Georgia Milestones Assessment System

Study/Resource Guide for Students and Parents

Physical Science

Study/Resource Guide

The Study/Resource Guides are intended to serve as a resource for parents and students. They contain practice questions and learning activities for the course. The standards identified in the Study/Resource Guides address a sampling of the state-mandated content standards.

For the purposes of day-to-day classroom instruction, teachers should consult the wide array of resources that can be found at www.georgiastandards.org.

Table of Contents

THE GEORGIA MILESTONES ASSESSMENT SYSTEM

Dear Student,

The **Georgia Milestones Physical Science EOC Study/Resource Guide for Students and Parents** is intended as a resource for parents and students.

This guide contains information about the core content ideas and skills that are covered in the course. There are practice sample questions for every unit. The questions are fully explained and describe why each answer is either correct or incorrect. The explanations also help illustrate how each question connects to the Georgia state standards.

In addition, the guide includes activities that you can try to help you better understand the concepts taught in the course. The standards and additional instructional resources can be found on the Georgia Department of Education website, www.georgiastandards.org.

Get ready—open this guide—and get started!

GEORGIA MILESTONES END-OF-COURSE (EOC) ASSESSMENTS

The EOC assessments serve as the final exam in certain courses. The courses are:

English Language Arts

- Ninth Grade Literature and Composition
- American Literature and Composition

Mathematics

- Algebra I
- Analytic Geometry
- Coordinate Algebra
- Geometry

Science

- Physical Science
- Biology

Social Studies

- United States History
- Economics/Business/Free Enterprise

All End-of-Course assessments accomplish the following:

- Ensure that students are learning
- Count as part of the course grade
- Provide data to teachers, schools, and school districts
- Identify instructional needs and help plan how to meet those needs
- Provide data for use in Georgia's accountability measures and reports

HOW TO USE THIS GUIDE

Let's get started!

First, preview the entire guide. Learn what is discussed and where to find helpful information. Even though the focus of this guide is Physical Science, you need to keep in mind your overall good reading habits.

- Start reading with a pencil or a highlighter in your hand and sticky notes nearby.
- Mark the important ideas, the things you might want to come back to, or the explanations you have questions about. On that last point, your teacher is your best resource.
- You will find some key ideas and important tips to help you prepare for the test.
- You can learn about the different types of items on the test.
- When you come to the sample items, don't just read them, *do* them. Think about strategies you can use for finding the right answer. Then read the analysis of the item to check your work. The reasoning behind the correct answer is explained for you. It will help you see any faulty reasoning in those you may have missed.
- Use the activities in this guide to get hands-on understanding of the concepts presented in each unit.
- With the Depth of Knowledge (DOK) information, you can gauge just how complex the item is. You will see that some items ask you to recall information and others ask you to infer or go beyond simple recall. The assessment will require all levels of thinking.
- Plan your studying and schedule your time.
- Proper preparation will help you do your best!

OVERVIEW OF THE PHYSICAL SCIENCE EOC ASSESSMENT

ITEM TYPES

The Physical Science EOC assessment consists of **selected-response** items only.

A **selected-response** item, sometimes called a multiple-choice item, is a question, problem, or statement that is followed by four answer choices. These questions are worth one point.

DEPTH OF KNOWLEDGE DESCRIPTORS

Items found on the Georgia Milestones assessments, including the Physical Science EOC assessment, are developed with a particular emphasis on the kinds of thinking required to answer questions. In current educational terms, this is referred to as Depth of Knowledge (DOK). DOK is measured on a scale of 1 to 4 and refers to the level of cognitive demand (different kinds of thinking) required to complete a task, or in this case, an assessment item. The following table shows the expectations of the four DOK levels in detail.

The DOK table lists the skills addressed in each level, as well as common question cues. These question cues not only demonstrate how well you understand each skill, but they relate to the expectations that are part of the Characteristics of Science and Nature of Science standards.

Level 1—Recall of Information	
Level 1 generally requires that you identify, list, or define. This level usually asks you to recall facts, terms, concepts, and trends and may ask you to identify specific information contained in documents, maps, charts, tables, graphs, or illustrations. Items that require you to “describe” and/or “explain” could be classified as Level 1 or Level 2. A Level 1 item requires merely that you recall, recite, or reproduce information.	
Skills Demonstrated	**Question Cues**
• Make observations • Recall information • Recognize formulas, properties, patterns, processes • Know vocabulary, definitions • Know basic concepts • Perform one-step processes • Translate from one representation to another • Identify relationships	• Tell what, when, or where • Find • List • Define • Identify; label; name • Choose; select • Compute; estimate • Express • Read from data displays • Order

Level 2—Basic Reasoning	
Level 2 includes the engagement (use) of some mental processing beyond recalling or reproducing a response. A Level 2 “describe” and/or “explain” item would require that you go beyond a description or explanation of recalled information to describe and/or explain a result or “how” or “why.”	
Skills Demonstrated	**Question Cues**
• Apply learned information to abstract and real-life situations • Use methods, concepts, theories in abstract and real-life situations • Perform multi-step processes • Solve problems using required skills or knowledge (requires more than habitual response) • Make a decision about how to proceed • Identify and organize components of a whole • Extend patterns • Identify/describe cause and effect • Recognize unstated assumptions; make inferences • Interpret facts • Compare or contrast simple concepts/ideas	• Apply • Calculate; solve • Complete • Describe • Explain how; demonstrate • Construct data displays • Construct; draw • Analyze • Extend • Connect • Classify • Arrange • Compare; contrast

Level 3—Complex Reasoning	
Level 3 requires reasoning, using evidence, and thinking on a higher and more abstract level than Level 1 and Level 2. You will go beyond explaining or describing "how and why" to justifying the "how and why" through application and evidence. Level 3 questions often involve making connections across time and place to explain a concept or "big idea."	
Skills Demonstrated	**Question Cues**
• Solve an open-ended problem with more than one correct answer • Create a pattern • Generalize from given facts • Relate knowledge from several sources • Draw conclusions • Make predictions • Translate knowledge into new contexts • Compare and discriminate between ideas • Assess value of methods, concepts, theories, processes, formulas • Make choices based on a reasoned argument • Verify the value of evidence, information, numbers, and data	• Plan; prepare • Predict • Create; design • Ask "what if?" questions • Generalize • Justify; explain why; support; convince • Assess • Rank; grade • Test; judge • Recommend • Select • Conclude

Level 4—Extended Reasoning	
Level 4 requires the complex reasoning of Level 3 with the addition of planning, investigating, applying significant conceptual understanding, and/or developing that will most likely require an extended period of time. You may be required to connect and relate ideas and concepts *within* the content area or *among* content areas in order to be at this highest level. The Level 4 items would be a show of evidence, through a task, a product, or an extended response, that the cognitive demands have been met.	
Skills Demonstrated	**Question Cues**
• Analyze and synthesize information from multiple sources • Examine and explain alternative perspectives across a variety of sources • Apply mathematical models to illuminate a problem or situation • Design a mathematical model to inform and solve a practical or abstract situation • Combine and synthesize ideas into new concepts	• Design • Connect • Synthesize • Apply concepts • Critique • Analyze • Create • Prove

DEPTH OF KNOWLEDGE EXAMPLE ITEMS

Example items that represent the applicable DOK levels across various Physical Science content domains are provided on the following pages.

All example and sample items contained in this guide are the property of the Georgia Department of Education.

Example Item 1

DOK Level 1: This is a DOK level 1 item because it requires the student to recall information concerning a known relationship between the angle of incidence and angle of reflection.

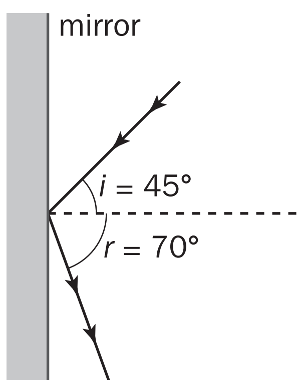
Physical Science Domain: Physics: Waves, Electricity, and Magnetism

Standard: SPS9. Students will investigate the properties of waves. d. Investigate the phenomena of reflection, refraction, interference, and diffraction.

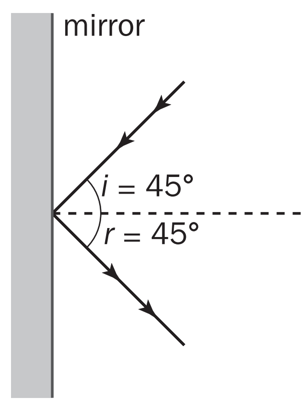
Standard: SCSh5. Students will demonstrate the computation and estimation skills necessary for analyzing data and developing reasonable scientific explanations. e. Solve scientific problems by substituting quantitative values, using dimensional analysis, and/or simple algebraic formulas as appropriate.

Which diagram correctly represents a light ray reflecting off a mirror?

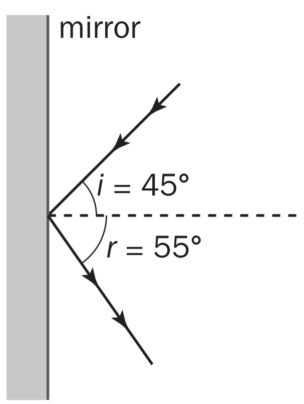
A.



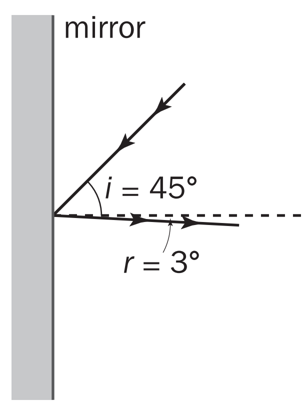
B.



C.



D.



Correct Answer: B

Explanation of Correct Answer: The correct answer choice is (B). For this choice, the angle of reflection is equal to the angle of incidence. Choices (A) and (C) are incorrect because the angle of reflection is larger than the angle of incidence. Choice (D) is incorrect because the angle of reflection is much smaller than the angle of incidence.

Example Item 2

DOK Level 2: This is a DOK level 2 item because it requires the student to apply learned information, the concept of convection, to abstract and real-life situations.

Physical Science Domain: Physics: Energy, Force, and Motion

Standard: SPS7. Students will relate transformations and flow of energy within a system. b. Investigate molecular motion as it relates to thermal energy changes in terms of conduction, convection, and radiation.

Standard: SCSh1. Students will evaluate the importance of curiosity, honesty, openness, and skepticism in science. b. Recognize that different explanations often can be given for the same evidence.

In a demonstration of heating by convection, your teacher heats a beaker of water to boiling on a hot plate. Which hypothesis correctly describes how heating by convection occurs?

A. As particles of a substance are heated, energy is transferred as more energetic particles within the substance move from one place to another.
B. As particles of a substance are heated, energy is transferred to neighboring particles by collisions of the particles.
C. As particles of a substance are heated, energy is transferred by gas bubbles within a liquid.
D. As particles of a substance are heated, energy is transferred by electromagnetic waves.

Correct Answer: A

Explanation of Correct Answer: The correct answer choice is (A). As particles of a substance are heated, energy is transferred as more energetic particles within the substance move from one place to another. In heating by convection, particles within a fluid gain energy from a heat source. Zones in the liquid closer to the heat source gain energy, become less dense, and rise. Zones within the liquid that are farther from the heat source are cooler and denser, and as a result, they sink. Cooler, less energetic particles sink and are then heated. Choice (B) is incorrect because it describes heating by conduction. Choice (C) is incorrect because it describes an observation of heating by convection, but does not correctly describe how convection occurs. Choice (D) is incorrect because it describes heating by radiation.

Example Item 3

DOK Level 3: This is a DOK level 3 item because it requires the student to make choices based on a reasoned argument, i.e., that objects will float in liquids as long as they are less dense than the liquid in which they are placed.

