism, matter and energy. It provides surprisingly simple answers to questions about why things are the way they are.
PS-6.1

Taylor, B. (2005). Teaching Physics With TOYS. Easy Guide Edition with CD-Rpm. Middletown, OH: Terrific Science Press
ISBN: 1-883822408
Lexile Level – NA
This revised edition encourages students to explore physics using toys. This package contains excellent information, material, and activities useful to teachers at many levels.
PS-6.1-6.3

Taylor, B. (1997) Exploring Energy with TOYS. McGraw-Hill ISBN: 0-07-064747-X
Lexile Level – NA
Energy concepts are illustrated with inexpensive toys. All activities are linked to National Standards.
PS-6.1-3, 9.9, 6.11

Bloomfield, Louis A. (2007) How Everything Works: Making Physics out of the Ordinary
ISBN 0-471-74817-X
Lexile Level - NA
This book explains the physics of everyday life, and explains the real scientific foundation behind what it explores. The reader will discover that science is truly part of your everyday world.
PS-6

DiSpezio, M. (1998). Awesome Experiments in Electricity and Magnetism. New York: Sterling ISBN: 0-8069-9819-9
Lexile Level - NA
Seventy-two brief activities through which a student can explore the basic concepts of electricity and magnetism are compiled. The three sections include static electricity, current electricity, and magnets and magnetism.
PS-6.5-6.11

Cunning, J. (1994) Hands-On Physics Activities with Real-Life Applications. West Nyack,NY: Center for Applied Research
ISBN: 0-87628-845-X
Lexile Level – NA
This book provides extensive physics activities with real-life applications. The activities use common materials and are simple to perform.
PS-6.1-6-1 l

Kakalios, James (2005) Physics of Superheroes . Penguin Books, New York, NY
ISBN 1592401465
Lexile Level - NA
This book tackles some of the achievements of modern superheroes like Superman and Spiderman and relates them to physics in such a way that anyone can understand.
PS-6

Tymony, Cy (2003) Sneaky Uses for Everyday Things. Andrews McMeel
ISBN: 0-7407-3859-3
Lexile Level - NA
Sneaky uses for everyday things – extract water and electricity from think air, how to turn a penny into a radio and other amazing feats.
PS-6

Beller, Joe and Magliore, Kim (2000) Hands-On Science Series: Electricity and Magnetism Walch Publishing Company, ME
ISBN 0-8251-3933-3
Lexile Level - NA
A collection of activities many of which designed for out-of-class involvement as well as team projects.
PS-6

Adams, Richard. 2000. Physics Projects for Young Scientists. New York, Franklin Watts, ISBNQC33.P48 2000
Lexile Level - NA
The book breaks down real world experiences while bringing in the physics. Provides ways to expand the projects to be more in depth.
PS-6

Gonick, Larry (1992) The Cartoon Guide to Physics, Harper Collins Publishers, NY
ISBN 0062731009
As the jacket copy says, "If you think a negative charge is something that shows up on your credit-card bill--if you imagine that Ohm's law dictates how long to meditate--if you believe that Newtonian mechanics will fix your car," here's the book for you.
All of PS-6

Suggested Streamline Video Resources

Basics of Physics: Exploring Energy
ETV Streamline SC
This program starts with an exploration of potential and kinetic energy and moves into a discussion of the main forms of energy.
Examples of Energy (1:08)
Work, Force and Energy (1:14)
Potential and Kinetic Energy (2:07)
Seven Forms of Energy (5:05)
Law of Conservation of Energy (4:35)
PS-6.1-6.4

Elements of Physics: Energy: Work and Power
ETV Streamline SC
Forms of energy, conversion from one form to another and work are explained.
An Introduction to Energy and Work (0:50)
Energy as Work (1:21)
Kinetic and Potential Energy (2:10)
PS-6.2, 6.3

Matter and Energy: Energy: What Is It?
ETV Streamline SC

Energy is defined. Potential and kinetic energy are described, as well as the Law of Conservation of Energy.
Energy at Work: How Do We Define It? (1:18)
The Scientific Definition of Work (1:14)
Two Types of Energy (1:21)
Forms of Energy (1:03)
How Energy Is Used (3:56)
Summary (0:49) PS-6.1 – 6.4

Electricity and Magnetism
ETV Streamline SC
This program is about magnetism and its relationship to electricity.
ABC's of Magnets (5:52)
What Makes Certain Materials Magnetic? (1:47)
Electromagnets (2:32)
Electricity From Magnetism (1:45)
Maglev (2:12)
PS-6.10, 6.11

Electricity and Magnetism: Measuring and using Electricity
ETV Streamline SC
Current, wattage, voltage and amerage are all terms used to describe and measure electricity.
Electrical Current (0.39)

Electricity and Magnetism : Static Electricity
ETV Streamline SC
PS-6.6

Electricity and Magnetism: Current Electricity
ETV Streamline SC
Current electricity is featured in this video.
Current Electricity: Circuits, Conductors and Insulators (4:30)
Series and Parallel (2.02)
PS-6.8, 6.9

Static electricity is the focus of this video
Static and Current Electricity (1:35)
Balloons on Wall (1:05)
Lightning (3:11)
Electric Transfer (2:58)
Van de Graaf Generator (6:33)
PS-6.5

Physical Science: Magnetism
ETV Streamline SC

Magnetism is introduced and magnetic fields are discussed.
Introduction to Magnetism (3:41)
Electromagnetism (2:58)
PS-6.11

Understanding Magnetism
ETV Streamline SC
The role of magnetism in our world is shown and Maglev trains are explained.
Linking Electricity and Magnetism (6:17)
Using Magnetism to Fly (2:33)
PS-6.11

Physics: A World in Motion: Ohm's Law and Energy
ETV Streamline SC
Ohm's Law is used to explain electrical safety.
Program Overview (1:04)
Resistance (4:12)
Ohm's Law (6:17) Suggested for Honors or High Level
Electric Safety (5:05) Suggested for Honors or High Level
PS-6.6

Career Connections

Physics Teacher – Teachers can experience the excitement and pleasure of educating others about the fields of physics. PS-6.1-6.11 embodies concepts which are essential to the understanding of physics.

Chemical physicist – studies the connections between chemistry and physics. This area is important for the development of fuels and alternate energy sources, a major component of PS-6.

Solid state physicist – studies the physics and application of the electric, magnetic, optical and acoustic properties of solid matter. Integrated circuits are the result of solid state physics. PS-6 incorporates these basic principles.

Engineer – works with a wide variety of materials such as coatings, glass fibers, equipment development, design and research. All engineers must require an understanding of the basic concepts in PS-6.

Medical physicist – studies and applies physics to medical practice, including uses of radiation, ultrasound and imaging techniques such as magnetic resonance imaging (MRI). PS-6 provides background for these important concepts.

Nuclear physicist – studies the nucleus of the atom, its radioactivity (including medical applications) and nuclear energy. The nuclear physicist works with accelerators and nuclear reactors, a major energy source which is an integral part of concepts taught in PS-6.

Auto Mechanic – works with engines of all types and must understand the transformations of energy that take place in motors and other components of automobiles, airplanes and other forms of transportation. PS-6 deals with such transformations of energy.

Acoustical physicist – studies sound, an evermore increasingly important form of energy. This knowledge can be applied in the design of such things as concert halls, stereos or synthesizers. Energy transformations are an important part of PS-6.

Laboratory technologist – work with physicists and engineers to develop, test and develop new products, operate specialized equipment and perform tests of materials and equipment. A good understanding of the principles presented in PS-6 is essential for a technician.

Electrician – wires buildings, works with architects to ensure a safe environment and is required to have a good understanding of all facets of electricity as found in PS -6.

Metallurgist – research and produce very powerful magnets. The study of magnetism is an essential component of PS-6.

PS-6.1 Explain how the law of conservation of energy applies to the transformation of various forms of energy (including mechanical energy, electrical energy, chemical energy, light energy, sound energy, and thermal energy).

Taxonomy Level: 2.7-B Understand/Explain Conceptual Knowledge

Previous/future knowledge: In the 6th grade students "explained how energy can be transformed from one form to another (including the two types of mechanical energy, potential and kinetic, as well as chemical and electrical energy) in accordance with the law of conservation of energy" (6-5.2).
In Physical Science students will expand their concept of conservation of energy by applying the concept to transformations between various types of energy. Students will understand cause and effects relationships involved in transformations.

Key concepts
Energy: mechanical, electrical, chemical, light, sound, thermal
Work
Law of conservation of energy

It is essential for students to understand that

- Energy cannot be created or destroyed.
    - It can be transformed from one form to another, but the total amount of energy never changes.
- Energy is the property of an object or a system that enables it to do work.
- If you consider a system in its entirety the total amount of energy never changes.
- There are many different kinds of energy.
    - *Mechanical energy* is energy due to the position of something or the movement of something. Mechanical energy can be potential kinetic or the sum of the two.
    - *Chemical energy* is a type of energy associated with atoms, ions, and molecules and the bonds they form. Chemical energy will change to another form of energy when a chemical reaction occurs.
    - *Electrical energy* is energy associated with current and voltage.
    - *Thermal energy* (heat) is associated with the movement of molecules.
    - *Light energy* is energy that associated with electromagnetic waves.
    - *Sound energy* is energy associated longitudinal mechanical waves.
- These different kinds of energy can change from one form to another without changing the total amount of energy. Examples might include but are not limited to:
  Example 1
    - Explain conservation of energy in terms of energy transformation in an electric circuit with a battery and a light bulb burning.
        - ♦ Chemical energy changes to electric energy.
        - ♦ The electric energy flows through the light bulb and turns electric energy to light and heat.

- ♦ The total of the energy from the chemical reaction is equal to the total energy that it transforms into.

Example 2

- o Explain conservation of energy in terms of energy transformation when baseball is thrown to another ball player.
  - ♦ A ballplayer converts chemical energy from the food she has eaten to mechanical energy when she moves her arm to throw the ball.
  - ♦ The work done on the ball converts the energy of the arm movement to kinetic mechanical energy of the moving ball.
  - ♦ When the second player catches the ball, the ball does work on the player's hand and glove giving them some mechanical energy.
  - ♦ The ball also moves the molecules in the glove heating them up.
  - ♦ The player that catches the ball absorbs the energy of the ball and this energy turns to heat.
  - ♦ The total heat produced is equal to the energy used to throw the ball.

It is not essential for students to:

- Explain the chemical reaction that releases chemical energy.
- Explain each type energy given in this document. (They only need a general understanding of the nature of each type of energy for this indicator.)

Assessment Guidelines

The verb, *explain*, implies a cause and effect relationship. Since the verb for this indicator is *explain* the major, focus of assessment will be for students to show not only they know the effect – energy is conserved **-** but also that they can "construct a cause and effect model". In this case the model should be that energy is conserved as it continually transforms from one type to another. Because the indicator is written as conceptual knowledge, assessments should require that students understand transformation of different types of energy and the relationship of this transformation to the conservation of energy.

In addition to *explain*, assessments may require that students:

- *exemplify* energy transformations;
- *infer* the transformations of different types of energy;
- *summarize* energy transformations;
- *remember* basic concepts of energy; or
- *summarize* electromagnetic induction.

PS-6.2 Explain the factors that determine potential and kinetic energy and the transformation of one to the other.

Taxonomy Level: 2.7-B Understand/Explain Conceptual Knowledge

Previous/future knowledge: In the 6th grade students "explained how energy can be transformed from one form to another (including the two types of mechanical energy, potential and kinetic, as well as chemical and electrical energy) in accordance with the law of conservation of energy." (6-5.2)
In Physical Science the students will expand their concepts of kinetic and potential energy by explaining the transformations between the two and the factors involved.

Key Concepts:
Potential energy: gravitational potential energy
Kinetic energy

It is essential for students to understand:

- Transformations of potential and kinetic mechanical energy.
  - Mechanical energy is energy due to the position of something or the movement of something.
  - Mechanical energy can be potential or kinetic or the sum of the two.
- That potential energy is energy of position.
  - Gravitational potential energy is greater when the height is greater.
  - Gravitational potential energy is greater when the weight of the object is greater.
- That kinetic energy is energy of motion.
  - Kinetic energy is greater when the speed is greater.
  - Kinetic energy is greater when the mass of the object is greater.
- Transformations between gravitation potential energy and kinetic energy.
  - Some examples might be but are not limited to:

    Example 1
    - ♦ An object is on the ground. It has zero potential energy with respect to the ground.
    - ♦ It is lifted to some height. It now has potential energy equal to the work it took to lift it to that height. Its potential energy depends on its weight and height above the ground.
    - ♦ When the object is dropped it is attracted by gravity and begins to speed up. Some of the energy turns to kinetic.
    - ♦ On the way down some of the energy is kinetic and some is potential but the total remains the same.
    - ♦ Just before it hits the ground most of the energy has turned to kinetic. It loses its potential energy because its height has gone to zero.
    - ♦ When it hits the ground some of the energy turns to sound and some turns to heat because it speeds up molecules when it hits the ground.

    Example 2

- ♦ When a pendulum swings it has mechanical energy. At the top of the swing all of its mechanical energy is potential energy that depends on its height and weight.
- ♦ The kinetic energy is greatest at the bottom of the swing because its speed is greatest. Potential energy is zero at the bottom of the swing because the height is zero.
- ♦ Between the top of the swing and the bottom of the swing it has both potential and kinetic energy because it has both height and movement.
- ♦ Eventually the pendulum will stop. It stops because of friction.
- ♦ The friction transforms the energy that was originally mechanical energy in the swinging pendulum into heat.

It is not essential for students to:

- Calculate potential or kinetic energy.
- Understand other types of energy transformations for this indicator.
- Understand other types of potential energy for this indicator.

Assessment Guidelines

The verb, *explain*, implies a cause and effect relationship. Since the verb for this indicator is *explain*, the major focus of assessment will be for students to show not only they know the effect **-** that energy transforms between potential and kinetic - but also that they can "construct a cause and effect model". Changes in height affect potential energy and changes in velocity affect kinetic energy and how these types of energy can transform to the other. Because the indicator is written as conceptual knowledge, assessments should require that students understand the relationships of height and weight on potential energy and speed and mass to changes in kinetic energy.

In addition to *explain*, assessments may require that students:

- *compare* kinetic and gravitational potential energy;
- *infer* effects of changes in height and speed with gravitation potential energy and kinetic energy;
- *exemplify* kinetic and gravitational potential energy and transformations between them;
- *summarize* kinetic and gravitational potential energy and transformations between them;
- *summarize* the effect of mass, height and weight on potential and kinetic energy; or
- *classify* kinetic and gravitational potential energy.

PS-6.3 Explain work in terms of the relationship among the force applied to an object, the displacement of the object, and the energy transferred to the object.

Taxonomy Level: 2.7-B Understand/Explain Conceptual Knowledge

Previous/future knowledge: In the 6th grade students recognize that energy is the ability to do work (force exerted over a distance) (6-5.6), and also explain how the design of simple machines (including levers, pulleys, and inclined planes) helps reduce the amount of force required to do work. (6-5.7)
In Physical Science the students will expand their concept of work by explaining the relationship among force, displacement, work, and energy.

Key Concepts:
Work: force, displacement,
Energy, Joules

It is essential for the student to understand that:

- Work is the product of the force applied to an object and the displacement the object is moved in the direction of the force.
- Work, force, and displacement are quantities that have magnitude and direction.
- In order to do work on an object these conditions must apply:
    - A force is applied to the object.
    - The object must move in the direction of the force.
- When work is done on an object, energy is transferred to that object.
    - Work is equal to change in energy.
    - When a net force is applied to an object and it moves the work is transformed to kinetic energy.
        - ♦ If a greater force is added or if it is applied over a greater distance then the kinetic energy will be greater.
- If an objected is lifted to some height it gains gravitational potential energy equal to the work done against gravity lifting it.
    - The work done against gravity is the same whether the object was lifted straight up or rolled up a ramp.
    - The greater the height the more gravitational potential energy the object has.
- The unit of measure for work and energy is j*oules*

It is not essential for the student to solve problems involving energy change due to work.

Assessment Guidelines
The verb, ***explain***, implies a cause and effect relationship. Since the verb for this indicator is ***explain*** the major, focus of assessment will be for students to show not only they know the effect – force applied over a distance does work and energy changes- but also that they can "construct a cause and effect model". In this case the model should involve how a force is applied in terms of direction, and distance, and size and how this

affects work and energy transformation. Because the indicator is written as conceptual knowledge, assessments should require that students understand the relationships among force, distance, and energy change for gravitational potential energy as well as kinetic energy.

In addition to ***explain***, assessments may require that students:

- ***compare*** work and energy; and ***infer*** energy change when work is done on an object;
- ***summarize*** work and energy change;
- ***exemplify*** work done and resulting energy change;
- ***recognize*** a situation where work is or is not done; or ***remember*** the definition of work.

PS-6.4 Use the formula W = Fd to solve problems related to work done on an object.