Physical Science Domain: Chemistry: Chemical Reactions and Properties of Matter

Standard: SPS2. Students will explore the nature of matter, its classifications, and its system for naming types of matter. a. Calculate density when given a means to determine a substance's mass and volume.

Standard: SCSh3. Students will identify and investigate problems scientifically. e. Develop reasonable conclusions based on data collected.

The density of four unknown liquids is given in the following table.

Density (g/cm^3)

Liquid 1	1.10
Liquid 2	1.20
Liquid 3	1.30
Liquid 4	1.40

A student places a small, solid cube in each of the liquids. The cube has a mass of 10 grams and a volume of 8 cubic centimeters. In which of the liquids will the cube float?

A. in Liquid 4 only
B. in Liquid 3 and Liquid 4 only
C. in Liquid 2, Liquid 3, and Liquid 4 only
D. in Liquid 1, Liquid 2, Liquid 3, and Liquid 4

Correct Answer: B

Explanation of Correct Answer: The correct answer is choice (B), in Liquid 3 and Liquid 4 only. An object will float in a liquid if its density is less than that of the liquid. To find the density of the object, divide its mass (10 grams) by its volume (8 cm^3). The answer is 1.25 g/cm^3. The density of the object is less than the density of Liquids 3 and 4. Therefore, the object will float in Liquids 3 and 4. Choice (A) is incorrect because the object will also float in Liquid 3. Choices (C) and (D) are incorrect because the object is denser than Liquids 1 and 2. Therefore it will not float in Liquids 1 and 2.

DESCRIPTION OF TEST FORMAT AND ORGANIZATION

The Georgia Milestones Physical Science EOC assessment consists of 75 items. You will be asked to respond to selected-response (multiple-choice) items.

The test will be given in two sections.

- You may have up to 70 minutes per section to complete Sections 1 and 2.
- The total estimated testing time for the Physical Science EOC assessment ranges from approximately 90 to 140 minutes. Total testing time describes the amount of time you have to complete the assessment. It does not take into account the time required for the test examiner to complete pre-administration and post-administration activities (such as reading the standardized directions to students).
- Sections 1 and 2 may be administered on the same day or across two consecutive days, based on the district's testing protocols for the EOC measures (in keeping with state guidance).
- During the Physical Science EOC assessment, a Physical Science Reference Sheet of formulas and the Periodic Table will be available for you to use. See page 17 for an example.

Effect on Course Grade

It is important that you take this course and the EOC assessment very seriously.

- For students in Grade 10 or above beginning with the 2011–2012 school year, the final grade in each course is calculated by weighting the course grade 85% and the EOC score 15%.
- For students in Grade 9 beginning with the 2011–2012 school year, the final grade in each course is calculated by weighting the course grade 80% and the EOC score 20%.
- A student must have a final grade of at least 70% to pass the course and earn credit toward graduation.

PREPARING FOR THE PHYSICAL SCIENCE EOC ASSESSMENT

STUDY SKILLS

As you prepare for this test, ask yourself the following questions:

- How would you describe yourself as a student?
- What are your study skills strengths and/or weaknesses?
- How do you typically prepare for a classroom test?
- What study methods do you find particularly helpful?
- What is an ideal study situation or environment for you?
- How would you describe your actual study environment?
- How can you change the way you study to make your study time more productive?

ORGANIZATION—OR TAKING CONTROL OF YOUR WORLD

- Establish a study area that has minimal distractions.
- Gather your materials in advance.
- Develop and implement your study plan.

ACTIVE PARTICIPATION

The most important element in your preparation is *you*. You and your actions are the key ingredient. Your active studying helps you stay alert and be more productive. In short, you need to interact with the course content. Here's how you do it.

- Carefully read the information and then DO something with it. Mark the important material with a highlighter, circle it with a pen, write notes on it, or summarize the information in your own words.
- Ask questions. As you study, questions often come into your mind. Write them down and actively seek the answers.
- Create sample test questions and answer them.
- Find a friend who is also planning to take the test and quiz each other.

TEST-TAKING STRATEGIES

Part of preparing for a test is having a set of strategies you can draw from. Include these strategies in your plan:

- Read and understand the directions completely. If you are not sure, ask a teacher.
- Read each question and all the answer choices carefully.
- If you use scratch paper, make sure you copy your work to your test accurately.
- Make a sketch for items that describe a situation. This will help you visualize what is being described and help you understand the problem.

- Underline the important parts of each task. Make sure that your answer goes on the answer sheet.
- Be aware of time. If a question is taking too much time, come back to it later.
- Answer all questions. Check your answers for accuracy.
- Stay calm and do the best you can.

PREPARING FOR THE PHYSICAL SCIENCE EOC ASSESSMENT

Read this guide to help prepare for the Physical Science EOC assessment.

The section of the guide titled “Content of the Physical Science EOC Assessment” provides a snapshot of the Physical Science course. In addition to reading this guide, do the following to prepare to take the assessment:

- Read your textbooks and other materials.
- Think about what you learned, ask yourself questions, and answer them.
- Read and become familiar with the way questions are asked on the assessment.
- Answer the practice Physical Science questions.
- There are additional items to practice your skills available online. Ask your teacher about online practice sites that are available for your use.

CONTENT OF THE PHYSICAL SCIENCE EOC ASSESSMENT

Up to this point in the guide, you have been learning how to prepare for taking the EOC assessment. Now you will learn about the topics and standards that are assessed in the Physical Science EOC assessment and see some sample items.

- ✍ The first part of this section focuses on what will be tested. It also includes sample items that will let you apply what you have learned in your classes and from this guide.
- ✍ The next part contains a table that shows the standard assessed for each item, the DOK level, the correct answer (key), and a rationale/explanation of the right and wrong answers.
- ✍ You can use the sample items to familiarize yourself with the item format found on the assessment.

All example and sample items contained in this guide are the property of the Georgia Department of Education.

The Physical Science EOC assessment will assess the Physical Science standards documented at www.georgiastandards.org. The Physical Science items also relate to a Characteristics of Science standard and a Nature of Science standard. Because science consists of a way of thinking and investigating and includes a growing body of knowledge about the natural world, you will need to understand the **Characteristics of Science** standards, the **Nature of Science** standards, and the **Content** standards for Physical Science. The Characteristics of Science and Nature of Science standards can also be found at www.georgiastandards.org.

The content of the assessment is organized into four groupings, or domains, of standards for the purposes of providing feedback on student performance.

- ✍ A content domain is a reporting category that *broadly* describes and defines the content of the course, as measured by the EOC assessment.
- ✍ On the actual test, the standards for Physical Science are grouped into four domains and divided between Chemistry and Physics as follows:

Chemistry

- Atomic and Nuclear Theory and the Periodic Table
- Chemical Reactions and Properties of Matter

Physics

- Energy, Force, and Motion
- Waves, Electricity, and Magnetism

- ✍ Each domain was created by organizing standards that share similar content characteristics.
- ✍ The Content standards describe the level of understanding each student is expected to achieve. The Characteristics of Science and Nature of Science standards describe the practices used by scientists to acquire these understandings. Both sets of standards combined include the knowledge and skills assessed on the EOC assessment and they are used to plan instruction throughout the course.

SNAPSHOT OF THE COURSE

This section of the guide is organized into five units that review the material covered within the four domains of the Physical Science course. The material is presented by topic rather than by category or standard. In each unit, you will find sample items similar to what you will see on the EOC assessment. The next section of the guide contains a table that shows for each item the standard assessed, the Characteristics of Science alignment, the DOK level, the correct answer (key), and a rationale/explanation about the key and distractors.

All example and sample items contained in this guide are the property of the Georgia Department of Education.

The more you understand about the topics in each unit, the greater your chances of getting a good score on the EOC assessment.

As you read through each unit, you will find that some material is repeated in two or more texts. The units are designed to show how the key ideas within the units apply in many different ways.

Physical Science Reference Sheet

Formulas

Force, Mass and Motion

Velocity = $\frac{\text{displacement}}{\text{time}}$ $(v = \frac{d}{t})$

Acceleration = $\frac{\text{final velocity} - \text{initial velocity}}{\text{time}}$ $(a = \frac{v_f - v_i}{t})$

Weight = mass × acceleration of gravity $(w = mg)$

Force = mass × acceleration $(F = ma)$

Work = force × distance $(W = Fd)$

Mechanical advantage =

$\frac{\text{effort distance}}{\text{resistance distance}} = \frac{\text{resistance force}}{\text{effort force}}$ $(MA = \frac{d_e}{d_r} = \frac{f_r}{f_e})$

Chemical Reactions and Properties of Matter

Density = $\frac{\text{mass}}{\text{volume}}$ $(D = \frac{m}{V})$

Volume of a rectangular solid = length × width × height $(V = lwh)$

Heat lost or gained =
mass × specific heat capacity × change in temperature $(Q = mc\Delta T)$

Waves, Electricity and Magnetism

Voltage = current × resistance $(V = IR)$

Georgia Milestones Assessment System

Constants and Relationships

Kelvin = °Celsius + 273 (K = °C + 273)

newton: 1 N = 1 kg • $\frac{\text{m}}{\text{s}^2}$

Acceleration due to gravity: $g \approx 10 \frac{\text{m}}{\text{s}^2}$

joule: 1 J = 1 N • m

Turn over for the Periodic Table.

Georgia Milestones End of Course (EOC) Physical Science

Periodic Table

Key

Atomic number	Element symbol	Element name	Average atomic mass
29	Cu	Copper	63.55

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** Hydrogen 1.01																	2 **He** Helium 4.00
3 **Li** Lithium 6.94	4 **Be** Beryllium 9.01											5 **B** Boron 10.81	6 **C** Carbon 12.01	7 **N** Nitrogen 14.01	8 **O** Oxygen 16.00	9 **F** Fluorine 19.00	10 **Ne** Neon 20.18
11 **Na** Sodium 22.99	12 **Mg** Magnesium 24.31											13 **Al** Aluminum 26.98	14 **Si** Silicon 28.09	15 **P** Phosphorus 30.97	16 **S** Sulfur 32.07	17 **Cl** Chlorine 35.45	18 **Ar** Argon 39.95
19 **K** Potassium 39.10	20 **Ca** Calcium 40.08	21 **Sc** Scandium 44.96	22 **Ti** Titanium 47.87	23 **V** Vanadium 50.94	24 **Cr** Chromium 52.00	25 **Mn** Manganese 54.94	26 **Fe** Iron 55.85	27 **Co** Cobalt 58.93	28 **Ni** Nickel 58.69	29 **Cu** Copper 63.55	30 **Zn** Zinc 65.39	31 **Ga** Gallium 69.72	32 **Ge** Germanium 72.61	33 **As** Arsenic 74.92	34 **Se** Selenium 78.96	35 **Br** Bromine 79.90	36 **Kr** Krypton 83.80
37 **Rb** Rubidium 85.47	38 **Sr** Strontium 87.62	39 **Y** Yttrium 88.91	40 **Zr** Zirconium 91.22	41 **Nb** Niobium 92.91	42 **Mo** Molybdenum 95.94	43 **Tc** Technetium (98)	44 **Ru** Ruthenium 101.07	45 **Rh** Rhodium 102.91	46 **Pd** Palladium 106.42	47 **Ag** Silver 107.87	48 **Cd** Cadmium 112.41	49 **In** Indium 114.82	50 **Sn** Tin 118.71	51 **Sb** Antimony 121.76	52 **Te** Tellurium 127.60	53 **I** Iodine 126.90	54 **Xe** Xenon 131.29
55 **Cs** Cesium 132.91	56 **Ba** Barium 137.33	57-71 ☆	72 **Hf** Hafnium 178.49	73 **Ta** Tantalum 180.95	74 **W** Tungsten 183.84	75 **Re** Rhenium 186.21	76 **Os** Osmium 190.23	77 **Ir** Iridium 192.22	78 **Pt** Platinum 195.08	79 **Au** Gold 196.97	80 **Hg** Mercury 200.59	81 **Tl** Thallium 204.38	82 **Pb** Lead 207.2	83 **Bi** Bismuth 208.98	84 **Po** Polonium (209)	85 **At** Astatine (210)	86 **Rn** Radon (222)
87 **Fr** Francium (223)	88 **Ra** Radium (226)	89-103 ☆☆	104 **Rf** Rutherfordium (261)	105 **Db** Dubnium (262)	106 **Sg** Seaborgium (266)	107 **Bh** Bohrium (264)	108 **Hs** Hassium (269)	109 **Mt** Meitnerium (268)	110 **Ds** Darmstadtium (281)	111 **Rg** Roentgenium (272)	112 **Cn** Copernicium (285)	113 **Uut** Ununtrium (284)	114 **Fl** Flerovium (289)	115 **Uup** Ununpentium (288)	116 **Lv** Livermorium (293)	117 **Uus** Ununseptium (294)	118 **Uuo** Ununoctium (294)