Taxonomy Level: 3.2-C Apply/Use Procedural Knowledge

Previous/future knowledge: In the 6^{th} grade students "recognized that energy is the ability to do work (force exerted over a distance) (6-5.6). In Physical Science students will expand their concept of work by developing a mathematical understanding of the concept.

Key Concepts:
Work
Force
Displacement
Joule

It is essential for students to:

- Solve problems for any variables in this equation using experimental data.
- Use dimensional analysis to determine the proper units. Using the SI system:
  - Force should be given in newtons
  - Distance should be given in meters.
  - Work will be newton-meters or joules.
- The displacement should be in the direction of the force.

It is not essential for students to:

- Solve problems involving input and output work of simple machines.
- Solve problems involving efficiency.
- Solve problems involving friction.
- Solve problems involving power.

Assessment Guidelines
The objective of this indicator is to *use* the correct procedure to mathematically determine the one of the variables in the formula W =Fd. *Use* (or implement) means to apply a procedure to an unfamiliar task; therefore, students should be able to apply this procedure many situations involving work.

PS-6.5 Explain how objects can acquire a static electric charge through friction, induction, and conduction.

Taxonomy Level: 2.7-B Understand/Explain Conceptual Knowledge

Previous/future knowledge: In the 4th grade students, "Classify materials as either conductors or insulators of electricity (4-5.8). In the 6th grade students "Identify the sources and properties of heat, solar, chemical, mechanical, and electrical energy. (6-5.1) Students have not studied static charge. In Physical Science students expand the concept of electrical energy. Students are introduced to the concepts of protons and electrons and their electrical properties. Students will use the understanding of these subatomic particles to explain how objects acquire a static electric charge through friction, induction, and conduction.

Key Concepts:
Static charge: electron, proton
Charging: friction, induction, conduction

It is essential for students to understand that:

- All matter is made up of atoms.
- Atoms are made up of three types of particles: protons, neutrons, and electrons.
- Two of the particles in atoms are electrically charged.
    - The protons, which are tightly help in the nucleus, are positively charged.
    - The electrons, which move around outside the nucleus, are negatively charged.
    - Atoms normally have the same number positive charges that they do negative charges. The effects of these charges cancel out and the object will have no net charge.
- The electrons in the atoms can be knocked off and move onto something else.
- Like charges repel each other. Positives repel positives and negatives repel negatives.
- Opposite charges attract. Negatives attract positives.
- When an object loses electrons it will have more protons than electrons and will have a net positive charge.
- If an object gains electrons it will have more electrons than protons and will have a net negative charge.
- Objects can be charged by:
    - *Friction*:
        - ♦ If you rub one against another, sometimes electrons leave one object and stick to another leaving both objects charged.
    - *Conduction*: Electrons can be transferred from one object to another by touching.
        - ♦ When a charged object touches another object some charge will transfer to the other object.
        - ♦ It is always the electrons that move in solid objects.
        - ♦ Objects charged by conduction will have the same charge as the object charging it therefore will repel it.

- *Induction*: Objects can be charged by bringing a charged object near a neutral object.
    - ♦ If a charged object is brought near a neutral object the charged object will attract unlike charges in the neutral object and repel like charges in the neutral object.
    - ♦ Electrons will move in the neutral object and leave the side nearest the charged object charged with a charge that is opposite the charging object.
    - ♦ After an object is charged by induction it will have the opposite charge of the charging object and will attract it.

It is not essential for the students to give specific examples of things that will charge positively or negatively by friction.

Assessment Guidelines
The verb, *explain*, implies a cause and effect relationship. Since the verb for this indicator is *explain* the major, focus of assessment will be for students to show not only they know the effect **-** that objects can become charged and attract or repel each other - but also that they can "construct a cause and effect model". In this case the model should be that electrons can be transferred in ways that will cause objects to become charged and attract or repel charges on other objects. Because the indicator is written as conceptual knowledge, assessments should require that students understand how and why objects become charged.

In addition to *explain*, assessments may require that students:
- *compare* positively and negatively charged objects;
- *infer* effects of interactions of charges and charged objects;
- *summarize* situations involving charged objects;
- *exemplify* situations involving charged objects and how they are charged; or
- *recall* that static electric charge is the result of transfer of electrons.

PS-6.6 Explain the relationships among voltage, resistance, and current in Ohm's law.

Taxonomy Level: 2.7-B Explain Conceptual Knowledge

Previous/future knowledge: In the 4th grade students summarize the functions of the components of complete circuits (including wire, switch, battery, and light bulb), (4-5.6) and also illustrate the path of electric current in series and parallel circuits (4-5.7). In the 6th grade students illustrate energy transformations (including the production of light, sound, heat, and mechanical motion) in electrical circuits (6-5.4). In Physical Science students will expand their concepts of current, voltage, and resistance in Ohm's law.

Key Concepts:
Voltage: volt
Resistance: ohm
Current: amp
Ohms law

It is essential for students to understand that:

- *Voltage*
  - is created by a chemical cell when it changes chemical energy to electrical energy or by a generator when it changes mechanical energy to electric energy.
  - is electric potential energy per charge. It provides the energy that pushes and pulls electrons through the circuit.
  - is measured in volts. The symbol is (v).
- When a wire connects the terminals of a battery or generators then the *voltage* will push and pull electrons through a conductor.
  - One terminal has extra electrons thus a negative charge. The other terminal has a deficit of electrons and thus a positive charge.
  - Electrons in the wire are pushed by the negative terminal and pulled by the positive terminal through the wire.
- *Electric current*
  - is the flow of electrons through a conductor
  - is measured in amperes or amps. The symbol is (a).
- *Resistance*
  - happens when the electrons flowing through the wire continually run into things in the wire and bounce around.
  - opposes the flow electron through a conductor.
  - is measured in ohms. The symbol is (Ω).
  - will slow the flow of current because it is harder for the current to get through the conductor.
    - When an electric current encounters resistance heat is produced
    - Wires that have a larger diameter have less resistance.
    - Longer wires have greater resistance.
    - In many materials an increase in temperature will increase resistance.
- Electric devices provide much of the resistance in a circuit.

- Ohms law describes the relationship between voltage, current, and resistance.
  - The voltage is the product of the current and resistance. (V = I R)
  - One volt will pull one amp of current through one ohm of resistance.
  - If the voltage increases and the resistance remains the same the current will increase.
  - If the voltage stays the same and the resistance increase then the current will decrease.

It is not essential for students to:
- Know the number of electrons in a coulomb.
- Know the term electromotive force or potential difference.
- Know about superconductors.

Assessment Guidelines
The verb, *explain*, implies a cause and effect relationship. Since the verb for this indicator is *explain* the major, focus of assessment will be for students to show not only they know the effect – that the voltage equals the product of the current and resistance - but also that they can "construct a cause and effect model". In this case the model should be based on what these quantities are and the how and why they affect to other variables. Because the indicator is written as conceptual knowledge, assessments should require that students understand the relationships among relationship among voltage, current, and resistance.

In addition to *explain*, assessments may require that students:
- *compare* the concepts of voltage, current, and resistance;
- *summarize* voltage, current and resistance; or
- *infer* what will happen when one of the variables changes.

PS-6.7 Use the formula V = IR to solve problems related to electric circuits.

Taxonomy Level: 3.2-C Apply/Use Procedural Knowledge

Previous/future knowledge: In the 4th grade students summarized the functions of the components of complete circuits (including wire, switch, battery, and light bulb) (4-5.6), and also illustrated the path of electric current in series and parallel circuits (4-5.7). In Physical Science students expand the concepts of voltage, current, and resistance by developing a mathematical understanding of the concept.

Key Concepts:
Voltage: volt
Current: amp
Resistance: ohm
Ohms law: V = IR

It is essential for students to understand:
- That V stands for voltage, I stands for current, R stands for resistance.
- The components of an electric circuit:
  - Sources of voltage are chemical cells (a battery is a combinations of cells) and generators.
  - Resistors, light bulb filaments, and other electric devices are sources of resistance.
- The units for the concepts involved:
  - *Voltage* is measured in volts. The symbol is (v).
  - The unit for *current* is an ampere or amp. The symbol is (a).
  - The unit for *resistance* is ohm. The symbol is (Ω).

It is also essential that students are able to:
- Solve problems that involve simple circuits.
- Solve for any of the variables in the equation.

It is not essential for students to:
- Find total resistance in a series or parallel circuit.
- Find the voltage drop across a resistance.
- Find the total voltage for batteries with different combinations of cells.

Assessment Guidelines
The objective of this indicator is to *use* the correct procedure to mathematically determine the one of the variables in the formulas V = I R. *Use* or implement means to apply a procedure to an unfamiliar task, therefore, students should be able to apply this procedure for situations involving any simple circuit.

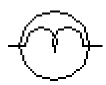
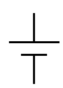
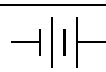
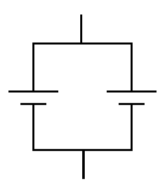
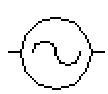
PS-6.8 Represent an electric circuit by drawing a circuit diagram that includes the symbols for a resistor, switch, and voltage source.

Taxonomy Level: 2.1-B Understand/Represent Conceptual Knowledge

Previous/future knowledge: In the 4th grade students summarized the functions of the components of complete circuits (including wire, switch, battery, and light bulb) (4-5.6), and also illustrated the path of electric current in series and parallel circuits (4-5.7). In Physical Science the students will expand the concepts of circuits by representing circuit diagrams.

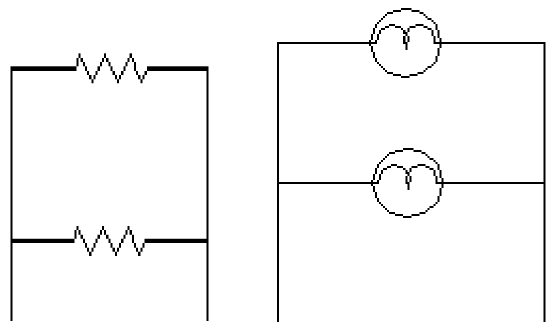
Key Concepts:
Circuits: parallel circuit, series circuit
Circuit components: resistor, switch, voltage source

It is essential for students to understand and be able to represent symbols for:

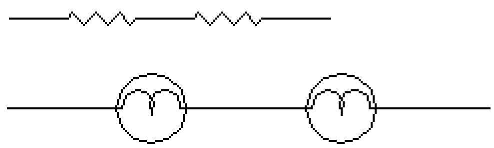
Wires	
Resistors	
Light bulbs	
Switches	
Chemical cell	
Battery circuit with 2 cells wired in series	
Battery circuit with 2 cells wired in parallel.	
AC source (generator)	

It is also essential for students to:

- Represent a circuit with resistors or light bulbs wired in parallel. PS-6.9



- Represent a circuit with resistors or light bulbs wired in series. PS-6.9



- Represent circuits by drawing a circuit diagram from a circuit which is pictured or described.
- Draw an open and a closed circuit.
- Interpret a circuit diagram.

It is not essential for students to represent devices not listed above.

Assessment Guidelines
The verb <u>*represent*</u> (interpret) means to change from one form of representation to another. For this indicator the students will <u>*represent*</u> concepts by drawing various circuits, using symbols to represent electrical devices.

In addition to <u>*represent*</u> students should be able to:

- <u>*identify*</u> circuits from diagrams;
- <u>*summarize*</u> circuits from diagrams;
- <u>*compare*</u> circuit diagrams; or
- <u>*exemplify*</u> symbols and diagrams.

PS-6.9 Compare the functioning of simple series and parallel electrical circuits.

Taxonomy Level: 2.7 B (Understand/Compare conceptual knowledge)

Previous/future knowledge: In the 4th grade students summarized the functions of the components of complete circuits (including wire, switch, battery, and light bulb) (4-5.6), and also illustrated the path of electric current in series and parallel circuits (4-5.7). In Physical Students will expand their concepts of series and parallel circuits comparing them and their functions.

Key Concepts:
Series circuits: current, resistance, voltage
Parallel circuits: current, resistance, voltage
Batteries: cells

It is essential for students to recognize and understand:

- *Series Circuits:*
  - In a series circuit there is a single path for electrons.
  - When another resistor is wired in series with the resistors in a circuit the total resistance increases because all of the current must go through each resistor and encounters the resistance of each.
  - The current in the circuit decreases when additional resistors are added.
  - When another light bulb is added to lights wired in series the lights will dim.
  - The current will be the same in each resistor.
  - When light bulbs are wired in series and one is removed or burns out all of the lights in the circuit go out.
    - When the light bulb is removed from the circuit it opens the circuit and current cannot flow.
- *Parallel circuits:*
  - When resistors are wired in parallel there is more than one path that the electrons can travel.
  - The voltage in each path is the same.
  - When another resistor is wired in parallel then the total resistance is reduced.
  - The total current in the circuit will increase when another path is added.
  - If light bulbs are wired in parallel and one burns out or is removed the other bulbs keep burning because the circuit is still complete.
- *Chemical cells in series and parallel:*
  - Chemical cells can be wired in series to make a battery.
    - Cells wired in series will increase the voltage of the battery.
  - Chemical cells can be wired in parallel to make a battery.
    - Cells wired in parallel do not change the voltage of the battery.
    - Cells are in parallel to make the battery last longer.

It is not essential for students to:
- Calculate the total resistance in a series or parallel circuit.

- Calculate the current in each branch of a parallel circuit.
- Calculate the total voltage of a battery when the cells are wired in series or parallel.

Assessment Guidelines
The objective of this indicator is to *compare* parallel and series circuits with regard their structure and how these circuits function in different situations. It is important that assessments go beyond recall of factual knowledge as conceptual knowledge is an understanding of interrelationships. Assessments should insure that students understand the relevance of the factual information to an overall conceptual model of series and parallel circuits.

In addition to *compare*, students should be able to:
- *illustrate* series and parallel circuits;
- *classify* circuits as series or parallel;
- *summarize* series and parallel circuits;
- *infer* the effects of changes in series and parallel circuits; or
- *recognize* series and parallel circuits.

PS-6.10 Compare alternating current (AC) and direct current (DC) in terms of the production of electricity and the direction of current flow.

Taxonomy Level: 2.6-B Understand/Compare Conceptual Knowledge

Previous/future knowledge: In the 4th grade students, "Illustrate the path of electric current in series and parallel circuits" (4-5.7). In the 6th grade students, "Explain how magnetism and electricity are interrelated by using descriptions, models, and diagrams of electromagnets, generators, and simple electrical motors.

In Physical Science expand the concept of electric current. They will understand the movement of the electric current and understand how each kind of current is produced.

Key Concepts

Current: AC current, DC current
Generator: electromagnetic induction
Battery: cell

It is essential for students to understand

- That electric current is the flow of electrons through a conductor.
- *Direct current (DC)*: DC current or direct current flows in one direction.
    - DC current can be produced using a chemical cell or a battery, which is a combination of cells.
    - (Strictly speaking a battery is a combination of more than one cell. Sometimes a "D cell" is referred to as a battery. This causes confusion with students.)
    - Electrons are repelled by the negative terminal of a battery and attracted to the positive terminal of a battery.
    - When a circuit is connected to the terminals the electrons will move from the negative terminal to the positive terminal.
- *Alternating current (AC)*: AC current or alternating current moves back and forth.
    - AC current can be produced by a generator using the principle of electromagnetic induction.
    - The terminals of a generator alternate between positive and negative.
    - Electrons are repelled by the negative terminal and attracted to the positive terminal just as in DC currents.
    - Since the terminals are continually changing from positive to negative the current continually changes direction.

It is not essential for students to know the number of times poles switch in a generator.

Assessment Guidelines

The objective of this portion of the indicator is to *compare* AC and DC current with regard to the movement of electrons. It is important that assessments go beyond recall of factual knowledge, as conceptual knowledge is an understanding of the interrelationships. Assessments should insure that students understand the relevance of the factual information to an overall conceptual model of DC and AC current and understand why each type of current moves the way it does.

In addition to *compare*e, students should be able to:

- *exemplify* AC and DC current and how each is produced;
- *classify* AC and DC current;
- *summarize* AC and DC current; or
- *compare* AC and DC current.

PS-6.11 Explain the relationship of magnetism to the movement of electric charges in electromagnets, simple motors, and generators.

Taxonomy Level: 2.7-B Understand/Explain Conceptual Knowledge

Previous/future knowledge: In the 6th grade students, "Explain how magnetism and electricity are interrelated by using descriptions, models, and diagrams of electromagnets, generators, and simple electrical motors" (6-5.3). In Physical Science students expand their concepts of the relationships of magnetism and electricity. They will develop a concept of electric current and its relationship to magnetism in electromagnets, generators, and simple electric motors.