☆ Lanthanide series	57 **La** Lanthanum 138.91	58 **Ce** Cerium 140.12	59 **Pr** Praseodymium 140.91	60 **Nd** Neodymium 144.24	61 **Pm** Promethium (145)	62 **Sm** Samarium 150.36	63 **Eu** Europium 151.96	64 **Gd** Gadolinium 157.25	65 **Tb** Terbium 158.93	66 **Dy** Dysprosium 162.50	67 **Ho** Holmium 164.93	68 **Er** Erbium 167.26	69 **Tm** Thulium 168.93	70 **Yb** Ytterbium 173.04	71 **Lu** Lutetium 174.97
☆☆ Actinide series	89 **Ac** Actinium (227)	90 **Th** Thorium 232.04	91 **Pa** Protactinium 231.04	92 **U** Uranium 238.03	93 **Np** Neptunium (237)	94 **Pu** Plutonium (244)	95 **Am** Americium (243)	96 **Cm** Curium (247)	97 **Bk** Berkelium (247)	98 **Cf** Californium (251)	99 **Es** Einsteinium (252)	100 **Fm** Fermium (257)	101 **Md** Mendelevium (258)	102 **No** Nobelium (259)	103 **Lr** Lawrencium (262)

UNIT 1: MOTION

The principles of force and motion influence our daily lives whether we walk, throw a ball, rake leaves, or launch missiles. At the atomic level, the relative motion of tiny particles such as atoms and molecules is used to explain the phases of matter. The relative proximity of one particle to another in a system describes the denseness of that matter. In this unit, students will have opportunities to observe, measure, and discuss how matter and the forces that act upon it combine to create regularities and patterns that explain scientific phenomena. Students will develop a conceptual understanding of force, motion, and matter through the use of the scientific practices described in the Characteristics of Science and Nature of Science standards. The tasks suggested in this unit integrate these Characteristics of Science and habits of mind to extend the student's critical and creative-thinking abilities in the context of the science concepts studied.

AREAS OF FOCUS

- Objects change their motion only when a net force is applied. (SPS8)
- Force, mass, and acceleration are interdependent. A change in any one of these affects the others. (SPS8)
- Knowledge of the conditions of an object's motion allows us to predict its future. (SPS8)
- Friction is an ever-present force that opposes motion. (SPS8)
- For gaseous substances, pressure, volume, and temperature are interdependent. (SPS5)
- Whenever one object exerts a force on another, an equal amount of force is exerted in return. (SPS8)
- A system is an ensemble of objects (real or abstract) in which each component relates to at least one other component of the group. (SPS7)
- Temperature is a measure of the internal energy of a system. (SPS5)
- The greater the particle or molecular motion, the higher the internal energy of a system. (SPS5)
- The phases of matter are states of a system that have relatively the same physical properties. (SPS5)
- A change in the energy of a system affects the attraction between the particles or molecules, and a phase change may occur. (SPS7)
- Density is a physical property that can be quantitatively measured using mass and volume. (SPS2)

KEY IDEAS

Simply stated, a **force** is an action that can change the motion of an object. A push or pull is an example of a force. The unit for force is the newton (N). All the forces acting on an object can be combined to determine the net force acting on the object. If all the forces acting on the object are balanced, the net force is zero and the motion of the object does not change. If an object is already at rest, it will remain at rest. If an object is moving, it will keep on moving. **Balanced forces** do not change the motion of an object, but if the combination of forces acting on an object is not balanced, then the net force is greater than zero and the motion of the object changes. **Unbalanced forces** change the motion of an object.

The distance an object moves per unit of time is known as the **speed**. The **velocity** is the speed of the object plus its direction. The average speed can be found by dividing the change in the displacement of an object by the change in time.

$$v_{\text{ave}} = \frac{d_{\text{final}} - d_{\text{initial}}}{t_{\text{final}} - t_{\text{initial}}}$$

Acceleration, like velocity, has magnitude and direction. The average acceleration of an object is found by dividing the change in the velocity of the object by the change in time.

$$a_{\text{ave}} = \frac{v_{\text{final}} - v_{\text{initial}}}{t_{\text{final}} - t_{\text{initial}}}$$

Sir Isaac Newton was the first scientist to describe the relationships among force, mass, and motion clearly. The three laws of motion are named after him.

- **Newton's first law** of motion states that an object *at rest* will stay at rest unless it is acted upon by an unbalanced force. An object *in motion* will continue to move in the same direction and with the same speed unless acted upon by an unbalanced force. An object's tendency to resist a change in motion is called **inertia**. Inertia is directly related to an object's mass. An object with a large mass has a large amount of inertia, while an object with a small mass has a small amount of inertia. Large forces are required to change the motion of objects with large masses, while small forces can change the motion of objects with small masses.
- **Newton's second law** of motion states that the acceleration, a, of an object is directly related to the net force, F, applied to the object and inversely related to the mass, m, of the object. The following equation represents Newton's second law of motion.

$$a = \frac{F}{m} \quad \text{or} \quad F = ma$$

According to the equation, the greater the net force acting on an object, the greater the acceleration of the object. Also, the greater the mass of the object, the lower the acceleration of the object. For example, a large truck has a much lower acceleration than a compact car given the same applied force by each engine. The larger mass (or inertia) of the truck resists acceleration.

- **Newton's third law** of motion states that forces occur as equal and opposite pairs. For every action force there is an equal and opposite reaction force. For example, when a book is sitting on a table, the weight of the book produces a downward action force on the table. The tabletop in turn pushes on the book with an upward reaction force. These forces are equal in magnitude but opposite in direction.

Types of Forces

- Gravitational
- Electromagnetic
- Nuclear (Atomic)
- Frictional

Gravitational force is a force between any two objects. The strength of the force is related to the mass of the objects and the distance between them. The more mass an object has, the greater the gravitational force it exerts. The Moon has less mass than Earth. The resulting lower gravitational force made the astronauts appear nearly "weightless" as they moved across the lunar surface. One should note that mass and **weight** are not the same quantity. An object has mass regardless of whether gravity or any other force is acting upon it. Weight, on the other hand, changes depending on the influence of gravity. The relationship between weight, W, and mass, m, can be written as the following equation:

$$W = mg$$

In this equation, g represents the acceleration due to gravity. At the surface of Earth, the acceleration of gravity is 9.80 m/s^2. The value of g decreases the farther away from the center of Earth an object gets. This means the weight of an object would decrease if it were placed on top of a mountain or put into space. Numerically, as the distance between two objects increases, the force of gravity decreases by a factor equal to the square of the distance. For example, if the distance between two objects is doubled, the force of gravity will decrease by a factor of four.

Other forces include **electromagnetic forces**. These forces include both electric forces and magnetic forces. The forces exerted within the nucleus of an atom are called **nuclear forces**. These forces hold the protons and neutrons together. **Frictional forces** tend to stop the motion of an object by dispersing its energy as heat. There are three types of frictional forces: sliding friction, rolling friction, and static friction. **Sliding friction** occurs when one solid surface slides over another solid surface. **Rolling friction** occurs when an object rolls across a solid surface. **Static friction** occurs between the surfaces of two objects that touch but do not move against each other. Static friction must be overcome for one of the objects to move.

Pressure (*P*), **volume (*V*)**, and **absolute temperature (*T*)** are usually used to describe the condition of a gas. Pressure is the force exerted on a surface per unit area. To understand how the above variables are related, consider air in a variable-volume container. When the temperature of a gas is increased, the atoms or molecules move faster since they have more energy. If the volume remains the same, the force pushing on the walls of the container increases, resulting in a rise in pressure. Conversely, if a gas is cooled at a constant volume, the pressure decreases. When a gas is compressed into a smaller volume, the surface area of the walls decreases, leading to an increase in pressure. When the converse is true, the pressure decreases. Chemists have summarized these relationships mathematically with the following laws:

***PV* =** a constant when the temperature is constant
V is directly proportional to ***T*** when the pressure is constant.

These laws can prove very useful when trying to describe the properties of a gas under changing conditions.

Atoms and molecules are in constant motion. The type and degree of motion determine the phase or state of matter.

- In the **solid phase**, atoms or molecules are held in a rigid structure. They are free to vibrate but cannot move around. As a result, solids have a definite volume and shape.
- The **liquid phase** is intermediate between solid and gas. Intermolecular forces hold these atoms or molecules loosely together but do not force them into a rigid structure. Liquid molecules are free to move about to a certain degree, so they have a definite volume. However, liquids conform to the shape of their container.
- In the **gas phase**, atoms and molecules experience their greatest freedom. The forces attracting gas molecules are almost nonexistent. As a result, gas molecules are much farther apart and can move freely about. The molecules take on the shape of their container but do not possess a definite volume.
- Finally, **plasmas** are gases that have been so energized that their atoms have been stripped of some or all electrons. Solar flares are great examples of plasmas. Solar flares eject extremely hot hydrogen ions (H^+) away from the Sun toward Earth.

Matter, the substance that is seen all around us, consists of anything that has mass and volume. The **density**, *d*, of a material object is defined as the ratio of the object's **mass**, *m*, to its **volume**, *V*. The formula used to calculate density is $d = \frac{m}{V}$. The density is a unique property of matter. Gases tend to have very low densities compared to solids and liquids. The large distances between atoms or molecules of gas are responsible for the very low density. Other properties of substances include color, melting point, boiling point, chemical reactivity, and electrical conductivity. A **physical property** is a characteristic of a substance that can be observed or measured without changing the identity of the substance. A **chemical property** characterizes how matter changes into entirely new substances. A set of known physical and chemical properties help identify a particular chemical substance.

SAMPLE ITEMS

Item 1

Which hypothesis describes the behavior of molecules when a substance changes from a gas to a liquid?

A. The average speed of the molecules increases, because they have lower energy in the liquid state.
B. The average speed of the molecules decreases, because they have lower energy in the liquid state.
C. The average speed of the molecules decreases, because they have higher energy in the liquid state.
D. The average speed of the molecules increases, because they have higher energy in the liquid state.

Item 2

It takes a person one half hour to run 6 kilometers at a constant rate along a straight-line path. What is the velocity of the person?

A. 0 km/hr in the direction of the path
B. 3 km/hr in the direction of the path
C. 6 km/hr in the direction of the path
D. 12 km/hr in the direction of the path

Item 3

A small marble is dropped to the floor. Assume that as the marble falls, the only force exerted on it is the force of gravity. How do the speed and acceleration of the marble change with time?

A. speed increases, acceleration increases
B. speed remains constant, acceleration increases
C. speed increases, acceleration remains constant
D. speed remains constant, acceleration remains constant

Item 4

Which observation BEST demonstrates Newton's first law of motion?

A. An astronaut weighs more on Earth than he does on the Moon, but his mass does not change.
B. A baseball thrown by a professional player has greater acceleration than a baseball you throw.
C. A book placed beside you on the back seat of a car slides to the floor as the car stops suddenly.
D. A stone thrown at a trashcan cannot knock it over, but a stone with more mass can knock it over.

ACTIVITY

Physics: Energy, Force, and Motion

Standards: SPS8a, SPS8b

You will explore the relationship between position, velocity, and acceleration for motion with constant speed and for motion with uniformly increasing speed. You will collect data on a moving object and use mathematical and graphical tools to determine the velocity and acceleration of the moving object.

Before beginning, make sure that the following materials are available:

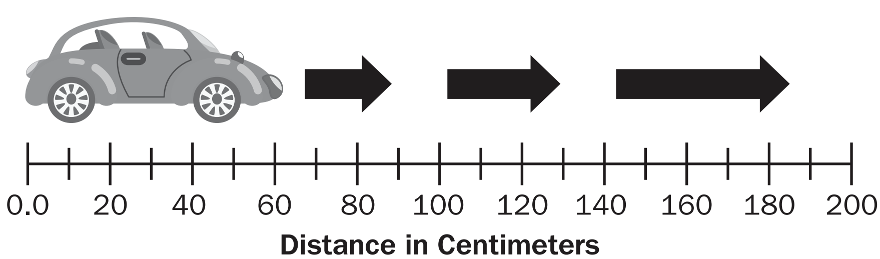
- tape
- timer
- graph paper
- toy vehicle

Note: These toy cars are readily available at science-supply stores, hobby stores, and toy stores.

To determine the relationship between position, velocity, and acceleration, observe the motion of toy cars and collect data on the position of each car, as a function of time, for the following situations.

- Constant-velocity motion
- Constant-acceleration motion

To determine the position of each car, place tape in 10 cm increments along a straight, two-meter length in order to form a coordinate line. Depending on the specific speed and acceleration of the car, the length and increments of the coordinate line may need to be adjusted. The first tape mark is the origin of the coordinate line and should be labeled 0.0. All other tape marks should be labeled accordingly.



Work with a family member or friend and follow these steps:

- Decide who will be the timekeeper. This person will work the timer and call out the time at one-second intervals.
- Place the car at the origin (0.0 cm).
- Release the car and have the timekeeper start the timer.
- As the timekeeper calls out the time increments, both of you should record the position of the car along the coordinate line.
- Continue recording data until the car reaches the end of the coordinate line.

Record data in a data table similar to the table shown below. Add a title to the table as part of the lab.

***t*(sec)**	***x*(cm)**	***v*(cm/sec)**	***a*(cm/sec^2)**
0.0	0.0	–	–
1.0			–
2.0			

To explore the mathematical relationship between position, velocity, and acceleration, calculate the position and acceleration at each time increment, using the equations,

$$v = \frac{x_2 - x_1}{t_2 - t_1}$$

$$a = \frac{v_2 - v_1}{t_2 - t_1}$$

Results should be placed in the appropriate column in the data table.

To understand the graphical relationship of position, velocity, and acceleration, create three graphs for each of the two situations, as follows:

a. Position versus time
b. Velocity versus time
c. Acceleration versus time

Discuss the following questions after completing the entire activity:

- *What are the mathematical and graphical relationships between position, velocity, and acceleration?*
- *What are the similarities and differences between constant-velocity motion and accelerated motion?*

UNIT 2: ENERGY

This unit is based on the understanding that energy can be transferred and transformed. In so doing, energy affects, and is affected by, matter. This unit ties together energy at the nuclear level, the atomic/molecular level and the macroscopic level of everyday experience. Content topics include radioactivity; energy transformations in systems; the relationships among force, mass, and motion; and the properties of waves. The suggested culminating activity integrates the Characteristics of Science with the Content standards.

AREAS OF FOCUS

- Transformations of energy usually release some energy, typically in the form of heat. (SPS7)
- Heat transfer occurs by conduction, convection, or radiation into cooler places. (SPS7)
- Different substances absorb different amounts of heat before their temperature changes. (SPS7)
- Temperature can change as heat is being transferred. (SPS7)
- If a substance's temperature or pressure is altered, a phase change may result. (SPS7)
- Waves carry energy that can be transferred or transformed in interactions with matter or other waves. (SPS9)
- The pitch of a sound is a measure of its frequency. (SPS9)
- Although electromagnetic and mechanical waves share some characteristics, they are different in the way they are generated and transfer energy. (SPS9)
- The speed at which sound travels is dependent upon the material in which it travels. (SPS9)
- As a wave encounters another medium, it may be reflected or refracted, or both. (SPS9)
- As a wave encounters an obstacle or an opening, it may be reflected, refracted, and/or diffracted. (SPS9)
- Two waves that meet will create a pattern of interference. (SPS9)
- The energy of a wave can be determined from the wave's physical characteristics. (SPS9)
- While the total amount of work remains constant, there is a mechanical advantage to using a simple machine, and it can be calculated. (SPS8)
- Work is defined as applied force acting through a distance. (SPS8)
- A simple machine changes the applied force and distance while maintaining the total amount of work. (SPS8)
- Mechanical advantage is a comparison of the applied force required in using a simple machine versus using no machine. (SPS8)
- Nuclear reactions convert matter into energy through the process of radioactive decay, fission, and fusion. (SPS3)

KEY IDEAS

Just as matter is conserved, so is energy. The **Law of Conservation of Energy** states that energy, like matter, cannot be created or destroyed; it can only be changed from one form of energy to another. Energy takes many forms in the world around us. Each form of energy can be converted to and from other forms of energy. Most people are familiar with sound, light, and electrical energy. **Electrical energy** is used in our homes to produce stereo sound through speakers, light from a fluorescent lamp, and **thermal energy** for cooking and heating. **Thermonuclear energy**, which is stored in the nucleus of atoms, is harnessed to produce electrical energy in modern power plants. **Chemical energy** is stored in the bonds that hold atoms together in molecules. When fuels or foods are broken down, chemical energy is converted to heat energy or to kinetic energy. **Kinetic energy** is the energy contained by moving objects due to their motion. Even objects at rest have energy because of their position. **Potential energy**, also known as stored energy, is the energy of position. When a boulder sits on top of a cliff, it has gravitational potential energy as a result of its height above the ground. When the boulder tumbles off the cliff, its gravitational potential energy is converted to kinetic energy. When a ball is thrown up into the air, the kinetic energy of the ball is converted into gravitational potential energy as the ball approaches its highest point. As the ball falls back to the ground, the potential energy it gained during its upward flight turns back into kinetic energy. Kinetic and potential energy are types of mechanical energy.

Some Types of Energy

- Chemical
- Electrical
- Electromagnetic
- Mechanical
- Nuclear
- Radiant or Light
- Sound
- Thermal

We obtain energy from a variety of sources. The most common source of energy used today is coal. The chemical energy contained in coal is converted to electrical energy through the following series of energy transformations:

Chemical —*burning*→ **Heat** —*turbine*→ **Mechanical** —*generator*→ **Electrical**

Petroleum and natural gas represent other fuels, which, along with coal, are known collectively as **fossil fuels**. The box to the right shows some of the sources of energy.

The movement of thermal energy from hot to cold materials is called **heat transfer**. There are three basic types of heat transfer: conduction, convection, and radiation.

- **Conduction** is the transfer of heat energy between materials that are in direct contact with each other. Heat transfer by conduction occurs as hot molecules and free electrons become agitated and collide with less energetic neighbors. These neighbors then become agitated and pass along thermal energy in a process similar to a “fire-bucket brigade.” The process of conduction can be felt in the handle of a metal spoon that has been placed in a bowl of hot soup. The hot soup transfers heat to the end of the spoon; the heat is then transferred through the spoon to the handle. The rate of heat transfer

Energy Sources

- Fossil Fuels
- Geothermal
- Hydroelectric
- Nuclear
- Solar
- Wind

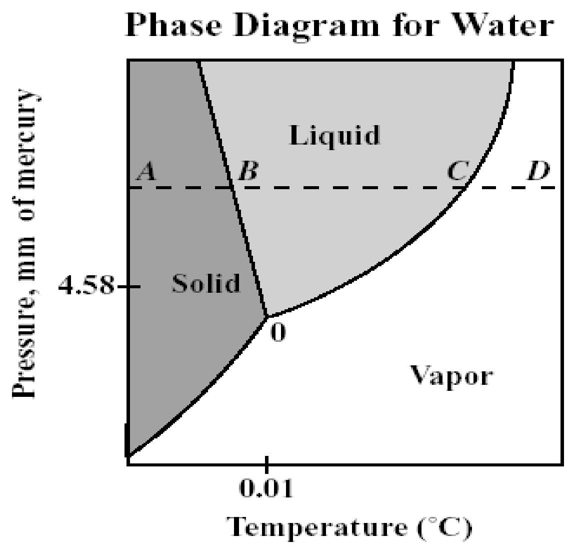
depends on the type of material. Good conductors, such as metals, conduct heat rapidly. **Insulators**, such as wood or plastic, conduct heat very slowly.

- **Convection** is the transfer of heat energy by the mass movement of fluids containing heated particles. Fluids are materials that can flow. Liquids and gases are examples of fluids. When particles of a fluid are heated, the particles move farther apart, causing the fluid to expand. This movement of heated particles creates convection currents. Home heating systems force heated air into rooms by way of convection currents. These currents heat the colder air in the room.
- **Radiation** is the transfer of heat energy through electromagnetic waves. These waves originate from accelerated charged particles. Electromagnetic waves travel through matter or through empty space. Heat transfer through empty space is unique to radiation. Both conduction and convection require a medium or matter to transfer heat energy. Since the space between the Sun and Earth is essentially a vacuum, the heat energy from the Sun is transferred to Earth only by radiation.

Different substances have varying capacities for storing energy within their molecules. Heat energy can cause molecules to move about faster, increasing their random kinetic energy. An increase in this energy raises the temperature of the substance. Heat energy can also increase the vibrational or rotational energy of molecules, but this does not result in a temperature increase. Each substance has a unique **specific heat capacity**, meaning different substances have the ability to absorb only a certain amount of heat. Values for some common substances are shown in the table below. The specific heat capacity is generally defined as the amount of heat energy required to raise the temperature of 1 kilogram of a substance by 1°C. It is a measure of how much heat energy a particular substance can hold. The units most commonly used are joules per kilogram per degree Celsius. The amount of heat energy that a substance gains or loses, Q, depends on the mass (m), the specific heat (c), and the change in the temperature (ΔT) of the substance. The formula for finding the heat energy is simply the product of the three factors, $Q = mc\Delta T$.

Specific Heat for Some Common Substances	
Substance	**Specific Heat, c $\left(\frac{J}{kg \cdot °C}\right)$**
Air (dry)	1,010
Aluminum	900
Copper	390
Ethanol	2,450
Glass	840
Ice (at –15°C)	2,000
Mercury	140
Steel	450
Water (at 15°C)	4,190

A **phase diagram** shows how a pure substance changes from one phase to another based on the temperature, *T*, and the pressure, *P*. The phase (*P*-*T*) diagram for water, below, shows how water changes phases. At point *O* on the diagram, $T = 0.01°C$ and $P = 4.58$ mm of mercury, which is 0.6% of one atmosphere of pressure. One atmosphere of pressure is equal to 760 mm of mercury. This amount of pressure on Earth is found at sea level at a temperature of 0°C. At this point, all three phases of water exist in equilibrium. Above point *O*, pathway *AD* has been marked on the diagram. Let's see what happens to water as we trace along that pathway. At point *A*, water exists as a solid. As the temperature increases at a constant pressure, we reach point *B* on the diagram. At that point, solid ice melts and the temperature remains constant until all ice has melted.