Key Concepts:
Electromagnet: core, coil
Motor: armature
Generator: electromagnetic induction

It is essential for students to understand:

- *Electromagnets:*
  - Electric currents produce magnetic fields.
  - The fields can be concentrated and thus strengthened by wrapping the wire in a coil.
    - ♦ More turns in the coil will strengthen the magnet.
    - ♦ Adding a core (like iron) will concentrate the magnetic field and strengthen the magnet.
    - ♦ The electromagnet can also be strengthened by increasing the current in the coil.
- *Motors:*
  - Electric motors change electric energy to mechanical energy by running an electric current through coils to make an electromagnetic.
    - ♦ Motors use magnets to push and pull other magnets and create motion.
    - ♦ Motors use the magnetic force from magnets to spin an armature (usually an electromagnetic).
- *Generators:*
  - When a wire or a coil of wire moves through a magnetic field an electric current can be produced. This is called electromagnetic induction.
  - Understand that generators use electromagnetic induction to produce and electric current.
  - A generator is similar to an electric motor.
  - A generator changes mechanical energy into electric energy by moving a coil past a magnetic field.
  - Generators produce AC current.

It is not essential for students to:

- Label the parts of a motor or generator.
- Compare the permeability of different core materials.
- Describe different types of motors or generators.

- Describe the function of a transformer.

Assessment Guidelines
The verb, ***explain***, implies a cause and effect relationship. Since the verb for this indicator is ***explain*** the major, focus of assessment will be for students to show not only they know the effect – that moving electric charge (current) produces a magnetic field and that when a wire moves past a magnetic field a current is produced. - but also that they can "construct a cause and effect model". The indicator is written as conceptual knowledge, assessments should require that students understand the relationship of electricity and magnetism within electromagnets, motors, and generators.

In addition to ***explain***, assessments may require that students ***compare*** motors and generators; ***summarize*** electric motors generators and electromagnets; or ***summarize*** electromagnetic induction.

Standard PS-7: The s
tudent will demonstrate an understanding of the nature and properties of mechanical and electromagnetic waves.

Supporting Content Web Sites

The Science of Stuff
A Freshman Scholars Seminar at the University of Wisconsin-Milwaukee
http://www.uwm.edu/~awschwab/specweb.htm
This site shows you how to build a spectroscope and use it to view spectra of light.
Indicator(s)
PS-7.5 and PS-7.6

Paul Falstad
http://www.falstad.com/mathphysics.html
This site contains java applet simulations of ripple tanks and many other applications that can simulate wave behavior.
Indicator(s)
PS-7.6 and PS-7.7

Physics lessons.com
DCMST Dearborn Public Schools
www.physicslessons.com
This site contains demonstrations and other lessons that the teacher can use in the classroom.
Indicator(s)
PS 7-6 and others

University of Aberdeen Department of Physics
http://www.abdn.ac.uk/physics/px2009/
This site contains applets of transverse and longitudinal waves and some good ones on refraction as well as other applets for wave characteristics.
Indicator(s)
7-2, 7-3, and 7-6

Optics Bench Applet
http://www.hazelwood.k12.mo.us/~grichert/optics/intro.html
This is an interactive applet for concave and convex lenses.
Indicator(s)
PS-7-6

StudyWorks On Line The Physics Classroom
http://www.physicsclassroom.com/Default2.html
This site contains tutorials and animations on wave phenomena.
Indicator(s)

PS 7-2, PS 7-3, PS 7-5, and PS 7-6

W. Bauer, 1999
http://www.lon-capa.org/~mmp/applist/doppler/d.htm
This site has a good interactive java applet on the Doppler Effect.
Indicator(s)
PS 7-7

NASA
http://imagers.gsfc.nasa.gov/ems/ems.html
This site shows the electromagnetic spectrum with its relative wavelengths and discusses electromagnetic radiation.
Indicator(s)
PS 7-5

Suggested Literature

Waves: From Surfing to Tsunami. Drew Kampion. Illustrated by Jeff Peterson and with prints and photographs. Gibbs Smith, Publisher. 80pp. Trade ISBN 1-58685-212-4, $19.95. (E) What causes waves to form? What makes them move? The melding of technical writing and storytelling, incredible photographs, and original artwork makes this book about wave formation and movement both interesting and easy to understand. This detailed analysis of wave action and influences also includes a section about tsunamis. Glossary, Web Resources, Photo Credits. NJP (V)

Suggested Streamline Video Resources

Science Investigations Physical Science: Investigating Sound and Light. Discovery Channel School (2004).
Segment and time
Properties of Waves (10:16)
Sound and Navigation (09:39)
Submarines and Sonar (02:15)
Echolocation and Dolphins (03:38)
Echolocation and Bats (03:45)

Description
The Properties of Waves segment introduces waves and using tsunamis as an example discusses waves and the energy of the waves moving with the water remaining in place. The last four segments demonstrate uses for sound reflection.
Indicator(s)
PS 7-1 and PS 7-6

Elements of Physics: Waves: Sound and Electromagnetism. United Learning (2006)
Segment and Time
The Nature of Waves (02:20)
Description
This segment introduces waves and some characteristics of waves.
Indicators
PS 7-3
Segment and Time
Sound Waves (02:55)
Description
This segment introduces sound waves.
Indicator(s)
PS (7-2)
Segment and Time
Electromagnetic Waves (03:07)
Description
This segment is an introduction to electromagnetic waves.
Indicator(s)
PS 7-5
Segment and Time
Wave Interference (06:40)
Description
This segment includes a brief discussion several characteristics of waves including interference and the Doppler Effect.
Indicators
PS 7-6 and PS7-7

Elements of Physics: Light: Optics and Electricity. United Learning
Segment and Time
Optics (02:07)
Description
This segment gives an introduction to reflection and the law of reflection.
Indicators
PS 7-6

Elements of Physics: Light: Optics and Electricity. United Learning
Segment and Time
What is Light? (02:16)
Description
This segment introduces the electromagnetic spectrum.
Indicators

PS-7.5

Elements of Physics: Light: Optics and Electricity. United Learning
Segment and Time
Putting the Electromagnetic Spectrum to Use (03:29)
Description
This segment describes some uses of electromagnetic waves.
Indicators
PS 7-5

Career Connections

Optical Engineer, Electro-Optical Engineer, Opto-Mechanical Engineer, Physics Technician, Design Engineer, Software Engineer, Materials Engineer, Laser Engineer/Scientist, Ophthalmologist, Optometrist, Optician, Acoustical Engineer, Physicist

Web sites
http://www.optics.arizona.edu/Employment/NationalOpenings.htm

PS-7.1 Illustrate ways that the energy of waves is transferred by interaction with matter (including transverse and longitudinal /compressional waves).

Taxonomy Level: 2.2-B Understand/Illustrate Conceptual Knowledge

Key Concepts
Wave: transverse, longitudinal/compressional
Energy transfer
Medium

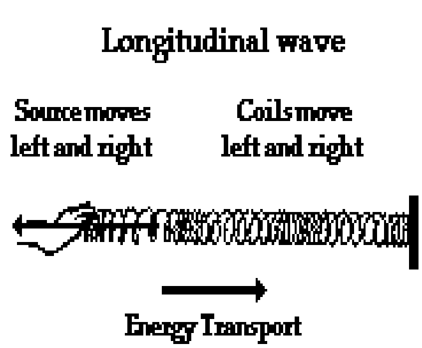
Previous/future knowledge: In 8th grade students "recall that waves transmit energy but not matter" (8-6.1).

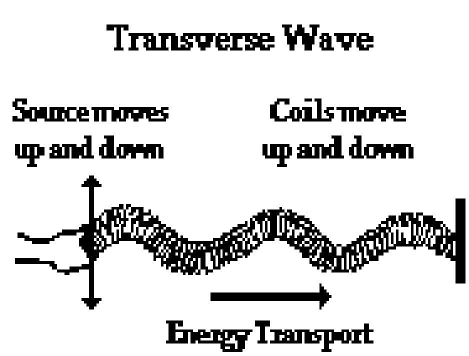
It is essential for students to

- Understand that a wave is a repeating disturbance that transfers energy through matter or space.
  - Wave motion always transfers energy, but not matter from one place to another.
  - When a wave moves through matter, the matter is disturbed so that it moves back and forth, but after the wave passes, the matter will be in about the same position that it was before the wave passed.
- Give general examples of various waves, illustrating, with diagrams or descriptions, the direction of the disturbance and the motion of the particles of the medium in each. Each illustration should:
  - Describe the energy (light, sound, mechanical disturbance, etc)
  - Describe the direction and the path that the energy takes
  - Identify the medium if any
  - Describe the direction that the particles of the medium are disturbed as the wave passes
  - Describe the position of the particles of the medium before and after the wave passes.