From point *B* to point *C*, water exists as a liquid and the temperature increases. At point *C*, water boils, turning into a vapor (or gas). The temperature remains constant again during this phase change. After vaporization is complete, the temperature of the resulting vapor increases until we reach point *D*. There are no other phase changes after this point. Notice that if another pathway is marked out at a constant pressure of less than 4.58 mm of mercury (below point *O*), water will experience only one phase change, solid to vapor.

Waves are phenomena that occur, seen and unseen, all around us. Suppose that a student drops a stone in a pond. The surface of the water becomes disturbed. Some of the kinetic energy of the stone as it falls in the water is transferred to surrounding water molecules. This causes the surface of the water to be disturbed as water molecules move up and down while transferring energy through the water. This energy transfer can be seen moving in all directions through waves moving outward in concentric circles. Particles of matter do not move along with the waves. Only the energy that creates the waves moves with them. Waves by definition are disturbances that repeat the same cycle of motion and transfer energy through matter or empty space.

Mechanical waves (such as sound waves) are similar to electromagnetic waves (such as light waves) in that both types of waves transmit energy over a distance. However, there are some major differences:

- Sound waves require a medium for propagation. Light waves may travel either through a transparent medium or through empty space.
- Sound travels through all substances, but light is absorbed by opaque materials.

- A sound wave travels slowly through air at a speed of about 340 meters per second at 15°C. Electromagnetic waves, on the other hand, travel through air or the vacuum of space at extremely high speeds of about 300,000 kilometers per second.

Sound waves travel by vibrating from particle to particle. Because of this, the nature of a medium has a significant effect on the speed of sound. Sound travels faster through solids and liquids than it does through gases because particles are closer together in solids or liquids than in gases. Sound also travels fastest through elastic materials. For example, sound travels at about 1,500 meters per second in water, but in aluminum, which is more elastic, the speed of sound is about 5,000 meters per second. In materials of the same phase, or state of matter, the speed of sound tends to decrease as the density increases. The molecules of a denser substance have greater inertia and do not move as quickly as molecules of a less dense substance. The table below shows the speed of sound in various substances.

Speed of Sound (at 25°C)		
Substance	**State**	**Speed (m/s)**
Air	Gas	346
Helium	Gas	965
Ethanol	Liquid	1,497
Water	Liquid	1,162
Steel	Solid	5,960
Lead	Solid	1,960

Because waves involve the transfer of energy, the properties of a wave will change when a wave encounters another wave or an object. Waves undergo four basic interactions. **Reflection** occurs when a wave hits an object that it cannot pass through or when it reaches the boundary of the medium of transmission. Both situations involve the return of the wave as it bounces off the object or medium boundary. **Refraction** takes place when a wave passes from one medium into another at an angle and bends (changes direction) due to a change in speed. **Diffraction** results when a wave passes through a hole or moves past a barrier and spreads out in the region beyond the hole or barrier. Finally, **interference** occurs when two or more waves arrive at the same point at the same time. As a result, they combine to produce a single wave. This new wave will have different properties from the two waves that composed it.

The idea of work is familiar to most people. For example, it takes more work to move heavier objects such as a car at rest than a much-lighter bicycle. **Work** is the transfer of energy when an applied force moves an object over a distance. For work to be done, the force applied must be in the same direction as the movement of the object and the object must move a certain distance. A person may push on a wall and get tired muscles as a result, but unless the wall moves, the person has done zero work. Work can be summarized using the following equation:

$$W = Fd$$

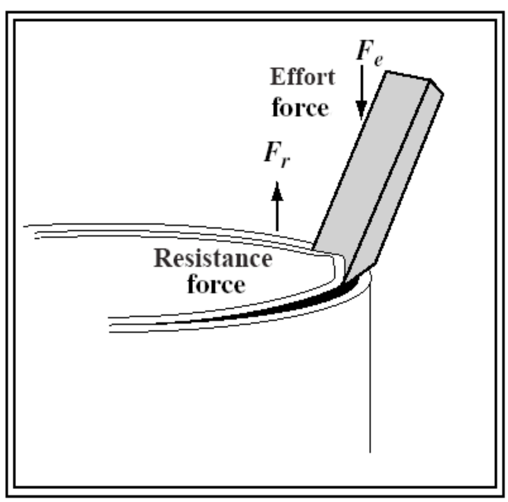
In the equation, W is equal to work, F is equal to the force applied, and d is equal to the distance that an object has moved. Remember, force is measured in newtons (N) and distance is measured in meters (m). A unit of work is the newton-meter (N-m) or the joule (J).

Work can be made easier or done faster by using machines. Machines that work with one movement are called **simple machines**. There are six types of simple machines. These are listed in the box below.

Simple Machines

- Inclined Plane
- Lever
- Pulley
- Screw
- Wedge
- Wheel and Axle

Simple machines cannot increase the amount of work done, but they can change the size and direction of the force applied. The force applied to a simple machine is called the **effort force**, F_e. For a machine to do work, an effort force must be applied over a distance. The force exerted by the machine is called the **resistance force**, F_r. For example, consider how a painter uses a screwdriver as a lever to pry open the lid on a can of paint. An illustration showing the bottom end of the screwdriver and the top of a paint can is shown. When the painter pushes down on the screwdriver, an effort force is applied over a distance, known as the **effort distance**, d_e. As a result, the tip of the screwdriver exerts a resistance force against the lid of the paint can. This force moves the lid of the can over the **resistance distance**, d_r.



The number of times a machine multiplies the effort force is called the **mechanical advantage**. The mechanical advantage is determined using the following equations:

$$MA = \frac{F_r}{F_e} \text{ or } MA = \frac{d_e}{d_r}$$

For example, if 15 N of force is applied to the handle of the screwdriver to lift a resistance of 150 N, the mechanical advantage of the screwdriver is 10. The tip of the screwdriver has multiplied the effort force 10 times. Refer to your textbook to see how the mechanical advantage of other simple machines can be calculated.

Sometimes very heavy elements have unstable nuclei. Atoms of these elements are radioactive. A radioactive element may decay and give off three types of radiation:

- **Alpha** (α) radiation or particles: These particles consist of helium (He) nuclei, which are very large. Usually a sheet of paper can stop them.
- **Beta** (β) radiation or particles: These particles consist of electrons (e^-), which are much smaller and lighter than alpha particles. They have much more penetrating power, and a thick wooden board is required to stop them.
- **Gamma** (γ) rays: This radiation is an extremely energetic form of light. Usually several inches of lead or a few feet of concrete are required to shield people from the damaging effects of gamma radiation.

Every radioactive element has a distinctive rate of decay. This rate is measured by the **half-life** ($t_{1/2}$). The half-life is the time required for one-half of the atoms to undergo decay to isotopes of other atoms. Radon, a radioactive gas, has a half-life of 3.8 days. That means after 3.8 days, only one-half of the original radon atoms are left. After 7.6 days, only one-fourth are left, and so on.

Fission occurs when some atomic nuclei decay spontaneously or when they are bombarded by neutrons. This results in the production of lighter elements and radiation. On the beneficial side, fission provides a significant amount of electrical energy for the United States and other developed nations. Compared to coal or oil, fission provides about a million times more energy per pound of fuel. It also eliminates air pollutants. On the other hand, nuclear waste from fission creates disposal problems. Improper disposal of radioactive wastes underground might lead to radioactive contamination of water supplies.

Fusion as a future energy source might provide all the benefits of fission with few of its problems. Fusion occurs when two light nuclei, such as hydrogen, collide and combine to form heavier nuclei. Fusion occurs in the Sun and is one of the most energetic processes in the universe.

SAMPLE ITEMS

Item 5

The specific heat of pure water is 4.184 J/g °C. A 10.00-gram sample of pure water goes from 22.00°C to 32.00°C.

How much heat did the sample gain?

A. 41.84 J
B. 418.4 J
C. 920.5 J
D. 1339 J

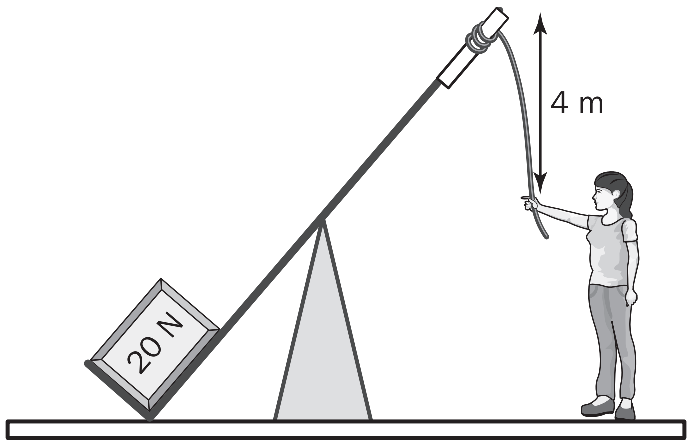
Item 6

Which of these is correct about an object dropped from the top of a cliff?

A. As it travels downward, it gains kinetic energy and gains gravitational potential energy.
B. As it travels downward, it gains kinetic energy and loses gravitational potential energy.
C. As it travels downward, it loses kinetic energy and gains gravitational potential energy.
D. As it travels downward, it loses kinetic energy and loses gravitational potential energy.

Item 7

A student pulls a lever down 4 m. The lever lifts a box that weighs 20 N up a distance of 2 m.



How much work was done on the box?

A. 10 J
B. 40 J
C. 80 J
D. 160 J

Item 8

Which of these is evidence that electromagnetic waves do not require a medium?

A. Sounds can be heard through a solid wall.
B. Light cannot be seen through a solid wall.
C. X-rays provide an image of human bones.
D. Radiation from the Sun reaches Earth.

ACTIVITY

Physics: Energy, Force, and Motion

Standard: SPS7a

Design and build a model water turbine capable of lifting a small weight. You will use your model to explore how the turbine is used to convert the energy of flowing water into a form that can be used to do work on the small weight. You will also collect data and analyze your results graphically.

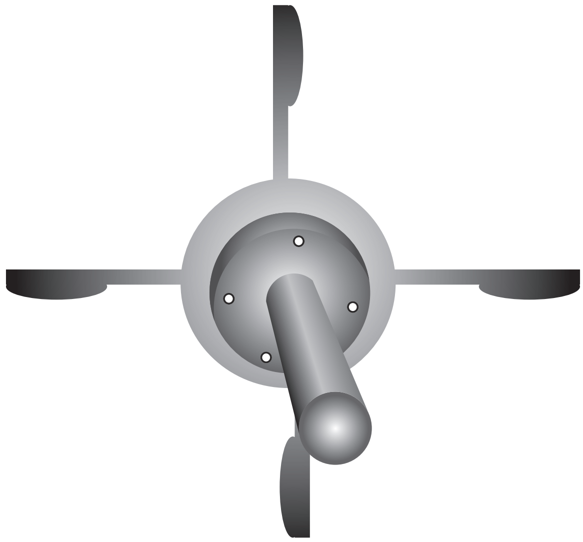
Before beginning, make sure that the following materials are available:

- empty thread spool (2)
- dowel
- protractor
- plastic spoons (4)
- glue
- scissors
- bucket
- thin metal wires (2)
- string
- small weight
- gallon jug filled with water
- ruler
- stopwatch
- duct tape

To explore the use of hydropower to do work, you will build a simple water turbine. Complete the following steps to build this device:

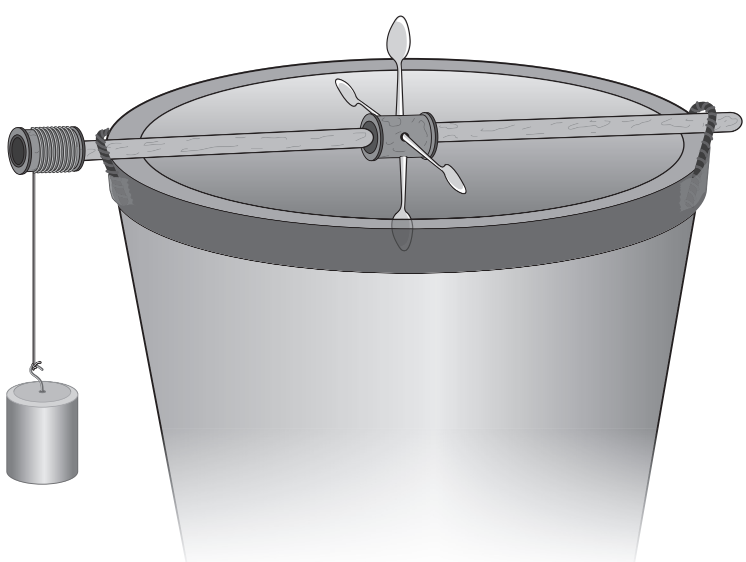
- Insert the dowel through the center of one spool. Glue the spool to the dowel about 10 cm from the center.
- Use a protractor to make four equidistant marks on the curved surface of the spool. Use the scissors to make notches at these marks, wide enough to fit a spoon handle.
- Cut off the top half of each spoon handle and discard it. Insert the shortened spoon handles into the four notches you made in the spool.
- Make sure that the bowls of the spoons are facing upwards and in the same direction, to catch the water.
- Once the spoons are positioned, use glue to secure them in place.

The following diagram shows a cross-section of the turbine.



Once the turbine is completed, secure it over the bucket.

- Place the dowel horizontally across the bucket so that the turbine is centered over the opening. The longer end of the dowel will extend over the side of the bucket.
- Bend both metal wires into an inverted U-shape and use them to secure the dowel to the sides of the bucket. Use duct tape to attach the wires to the bucket. Leave enough space between the wire loops and the dowel so that the dowel can rotate freely while resting on the edge of the bucket.
- Place the remaining spool on the long end of the dowel and glue it in place. Attach one end of the string to the spool. Wind the string around the spool and attach the small weight to the loose end. Once assembled, rotating the turbine blades will raise and lower the weight.



To make the water turbine lift the weight, unwind the string just enough for the weight to reach the ground. Hold the gallon jug 0.10 m above the turbine. Slowly pour the water onto the spoons, making the turbine revolve. Use a stopwatch to record the time it takes for the weight to reach the top of the bucket. Pour the water from the bucket back into the gallon jug and reposition the weight. Repeat the experiment with the gallon jug held at various heights. Attempt to keep the rate of water flow and the distance the weight travels constant for each experiment.

To analyze the water-turbine system, create a graph of the time it takes for the weight to be lifted, as a function of the height from which the water was poured.

Discuss the following question after completion of the entire activity:

How is energy transferred in this system?

You may also wish to explore other aspects of this experiment, including the engineering design of the turbine and the impact of the water-flow rate on the experiment.

UNIT 3: MATTER

The periodic table of elements is a scientific tool that shows trends based on atomic structure. Students will examine the structure of the atom in terms of protons, electrons, neutrons, atomic number, atomic mass, and isotopes. The arrangement of elements of the periodic table will enable students to describe trends and give locations of metals, nonmetals, and metalloids.

Some elements on the periodic table are radioactive. Radioactivity occurs when an unstable atomic nucleus emits either alpha or beta particles or gamma rays. Nuclear energy is produced from radioactive elements. Although it is a useful source of alternative energy, radioactivity also introduces safety hazards.

AREAS OF FOCUS

- The characteristics of an atom are determined by its structure. (SPS4)
- A change in the nuclear structure or electron configuration, or both, results in the emission of radiation. (SPS3)
- Valence electrons determine the chemical properties of atoms. (SPS4)
- Nuclear reactions convert matter into energy through the process of radioactive decay, fission, and fusion. (SPS3)
- The rate of radioactive decay for an isotope is constant and is measured by its half-life. (SPS3)
- The number of protons determines the type of element. (SPS4)
- The elements, arranged by increasing atomic number, exhibit periodic trends in properties. (SPS4)
- Non-stable nuclei are radioactive and emit ionizing radiation in the form of alpha, beta, or gamma radiation. (SPS3)
- Properties such as valence electrons, ion formation, metallic or nonmetallic properties, and phase at room temperature can be predicted for representative elements by using the periodic table. (SPS4)
- Chemical reactions are the result of changes in electron configuration. (SPS4)

KEY IDEAS

As far as scientists can tell, the universe we live in is composed of many tiny particles called atoms. The concept of the atom began with the ancient Greeks, but this concept did not fully develop until after A.D. 1700. Today scientists know that atoms contain even tinier particles.

These particles are the **proton**, the **neutron**, and the **electron**. The proton and neutron are located in the **nucleus**, or center, of the atom. The proton has a single positive (+) charge, while the neutron has a zero (0), or neutral, charge. The proton and neutron have approximately the same mass. The electron has a single negative (–) charge and is about 2,000 times lighter than the proton or neutron. Electrons, unlike the proton and neutron, are found outside the nucleus in a region called the **electron cloud**. The electron cloud is divided into **energy levels**, which are sometimes referred to as **electron shells**. Each energy level can hold a certain number of electrons. The first energy level, which is closest to the nucleus and has the lowest amount of energy, can hold only two electrons (see the box titled “Energy Levels”). Electrons with higher energy are found in energy levels farther from the nucleus. Electrons in the outermost energy level, or **valence shell**, are called **valence electrons.** The outermost electrons determine how the element will react chemically with other elements.

Energy Levels

Maximum number of electrons for each energy level:

Energy Level	No. of Electrons
1	2
2	8
3	18
4	32

There are many ways to describe the atom. One way is to use the **atomic number.** It tells how many protons reside in the nucleus and identifies the element. For example, an element with an atomic number of 6 (an atom with six protons) is a carbon atom with the chemical symbol C. All atoms with the same number of protons are of the same element, no matter how many electrons or neutrons they might have.

Look It Up

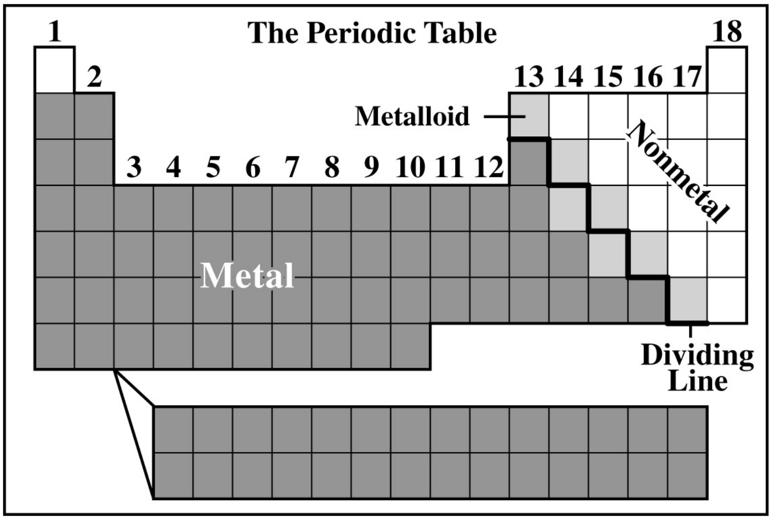
Use the periodic table to locate the following information about the first 20 elements:

- Element name
- Symbol
- Atomic number
- Atomic mass

Isotopes are atoms that have the same number of protons but different numbers of neutrons. As a result, a single element may contain atoms that have different masses. The **atomic mass** is the average mass of all the different isotopes that make up the element.

In the nineteenth century, chemists discovered that certain elements had similar properties. They found that when elements were arranged according to reactivity, a periodic pattern in the properties of the elements could be seen. The **periodic table** was then developed to organize and classify these elements and even predict the existence of elements that had not yet been discovered.

There are three major classifications for the elements. These can be seen in the periodic table below.



- The **metal** elements are located to the left of the dividing line. These elements are all solids at room temperature with the exception of mercury (Hg). Metals are notable for their shiny luster and ability to conduct electricity.
- The **nonmetal** elements are located to the right. Nitrogen (N), oxygen (O), fluorine (F), chlorine (Cl), and the noble gases (in the last column) are gases at room temperature. Bromine (Br) is a liquid, while all other nonmetals are solid. Nonmetals do not conduct electricity.
- **Metalloids** have both metallic and nonmetallic properties. These are solid at room temperature. They are located between the metals and nonmetals and straddle the diagonal dividing line. Metalloids are useful as part of electronic circuits.

Elements are also arranged by **group numbers**. These numbers may be seen at the top of each column in the periodic table above. The **representative elements** are those elements located in columns 1–2 and 13–18. Group 1 and 2 elements have the same number of valence electrons as their group number. The number of valence electrons for Group 13–18 elements can be found by subtracting 10 from the group number. Valence electrons for non-representative elements (Groups 3–12) will not be covered on the test. It is important to note that elements within the same group have the same number of valence electrons. Since they have the same number of valence electrons, they react with other elements in a very similar way. Elements in Group 1, the **alkali metals**, and Group 2, the **alkaline earth metals**, are the most reactive metals, while the **noble gases** (Group 18) are the most nonreactive elements.

When a metal and a nonmetal react with each other, the metal forms a positive ion (cation) and the nonmetal forms a negative ion (anion). Metals in Group 1 lose one electron to form an ion with a charge or valence number of $^{+}1$. Group 2 metals lose two electrons to form ions with a $^{+}2$ charge. Nonmetallic elements in Groups 15, 16, and 17 gain electrons, forming ions with a $^{-}3$, $^{-}2$, and $^{-}1$ charge, respectively.

Every radioactive element has a distinctive rate of decay. This rate is measured by the **half-life** ($t_{1/2}$). The half-life is the time required for one-half of the atoms to undergo decay to isotopes of other atoms. Radon, a radioactive gas, has a half-life of 3.8 days.

That means after 3.8 days, only one-half of the original radon atoms are left. After 7.6 days, only one-fourth are left, and so on.

Fission occurs when some atomic nuclei decay spontaneously or when they are bombarded by neutrons. This results in the production of lighter elements and radiation. On the beneficial side, fission provides a significant amount of electrical energy for the United States and other developed nations. Compared to coal or oil, fission provides about a million times more energy per pound of fuel. It also eliminates air pollutants. On the other hand, nuclear waste from fission creates disposal problems. Improper disposal of radioactive wastes underground might lead to radioactive contamination of water supplies.

Fusion as a future energy source might provide all the benefits of fission with few of its problems. Fusion occurs when two light nuclei, such as hydrogen, collide and combine to form heavier nuclei. Fusion occurs in the Sun and is one of the most energetic processes in the universe.

Memory Aid—Fission/Fusion Confusion

Here is a way to help remember the difference between fission and fusion. *Fission* is similar to *fissure*, the process of splitting. So fission happens when the nucleus splits in two. *Fusion* is like *fuse*, to unite two things. So fusion occurs when two nuclei join.

Sometimes very heavy elements have unstable nuclei. Atoms of these elements are radioactive. A radioactive element may decay and give off three types of radiation:

- **Alpha** (α) radiation or particles: These particles consist of helium (He) nuclei, which are very large. Usually a sheet of paper can stop them.
- **Beta** (β) radiation or particles: These particles consist of electrons (e^-), which are much smaller and lighter than alpha particles. They have much more penetrating power, and a thick wooden board is required to stop them.
- **Gamma** (γ) rays: This radiation is an extremely energetic form of light. Usually several inches of lead or a few feet of concrete are required to shield people from the damaging effects of gamma radiation.