Examples of illustrations include.

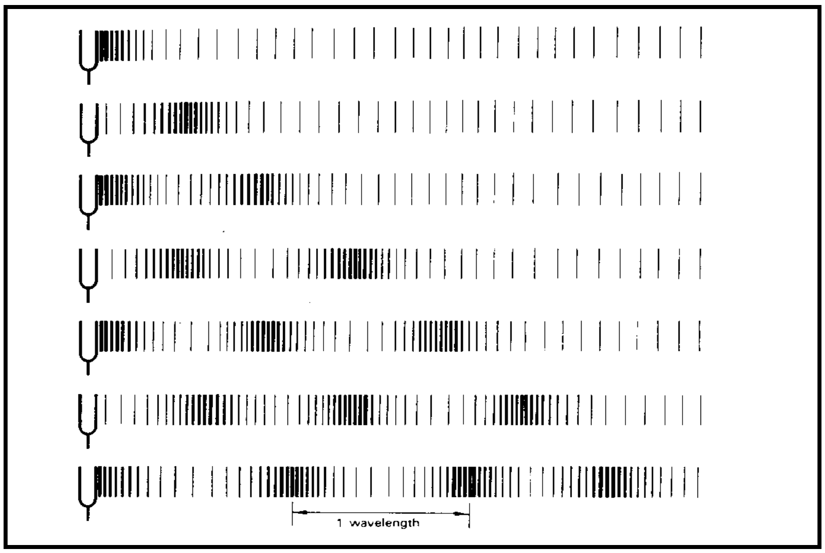
- ***<u>"Slinky" waves</u>*** - transverse and/or longitudinal (see PS-7.2) A wave in a "slinky" illustrates a mechanical disturbance caused by a force displacing one of the spring coils.





- The energy of a wave in a “slinky” spring will pass from the point on the spring where a coil has been displaced to the end of the slinky.
- The medium consists of the slinky coils.
- The coils either move back and forth parallel to the length of the spring, or back and forth perpendicular to the length of the spring
- After the wave passes, the coils return to approximately the position where they were before the wave passed.

- ***Sound waves:***



The energy of the wave transmits from the tuning fork out in all directions. The shape of the wave will approximate the shape of concentric spheres.

Air Molecules move parallel to the direction of the wave motion

- A Sound wave is a mechanical disturbance caused by a force displacing molecules in the medium through which it passes.
- A sound wave's energy travels out in all directions from a vibrating object.
- A sound wave travels through the medium.
- The particles move back and forth, parallel to the direction of the wave
- After a sound wave passes, the molecules moving in approximately the area where they were before the wave passed.

- ***Light waves***
  - A light waves (or other electromagnetic radiation) is energy that can be transmitted without mechanical disturbance of the particles of a medium
  - Light waves travel in straight lines in all directions from the source of the light

  - Light waves do not need a medium to travel through.
- Light waves transmit energy through empty space to the earth from the sun.

Students should understand that all waves transfer energy from place to place and if the wave moves though a medium, the particles of the medium can be displaced in a variety of ways but they are not transported with the energy of the wave.

Assessment Guidelines

The verb *illustrate* means to find specific illustrations or use illustrations of a concept or principle, therefore the major focus of assessment will be for students to give illustrations that show that they understand that energy is always transferred from one place to another with wave motion while the particles of the medium (if there is a medium) can be displaced in a variety of ways. Illustrations should show that students understand that the energy is being transferred in a variety of waves and how the transfer of energy is different from the displacement of particles in the medium. Because students must demonstrate conceptual knowledge, assessments should require that students understand why their illustrations meet the above criteria.

In addition to *illustrate*, students should be able to:

- *identify* transverse and longitudinal waves from illustrations;
- *compare* transverse and longitudinal wave particle motion and energy transfer direction or
- *summarize* the characteristics of longitudinal/transverse waves.

PS-7.2 Compare the nature and properties of transverse and longitudinal/compressional mechanical waves.

Taxonomy Level: 2.6-B Understand/Compare Conceptual Knowledge

Key Concepts
Mechanical waves: transverse waves, longitudinal or compressional waves
Wave properties: crest, trough, compression, rarefaction

Previous/future knowledge: In the 8th grade students distinguish between mechanical and electromagnetic waves (8-6.2), and explain how scientists use seismic waves—primary, secondary, and surface waves—to determine the internal structure of Earth (8-3.2).

In Physical Science students will compare properties and nature of transverse and longitudinal waves. Students will consider particle movement within the medium to compare transverse and longitudinal waves.

It is essential for students to understand:

- That there are two types of waves, electromagnetic and mechanical.
  - Electromagnetic waves may travel through a medium but do not need a medium for transmission. Electromagnetic waves transfer energy through a medium or space. (Electromagnetic waves will be addressed in PS-7.5)
  - Mechanical waves must have a medium through which to move. Mechanical waves transfer energy through the particles of a medium.
    - ♦ The particles of the medium move back and forth, but the wave (energy), itself is transmitted progressively from one place to another.
- The <u>nature of</u> transverse and longitudinal mechanical waves.
  - In a ***transverse wave***, as the wave (energy) moves through the medium, the direction of the back and forth motion of the particles is perpendicular to the direction that the wave is moving.
    - ♦ Examples of transverse mechanical waves might include but are not limited to: Some Slinky waves, secondary earthquake waves~~,~~ and waves in the string of stringed instruments such as a guitar.
  - In a ***longitudinal wave***, as the wave (energy) moves through the medium, the direction of the back and forth motion of the particles is parallel to the direction that the wave is moving.
    - ♦ Examples of longitudinal mechanical waves might include but are not limited to: Some Slinky waves, sound waves, primary earthquake waves, shock waves from a sonic boom or explosion, and ultrasonic waves.
- The <u>wave properties</u> of transverse waves - crests and troughs and longitudinal waves - compressions and rarefactions.
  - In a ***transverse wave*** the point of maximum displacement of the particles in a medium from the equilibrium position is called a crest or trough.

- In a ***longitudinal wave*** the particles of the medium are pushed closer together to form a high-pressure area called a compression and spread out to form a lower pressure area with fewer particles called a rarefaction.

- That some waves cannot be classified as transverse or longitudinal waves
  - The motion of the particles in some waves can be described as circular. Surface water waves fall into this category.
  - In torsion waves the motion of the particles is a twisting motion.

Misconception:
Students sometimes think that waves are one or two-dimensional. Many waves such as sound and light waves are often three-dimensional.

It is not essential for students to

- Describe the motion of particles in waves, which are not transverse or longitudinal waves such as torsion waves or water surface waves. Students should, however, be able to recognize these waves as non-examples if the motion of the particles in the medium is described.

Assessment Guidelines
The objective of this portion of the indicator is to *compare* transverse and longitudinal waves with regard to the movement of the particles in the medium, the direction that the wave moves, and the properties of the waves. It is important that assessments go beyond recall of factual knowledge, as conceptual knowledge is an understanding of the interrelationships. Assessments should insure that students understand the relevance of the factual information to an overall conceptual model of mechanical waves.

In addition to *compare*, students should be able to:

- *exemplify* transverse and longitudinal waves - give examples or draw or label illustrations which depict the motion of particles and the motion of the wave;
- *classify* waves - determine which of the two types of waves (transverse or longitudinal) is being described based on the motion of particles and the motion of the wave; or
- *summarize* transverse and longitudinal mechanical waves by abstracting the general characteristics of these waves.

PS-7.3 Summarize characteristics of waves (including displacement, frequency, period, amplitude, wavelength, and velocity as well as the relationships among these characteristics).

Taxonomy Level: 2.4-B Understand/Summarize Conceptual Knowledge

Key Concepts
Displacement
Frequency - hertz
Wave properties: period, amplitude, wavelength, velocity

Previous/future knowledge: In the 8th grade students "summarize factors that influence the basic properties of waves (including frequency, amplitude, wavelength, and speed)" (8-6.1). In Physical Science the students expand on this idea and summarize the relationships among these characteristics. Students will understand the relationship of the movement of the particles in the medium and the wave characteristics. In Physical Science the concept of displacement is introduced both with respect to the wave energy and with respect to the movement of the particles in the medium. The term wave velocity is introduced for the first time in Physical Science.

It is essential for students to understand:
- Characteristics of waves can be explained in terms of how the particles in the medium behave.
  - ***Amplitude***
    - The amplitude is the greatest displacement of the particles in a wave from their equilibrium (rest) position.
    - In a transverse wave amplitude is measured from the equilibrium or rest position of the medium to a crest or trough.
  - **Displacement**
    - Displacement with respect to waves will refer to the displacement of the particles in the medium.
    - This quantity has magnitude and direction.
    - It is the distance of a vibrating particle from the midpoint of its vibration. (Displacement is used in discussing amplitude and interference of mechanical waves.)
  - ***Frequency***
    - The frequency of the wave is the number of complete cycles (or vibrations) the particles go through per second or the number of waves that pass a point per second.
    - The unit for frequency is hertz, which is one vibration per second or one cycle per second or one wave per second.
    - The frequency and the wavelength are inversely related. When the frequency gets greater the wavelength get shorter.
  - ***Period***
    - The period of a wave is the time for one cycle (or vibration) or the time for one complete wave to pass a point.

    - ♦ The period is usually measured in seconds.
    - ♦ The period and the frequency are inversely related. An increase in frequency would result in a decrease in period.

- ○ ***Wavelength***
    - ♦ Wavelength of a wave is distance between a point in a wave and the next similar (in phase) point.
    - ♦ In a transverse wave the wavelength can be measured from a crest to the next crest or from a trough to the next trough.
    - ♦ In a longitudinal wave the wavelength can be measured from point in the compression to a similar point in the next compression or from a rarefaction to a similar point in the next rarefaction.

Teacher Note: (Since most longitudinal waves (such as sound waves) are not visible, the wavelength is often measured by indirect means.)

- ○ ***Velocity***
    - ♦ The velocity of the wave is a function of the medium and the type of wave and will not change unless the characteristics of the medium or type of wave changes.
    - ♦ Changes in frequency or wavelength do not affect the velocity of mechanical waves. When one of these increases the other decreases and the product of the two is a constant, which is the velocity.
    - ♦ When the medium changes the speed of waves changes. Examples include but are not limited to: Sound travels faster in steel than in air. Sound travels faster in warm air than cooler air. Light travels faster in air than in glass. Transverse waves travel slower in a heavy rope than in a light rope.

It is not essential for students to:

- Know the speed of waves in certain media
- Explain why waves travel slower in one specific medium than another.

The objective of this indicator is to *summarize* the characteristics of waves. When a student summarizes a concept he/she abstracts a general theme or major points about each characteristic of a wave and the relationships among these characteristics. It is important that assessments go beyond recall of factual knowledge, as conceptual knowledge is an understanding of the interrelationships. Assessments should insure that students understand the relevance of the factual information to an overall conceptual model of wave characteristics.

In addition to *summarize*, assessments may require that students:

- *compare* the characteristics of different types of waves;
- *exemplify* characteristics of different types of waves; or
- *identify* wave characteristics form a description.

PS-7.4 Use the formulas v = f λ and v = d/t to solve problems related to the velocity of waves.

Taxonomy Level: 3.2-C Apply/Use Procedural Knowledge

Key concepts
Wave speed
Frequency - hertz
Wavelength

Previous/future knowledge: In the 8th grade students use the formula for average speed, v = d/t, to solve real-world problems (8-5.2). The students used this formula for finding speed of objects but not waves.
In Physical Science students will use the formulas v = f λ and v = d/t in different and unfamiliar situations to solve problems relating to all of the variables in the indicator with respect waves.

It is essential for students to:

- Solve problems for any variables in these two equations using experimental data.
- Use dimensional analysis to determine the proper units. Examples:
    - If distance is given in meters and time is given in seconds then velocity will be m/s.
    - If frequency is given in hertz and time is given in seconds then velocity will be m/s.
    - If velocity is given in km/h and time is given in hours then distance will be kilometers.

It is not essential for students to:

- Solve problems involving both formulas.
- Solve vector problems involving waves. For math problems involving the wave standard in Physical Science the quantities are treated as scalar quantities rather than vector quantities.
    - In formula v = d/t, the quantity "v" represents velocity and is a vector quantity and should have a direction. The quantity "d" represents displacement and also involves direction.
        - ♦ For the purposes of the wave problems "v" will represent the scalar quantity speed.
        - ♦ For the purposes of the wave problems "d" will represent the scalar quantity distance.
    - For the formula v = f λ the quantity "v" will represent the scalar quantity speed.

Assessment Guidelines
The objective of this indicator is to *use* the correct procedure to mathematically determine one of the variables in the formulas v = f λ and v = d/t. *Use* means to apply a procedure to an unfamiliar task, therefore, students should be able to apply this procedure for situation involving any type of waves.

PS-7.5 Summarize the characteristics of the electromagnetic spectrum (including range of wavelengths, frequency, energy, and propagation without a medium).

Taxonomy Level: 2.4-B Understand/Summarize Conceptual Knowledge

Key Concepts
Electromagnetic spectrum
Visible spectrum
Propagation without a medium

Previous/future knowledge: In the 8^{th} grade students "compare the wavelength and energy of waves in various parts of the electromagnetic spectrum (including visible light, infrared, and ultraviolet radiation)" (8-6.8). Physical Science requires that students expand their concept of the nature of electromagnetic radiation. Students will summarize different types of radiation within the spectrum. The students will summarize the concepts of wavelength, frequency, energy, and propagation without a medium of electromagnetic radiation.

It is essential for students to understand:

- The electromagnetic radiation includes a wide range of frequencies and wavelengths. The entire range of frequencies is called the electromagnetic spectrum.
- The relative positions of the different types of electromagnetic radiations on the spectrum.
  - Students should know the order of electromagnetic radiation from low frequency to high frequency: radio waves, microwaves, infrared radiation, visible light (red, orange, yellow, green, blue, violet), ultraviolet, X-rays, and gamma rays.
- The energy of electromagnetic radiation is directly proportional to the frequency. When listed in order from lowest energy to highest energy, the list is the same as when listed from lowest frequency to highest.
  - Electromagnetic radiation with higher frequency than visible light also has a higher energy. This is why ultraviolet light can burn your skin and X-rays and gamma can damage tissues.
  - Electromagnetic radiation with a lower frequency than visible light and has less energy than visible light.
- The higher frequency electromagnetic waves have shorter wavelengths.
- Wavelengths vary greatly from very long wavelengths (many meters) to very short wavelengths (the size of atomic nuclei).
- Electromagnetic radiations travel in space with no medium or may travel through a transparent medium.
  - Electromagnetic radiation is a transverse wave.
  - Electromagnetic waves have an electric part and a magnetic part that are perpendicular to each other.

It is not essential for students to:

- Explain the nature of the oscillating electric and magnetic fields in electromagnetic waves.
- Give the specific numbers for the wavelength or frequency range of different types of electromagnetic radiation.
- Understand the concept of photons of energy but this may be a good class discussion depending on the level of the students.
- Understand how different spectra continuous, bright line/emission, dark line/absorption) are produced.

Assessment Guidelines

The objective of this indicator is to *summarize* the concepts of wavelengths, frequency, energy, and propagation without a medium for the different types of electromagnetic radiation. When a student summarizes a concept he/she abstracts a general theme or major points. It is important that assessments go beyond recall of factual knowledge, as conceptual knowledge is an understanding of the interrelationships. Assessments should insure that students understand the relevance of the factual information to an overall conceptual model of electromagnetic radiation and the electromagnetic spectrum.

In addition to *summarize*, assessments may require that students:

- *compare* the frequency, wavelength, and energy of different types of electromagnetic radiation;
- *infer* characteristics of a type of electromagnetic radiation from its position in the spectrum; or
- *exemplify* characteristics and types of electromagnetic radiation.

PS-7.6 Summarize reflection and interference of both sound and light waves and the refraction and diffraction of light waves.

Taxonomy Level: 2.4 B Understand/Summarize Conceptual Knowledge

Key Concepts
Wave behaviors: reflection, refraction, diffraction,
Interference: constructive and destructive
Concave and convex lenses
Plain mirrors
Law of reflection

Previous/future knowledge: In the 8^{th} grade students summarize the behaviors of waves (including refraction, reflection, transmission, and absorption) (8-6.4); Explain hearing in terms of the relationship between sound waves and the ear. (8-6.5); Explain sight in terms of the relationship between the eye and the light waves emitted or reflected by an object" (8-6.6); Explain how the absorption and reflection of light waves by various materials result in the human perception of color (8-6.7).
In Physical Science the students will expand the ideas of reflection and refraction of light and reflection of sound. The students will be introduced to the ideas of constructive and destructive interference of sound and light waves. The students will also be introduced to the concept of light diffraction of light.