SAMPLE ITEMS

Item 9

Use the periodic table to determine which of the following contains 20 protons and 19 electrons.

A. an ion of calcium
B. an ion of potassium
C. a neutral calcium atom
D. a neutral potassium atom

Item 10

The half-life of cadmium-109 is 464 days. A scientist measures out a 256.0 g sample.

Approximately how many grams of cadmium-109 would remain after 1,392 days?

A. 32.0 g
B. 64.0 g
C. 2,048.0 g
D. 1,024.0 g

Item 11

The elements neon and argon are not reactive. Which hypothesis BEST explains this?

A. They are not stable atoms.
B. They are not readily available on Earth.
C. They tend to give up all of their valence electrons easily.
D. They have the maximum possible number of electrons in their outermost shell.

Item 12

According to placement in the periodic table, which of these BEST explains why an ionic bond is the MOST LIKELY type of bond formed between a metal and a nonmetal?

A. An ionic bond is formed between oppositely charged ions; metals and nonmetals are likely to be oppositely charged.
B. An ionic bond is formed when two atoms share electrons; a metal and nonmetal are likely to share electrons.
C. An ionic bond is formed when one of the atoms is nonreactive; metals tend to be nonreactive and form ionic bonds.
D. An ionic bond is formed when one of the atoms is nonreactive; nonmetals tend to be nonreactive and form ionic bonds.

Item 13

The table lists the number of protons and neutrons contained in four different atoms.

Composition of Atoms

	Number of Protons	Number of Neutrons
Atom 1	5	6
Atom 2	6	6
Atom 3	6	7
Atom 4	7	7

Which two atoms are isotopes of the same element?

A. Atom 1 and Atom 2
B. Atom 1 and Atom 3
C. Atom 2 and Atom 3
D. Atom 3 and Atom 4

ACTIVITY

Chemistry: Atomic and Nuclear Theory and the Periodic Table

Standards: SPS1a, SPS4a, SPS4b

You will build some atomic models to explore the structure of atoms. You will study how the number of protons, neutrons, and electrons affect atomic mass, atomic number, common isotopes, type of ion formed, and bonding properties. You will use the models to examine trends in the periodic table.

Before beginning, make sure that the following materials are available:

- 2.0 cm diameter polystyrene balls, red
- 2.0 cm diameter polystyrene balls, green
- 0.5 cm diameter polystyrene balls, blue
- a supply of white paper
- a copy of the periodic table
- a digital camera

To help you understand the structure of an atom, you will build a model using the following color-coding for the polystyrene balls:

red = proton

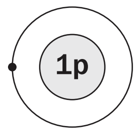
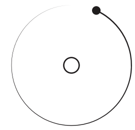
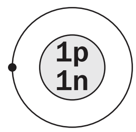
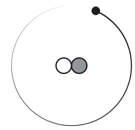
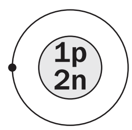
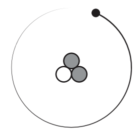
green = neutron

blue = electron

Now build the first- and second-row elements of the periodic table:

- To explore the neutral hydrogen atom, its isotopes, and its positive ion, place one proton (red ball) in the center of the paper. This single ball represents the ionic form of hydrogen-1. Add green or blue balls to the model as appropriate to form neutral hydrogen and the isotopes hydrogen-2 and hydrogen-3.
- Next you will build atomic models for elements with higher atomic numbers. Indicate the electron shells in each atom by drawing rings on the white paper around the central nucleus.
- As you build the models, fill the shells with the appropriate number of polystyrene electrons for each atom (a maximum of two electrons in the first ring and a maximum of eight electrons in the second and third rings). For example, to represent the atom for oxygen, use red and green balls to create a nucleus. Then draw two shells around the nucleus. On the first shell, place two blue electrons and on the second, six electrons. It is important to note that these rings will not be drawn to scale.
- Build atomic models for the elements in the first and second periods of the periodic table. For each element, build all of the common isotopes of the neutral atom. Choose one isotope for each element and explore its ionic forms.

Draw and label your models and record your findings in a table similar to the table shown below. Photograph each model you create and include the pictures in the table.

Element Symbol/Name	Model with Labels	Picture	Protons	Neutrons	Electrons
Hydrogen-1			1	0	1
Hydrogen-2			1	1	1
Hydrogen-3			1	2	1

To investigate trends in the periodic table, use your data table and atomic models to note the similarities in atomic structure among atoms in the same row (period) and in the same column (group).

To investigate bonding in atoms, build an ionic bond and a covalent bond.

- To explore an ionic bond, use the polystyrene balls to build a model of neutral lithium and neutral fluoride. Count the number of valence electrons in each atom and then transfer one electron from lithium to fluoride. Note the charge on each atom and discuss the electrostatic attraction between the two ions and the formation of the molecule, lithium fluoride. Diagram each step in your investigation. You may also investigate other ionic compounds.
- To explore a covalent bond, use the polystyrene balls to build two identical models of neutral oxygen. Count the number of valence electrons in each atom and then arrange the models so that the atoms can share four electrons.
- Diagram each step in your investigation. You may also investigate other covalently bonded molecules.

Discuss the following questions after completion of the entire activity:

- *What varies among different isotopes of the same element?*
- *What varies among different ions of the same element?*
- *What is the primary difference between two neighboring atoms on the periodic table?*
- *What are the structural similarities shared by elements in the same period?*
- *What are the structural similarities shared by elements in the same group?*

UNIT 4: CHEMISTRY IN MOTION

In simple terms, chemistry is the study of particle collisions in which electrons are agitated by energy differences and subjected to dislocation. In chemical reactions, the mass of the matter before and after the reaction remains the same. Students will explore to what extent solute particles interact with a solvent, and any new properties that may occur, such as changes in the concentration of hydrogen (H^+) or hydroxide (OH^-) ions.

AREAS OF FOCUS

- A chemical reaction results in the formation of a new substance. (SPS2)
- Bonds between atoms are created when electrons are transferred or shared. (SPS1)
- IUPAC conventions provide a standard system for naming compounds and writing formulas. (SPS2)
- Matter cannot be destroyed or created in a chemical reaction. (SPS2)
- Solutions are mixtures in which the relative proportion of solute and solvent varies. (SPS6)
- The degree to which a solute dissolves is affected by physical conditions of the system. (SPS6)
- The properties of a solution, such as conductivity and acidity, are related to whether the solute is ionic or covalent. (SPS6)
- Acidic solutions have an excess of hydrogen ions, and basic solutions contain excess hydroxide ions. (SPS6)

KEY IDEAS

Conservation of Matter in Chemical Reactions

Matter, like energy, is neither created nor destroyed. In a chemical reaction, the same number of atoms occurs in the products as in the original reactants. As a result, the mass of the **products** always equals the mass of the **reactants**. This statement summarizes the **Law of Conservation of Mass**. One example of this law in action involves the burning of firewood. At first glance, it appears that the Law of Conservation of Mass is violated because the mass of the ashes left over is much less than the mass of the original wood. In fact, if one could measure the mass of the smoke, water vapor, and carbon dioxide given off in addition to the ash, the mass would exactly equal that of the unburned firewood.

The Law of Conservation of Matter/Mass can be used to balance **chemical equations**, which are used to show what happens in a chemical reaction. In chemical equations, the coefficients in front of the chemical formulas represent the number of molecules of reactants or products. The combustion reaction of hydrogen and oxygen is shown below.

$$2H_2 + O_2 \rightarrow 2H_2O$$

The chemical equation shows that two molecules of hydrogen plus one molecule of oxygen yields two molecules of water. Notice that the number of hydrogen atoms (2 × 2 = 4) and oxygen atoms (1 × 2 = 2) on the reactants side (left side of the arrow) of the equation equals the number of hydrogen and oxygen atoms on the products side (right side of the arrow) of the equation. The equation is balanced because the numbers of atoms of each element (H, O) are the same on both sides of the arrow.

The combustion reaction of hydrogen and oxygen is also known as a **synthesis** reaction. In a synthesis reaction, two or more simple substances combine to form a complex substance. A synthesis reaction is represented by the general equation ***A* + *B* → *AB***. When balancing an equation for a synthesis reaction, the coefficients should be used to make the number of atoms of each element the same on each side of the equation. The following "bookkeeping" method was used to obtain the above balanced equation. The equation was first written without coefficients. Understand that even though no coefficients are written in the original equation, one coefficients are understood. The steps are shown below.

In Step 1, two hydrogen atoms appeared on both sides of the equation. No change was needed.

$$H_2 + O_2 \rightarrow H_2O$$

Step 1

Element	No. of Atoms in Reactants	No. of Atoms in Product(s)
H	2	2
O	2	1

The reactants side contained two oxygen atoms, while the products side contained only one oxygen atom. In Step 2, the number of water molecules was multiplied by two to balance the oxygen atoms. A two coefficient was placed before the H_2O.

$$H_2 + O_2 \rightarrow 2\ H_2O$$

Step 2

Element	No. of Atoms in Reactants	No. of Atoms in Product(s)
H	2	4
O	2	1 x 2

Finally, in Step 3, the reactants side still contained two hydrogen atoms, while the products side contained four hydrogen atoms. The hydrogen molecule (H_2) was multiplied by two to balance the hydrogen atoms. The equation is balanced when a two coefficient is placed before the H_2.

$$2H_2 + O_2 \rightarrow 2\ H_2O$$

Step 3

Element	No. of Atoms in Reactants	No. of Atoms in Product(s)
H	2 x 2	4
O	2	1 x 2

Similar bookkeeping can be used to balance other types of simple equations. A **decomposition** reaction is the opposite of a synthesis reaction. In a decomposition reaction, a complex substance breaks down into simple parts. It is represented by the general equation ***AB* → *A* + *B***. An example of this reaction is the decomposition of limestone (calcium carbonate).

$$CaCO_3 \rightarrow CaO + CO_2$$

Notice that the equation is balanced as written. Count the number of atoms of each element on each side of the equation (right and left of the yield sign, →). On the reactants side of the equation are one atom of calcium, one atom of carbon, and three atoms of oxygen. On the products side of the equation are one atom of calcium, one atom of carbon, and three atoms of oxygen. One coefficients are understood, though not written.

A single replacement reaction involves a single uncombined element replacing another element in a compound forming a different compound. A single-replacement reaction may be represented by the general equation ***A* + *BC* → *AC* + *B***. An example of this reaction is the replacement of a silver ion by copper in a silver nitrate solution.

$$Cu + 2AgNO_3 \rightarrow Cu(NO_3)_2 + 2Ag$$

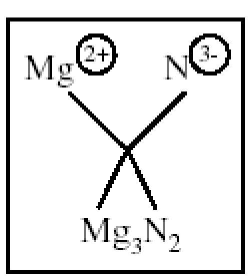
Notice that the coefficients are placed before $AgNO_3$ and Ag to balance the equation.

In a double-replacement reaction, two elements in two different compounds replace each other, forming two different compounds. A double-replacement reaction has the general equation ***AB* + *CD* → *AD* + *CB***. The neutralization of hydrochloric acid by sodium hydroxide is a good example of this type of reaction.

$$NaOH + HCl \rightarrow NaCl + HOH$$

This equation is also balanced as written with no need for coefficients other than the one-coefficients, which are understood. If you count the number of atoms of each element on the reactants side of the equation and the number of atoms of the same elements on the products side of the equation, you will find that they are equal. There is one sodium (Na) atom on the left side (reactants) and right side (products) of the arrow; one oxygen (O) atom on both sides; one chlorine (Cl) atom on both sides; and two hydrogen (H) atoms on both sides. The equation is balanced.