It is essential for students to understand:

- That waves interfere with each other.
    - Interference may be constructive
        - A crest will interfere with another crest constructively to produce a larger crest and a trough will interfere to produce a larger trough.
        - Compressions interfere constructively with each other as do rarefactions.
    - Interference may be destructive
        - A crest will interfere with a trough to lessen or cancel the displacement of each.
        - Compressions interfere with rarefactions to lessen or cancel the displacement of each.

Sound waves

- Sound is a longitudinal mechanical wave, requires a medium, and can be produced by vibrating objects.
- Sound like other waves *reflects*.
    - Sound produces echoes when it bounces off hard surfaces.
- Sound waves *interfere* with each other changing what you hear.
    - Destructive interference makes sounds quieter; constructive interference makes sounds louder.
    - Sound waves reflect in tubes or some musical instruments to produce standing waves which reinforce sound through constructive interference to make the sound louder.

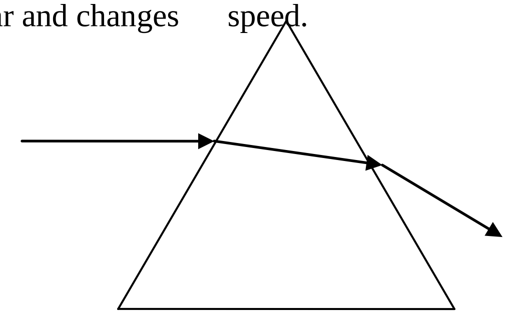
Light waves

- Light waves *reflect*
  - When light rays reflect they obey the "Law of Reflection". The angle of incidence is equal to the angle of reflection.
    - ♦ The angle of incidence is the angle between the incident ray and a line normal (perpendicular) to the surface at the point where the light strikes.
    - ♦ The angle of reflection is the angle between the reflected ray and the normal line.

Light waves *reflect in plain mirrors* to produce images.

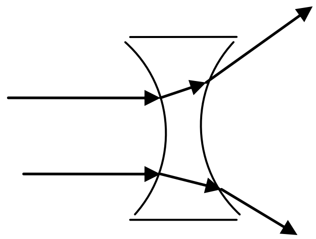
- ♦ The image appears as far behind the mirror as the object is in front of it.
- ♦ The image and the object appear to be same size.
- ♦ The image is upright.

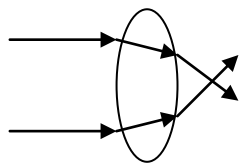
- Light like other waves can *diffract.*
  - Diffraction is the bending of a wave around a barrier or around the edges of an opening.
    - ♦ Waves with a longer wavelength diffract more readily so in order to observe light diffraction the barriers or openings must be small
    - ♦ When light waves diffract interference patterns can often be observed.
- Light can *interfere* to produce interference patterns.
  - Light can interfere constructively and destructively.
    - ♦ When light interferes a pattern is often seen with light and dark areas created by constructive and destructive interference.
    - ♦ At other times interferes to produce a color pattern. When a color interferes destructively we will see the colors that are not interfered with destructively.
  - Light can reflect off the bottom and top surfaces of thin film such as oil on water or bubbles and produce a color pattern due to interference.
  - Light can diffract through small slits or around lines to produce light and dark patterns or color patterns due to the interference of light
- Light like other waves can *refract*.
  - Waves refract when they change direction upon entering another medium in which the waves travel at different speeds.
    - ♦ The waves must strike the new medium at an angle other than straight on in order to change direction.
  - Light refracts when it enters a different medium at an angle other than perpendicular and changes speed.



  - Students should be able to predict the way that the light rays will bend.
    - ♦ Light slows down when it enters the prism and bends down when it strikes at this angle.

        - When light exits the prism it speeds back up and bends down again.
    - When white light enters another medium such as a prism the colors may spread out. This is because the violet end of the spectrum slows down more than the red end and therefore bends more.
    - Lenses may be a concave (diverging) lens or convex (converging) lens.
    - Students should be able to draw the resulting rays as light passes through each type of lens.





It is not essential for students to:

- Understand the distance an object must be placed to produce certain images with different types of lenses or mirrors or the sizes of those images.
- Understand concave and convex mirrors.
- Understand focal length.
- Understand that light waves form real or virtual images of different sizes when passing through lenses.
- Understand how sound waves are made by musical instruments.

Assessment Guidelines

The objective of this indicator is to *summarize* the concepts of reflection, refraction, diffraction and interference for light and reflection and interference for sound. When a student summarizes a concept he/she abstracts a general theme or major points. It is important that assessments go beyond recall of factual knowledge as conceptual knowledge is an understanding of the interrelationships. Assessments should insure that students understand the relevance of the factual information to an overall conceptual model for sound and light wave behavior.

In addition to *summarize*, assessments may require that students:

- *compare* the behavior of light in different situations of reflection or refraction;
- *infer* how light reflects, refracts;
- *infer* what will be heard when sound interferes or reflects;
- *exemplify* behavior of light or sound in different situations or effects of that behavior; or

- *illustrate* light wave behavior when it encounters concave or convex lenses or a prism.

PS-7.7 Explain the Doppler effect conceptually in terms of the frequency of the waves and the pitch of the sound.

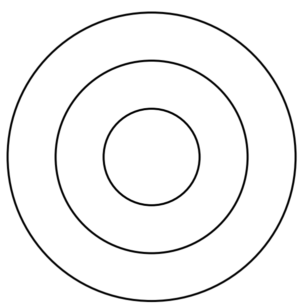
Taxonomy Level: 2.7-B Understand/Explain Conceptual Knowledge

Key Concepts
Doppler effect
Pitch
Frequency
Wavelength

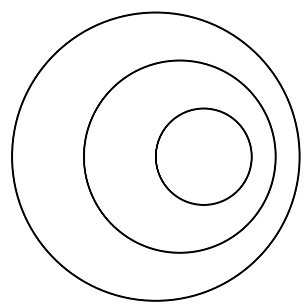
Previous/future knowledge: In the 8th grade students "Explained hearing in terms of the relationship between sound waves and the ear (8-6.5). In Physical Science the students will expand their concept of wave frequency and how they hear frequency of sound as pitch by explaining the Doppler effect.

It is essential for students to understand:

- The Doppler effect is an apparent frequency shift due to the relative motion of an observer and a wave source.
- The relative motion of a wave source and an observer.
  - A Doppler shift occurs when a wave source is moving towards an observer or away from the observer
  - A Doppler shift also occurs when the observer is moving toward the wave source
  - There is no shift when the source and observer are not moving toward or away from each other.



Waves from a source that is not moving.



Waves from a source that is moving to the right.

- As a wave source approaches an observer, the observer perceives a higher frequency than the source is producing. Wavelengths are shorter and the frequency is higher in front of a moving source.

  - The source of the wave is catching up with the wave in front of it. When it produces the next pulse the resulting wavelength is shorter. A shorter wavelength means that there will be a higher frequency
  - If the wave is a sound wave the observer will perceive a pitch that is higher than the pitch produced by the source.

- When the wave source is moving away from the observer he/she will perceive a lower frequency than the source in producing. Wavelengths are longer and the frequency is lower behind a moving source.
  - The source of the sound is moving away from the wave behind it. When it produces the next pulse the resulting wavelength is longer. A longer wavelength means that there will be a higher frequency.
  - If the wave is a sound wave the observer will perceive a lower pitch that the source is producing
- When the observer is moving toward a wave source he/she would perceive a higher frequency than the source is producing. The observer encounters waves more often than the source is producing them.
  - If the observer encounters more waves he/she perceives a higher frequency.
  - The observer would perceive a higher pitch in the case of sound waves.
- When the observer is moving away from a wave source he/she would perceive a lower frequency than the source is producing. The waves would have to catch up with him and he/she would encounter fewer waves.
  - If the observer encounters fewer waves he/she perceives a lower frequency.
  - The observer would perceive a lower pitch in the case of sound waves.

It not essential for students to understand why a red shift or blue shift occurs in light

Assessment Guidelines

As the verb for this indicator is ***explain*** the major focus of assessment will be for students to show that they know the effect each variable has on the perceived frequency of waves and on the pitch of sound Students should be able to construct "a cause and effect model". In this case, the model should be based on the fact that relative motion between a source of waves and an observer will affect the frequency at which waves are encountered. An observer will perceive a different frequency (pitch with sound) than the frequency of the source.

In addition to *explain*, assessments may require that students:

- *identify* the frequency that the listener observes in different situations to the frequency that the source is producing or the pitch heard by different observers in different locations with respect to the wave source;
- *summarize* how different situations affect the perception of relative pitch (frequency);
- *infer* from situations the relative pitch that the listener will observe; or
- *exemplify* situations which will produce the Doppler effect with sound waves.