Binary ionic compounds contain only two different elements. Ionic bonds form between metals and nonmetals because of a complete transfer of electrons from the metal to the nonmetal. The resulting oppositely charged ions attract. Sodium chloride, NaCl, is an example of a binary ionic compound. The correct formula for a binary ionic compound can be found by making a cross, as in the example below.



Notice that the charge on the nitride ion (N^{3-}) becomes the number of magnesium ions in the formula. Likewise, the charge on the magnesium ion (Mg^{2+}) becomes the number of nitride ions in the formula. In this way, the charges are balanced (+6 and –6), making magnesium nitride neutral. This method usually works, except when the charges on the ions are exact opposites. In that case, the ions should be combined in a 1:1 ratio to balance the charges.

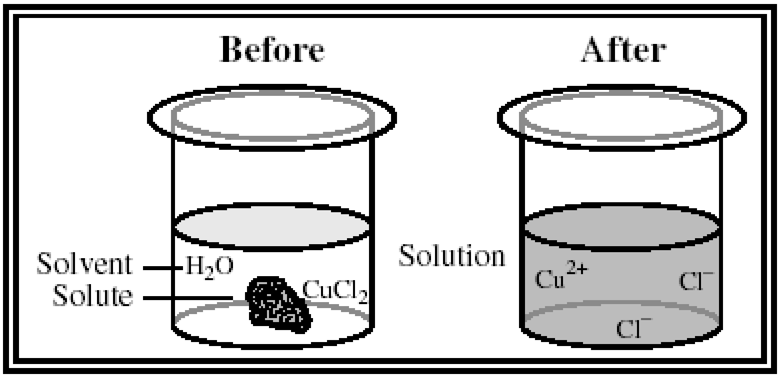
Any combination of cations and anions can form a binary ionic compound. To name this type of compound, simply write the name of the element that forms the cation first. Then follow with the name of the anion. The name of the anion will usually contain the first syllable of the element name and end with the suffix *-ide*. For example, the formula unit $AlCl_3$ would be named aluminum chloride. Notice that the cation has the element name and that the first syllable of chlorine, *chlor-*, has taken the *-ide* ending.

Covalent bonds form when atoms share one or more valence electrons. The names of **binary covalent compounds** must include prefixes to show the number of atoms of each element in the compound. The first atom is named after the element it represents. If there are two or more atoms of that element, the prefixes *di-*, *tri-*, or *tetra-* or a higher numeral prefix are used. The prefix *mono-* (one) is never used for the first element. All numerical prefixes, however, are used for the second element. An appropriate prefix indicates the number of the second atom. This prefix is placed before the first syllable of the element name. The suffix *-ide* is then added to the end. For example, the covalent compound CO_2 is named carbon dioxide. Notice the *di-* prefix for the second element and the lack of a prefix for the first element. Another example is P_2S_5. It is named diphosphorus pentasulfide. Notice that the *di-* prefix is used for the two phosphorus atoms and that the *penta-* prefix is used for the five sulfur atoms in the formula.

Numerical Prefixes

mono-	1
di-	2
tri-	3
tetra-	4
penta-	5
hexa-	6
hepta-	7
octa-	8
nona-	9
deca-	10

Matter is not always pure. It may contain mixtures of elements and compounds. A **solution** is a special type of mixture. It has a uniform composition throughout and is made up of two parts—a solute and a solvent. The **solute** is the substance that is being dissolved or broken down into smaller particles. The **solvent** is the substance doing the dissolving. Usually the solute is the substance that is in smaller quantity. For example, in a copper (II) chloride solution, the $CuCl_2$ is the solute, while water is the solvent. This example is shown in the box below. The **solubility** is the ability of a substance to dissolve in a solvent, such as water. When the maximum amount of solute that can be dissolved is added to the solvent, the solution becomes **saturated**. Below this maximum amount, the solution is **unsaturated**.



Conductivity is the measure of a solution's ability to conduct electricity. The conductivity gives important clues as to the type of solute dissolved. In **aqueous** (water-based) solutions, dissolved ionic compounds yield solutions with high conductivity. Cations and anions readily carry electrical charges through the solution. Strong acids and bases also have a high conductivity for the same reason.

Conductivity of Some Aqueous Solutions		
High Conductivity	**Low Conductivity**	**Zero Conductivity**
$AlCl_3$	CH_3CO_2H	CH_3OH
$CaCl_2$	(acetic acid)	(methanol)
H_2SO_4	NH_3	$C_{12}H_{22}O_{11}$
HCl	(ammonia)	(table sugar)
KCl	HF	$C_6H_{12}O_6$
KOH	(hydrofluoric acid)	(glucose)
$MgSO_4$		
NaCl		
NaOH		

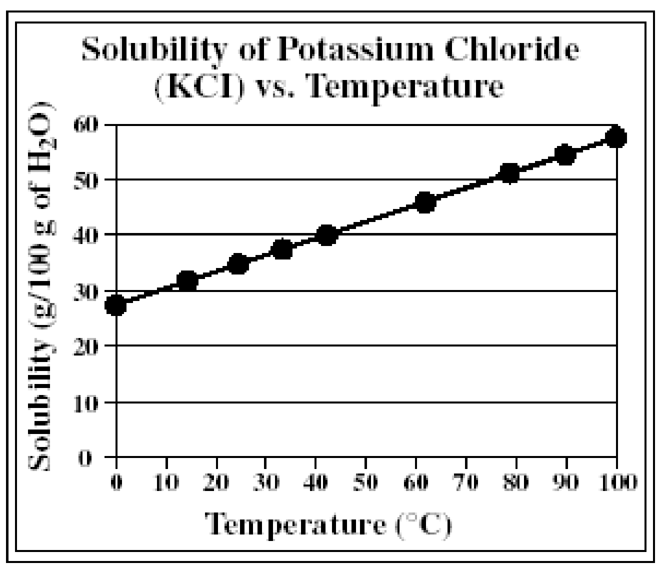
All of these solutions are considered **strong electrolytes**. Weak acids or bases ionize only partially, so they form solutions with low conductivity. These compounds are called **weak electrolytes.** Solutions made from covalent compounds have zero conductivity since they dissolve as molecules, not ions. They cannot carry electrical charges. These substances are known as **nonelectrolytes**. Some selected compounds and their electrical conductivity are shown in the box above.

The **concentration** describes how much solute has been dissolved in solution. Almost all concentration units express some kind of ratio. For example, the mass percent of a solution is equal to the mass of the solute (in grams) divided by the mass of the solution (in grams) times 100%. Solutions with higher concentrations tend to conduct electricity better than dilute solutions.

There are a number of factors that can affect the rate at which a solid solute dissolves in a liquid solvent:

- Stirring increases the amount of fresh solvent that comes in contact with a solute. When there is no stirring, the solvent around the solute becomes nearly saturated. Stirring keeps the solvent near the solute unsaturated, increasing the dissolving rate.
- When a solute is ground into smaller particles, the amount of surface area exposed to the solvent increases. This additional surface area allows the dissolving process to occur faster. The smaller the solute particles, the faster the rate of dissolving.
- Solvent molecules move faster when the temperature increases. These faster solvent molecules come in contact with solute particles more often, increasing the dissolving rate. Also, at higher temperatures, the solubility usually increases. Higher temperatures, therefore, favor higher dissolving rates.

A **solubility curve** shows how the amount of dissolved solute changes with temperature. The solubility curve shown graphs the solubility of potassium chloride (KCl) as a function of temperature. Notice that the dimensions of solubility are grams of solute per 100 grams of solvent (water). The solubility of most salts, such as KCl, increases with higher temperatures, as can be seen in the graph below.



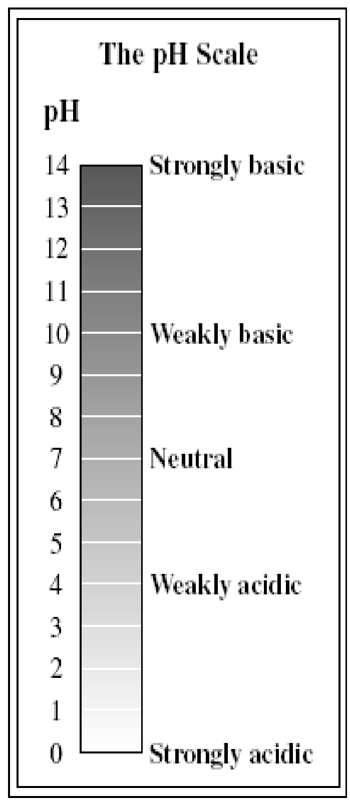
A solubility curve also shows the temperature at which a solute will begin to precipitate from solution. For example, if approximately 54 grams of KCl are dissolved in 100 grams of boiling water, the salt completely dissolves. When the solution cools, though, the KCl begins to precipitate at 90°C because the solution has become saturated. As you can see above, as the solution cools further, more of the KCl will precipitate out until, at 0°C, only 28 grams of the salt remain in solution. Can you determine from the graph how many grams of KCl will be dissolved in solution at 60°C? If you answered about 43 grams, you are correct.

As early as the 1600s, chemists recognized that matter could be classified as either **acid** or **base**. It took many more years to define and describe the behavior of these important compounds. Chemists today know that acids and bases have the properties shown in the following chart:

	Acid	Base
Taste	• Sour or tart	• Bitter
Touch	• Feels like water / may sting	• Feels smooth and slippery
Reactions with Metals	• Vigorously reacts with most metals to produce hydrogen, H_2	• Does not react with most metals
Electrical Conductivity	• Readily conducts electricity (less so for weak acids)	• Readily conducts electricity (less so for weak bases)
Litmus Paper* Test	• Turns blue litmus paper red	• Turns red litmus paper blue

*A type of paper containing a dye that changes colors when exposed to acids or bases

The **pH scale** gives a measure of the acidity or basicity of a solution. The lower the pH of a solution, the more acidic it is. The higher the pH, the more basic it is. Any solution with a pH less than 7 is acidic. A solution with a pH greater than 7 is considered basic. Any solution with a pH of exactly 7 is neutral. See the pH scale on the right. Lemon juice has a pH between 2 and 3. It is acidic. Common household bleach is basic, with a pH between 12 and 13. Pure water has a pH of 7 and is neutral. All compounds that give off **hydrogen ions** (H^+) in solution are acids. Bases are any compounds that accept the hydrogen ions to form a salt. For example, hydrochloric acid and sodium hydroxide react together in a **neutralization reaction**.



$$\underset{\text{acid}}{HCl} + \underset{\text{base}}{NaOH} \rightarrow \underset{\text{salt}}{NaCl} + \underset{\text{water}}{H_2O}$$

The hydroxide ion (OH^-) from the NaOH accepted the hydrogen ion (H^+) from the HCl to form water. The salt (NaCl) was formed from the sodium ion (Na^+) and the chloride ion (Cl^-) left over.

SAMPLE ITEMS

Item 14

What is the chemical formula for the stable ionic compound formed between aluminum and oxygen?

A. Al_2O_2
B. Al_2O_3
C. Al_3O_2
D. Al_3O_3

Item 15

Use this chemical equation to answer the question.

$$\_\_Fe + \_\_O_2 \rightarrow \_\_Fe_2O_3$$

What coefficients of Fe, O_2 and Fe_2O_3 balance this equation?

A. 2, 1, 2
B. 2, 3, 2
C. 4, 1, 2
D. 4, 3, 2

Item 16

A mixture is created with 5 grams of sugar, 5 grams of salt, and 4,000 cubic centimeters of water. Which is the solvent?

A. the salt
B. the sugar
C. the water
D. the mixture

ACTIVITY

Chemistry: Chemical Reactions and Properties of Matter

Standard: SPS6e

You will explore the acidic and basic properties of various soil samples and hypothesize possible links between soil type, soil pH, and plant diversity.

Before beginning, make sure that the following materials are available:

- plastic shovel
- plastic bags
- gloves
- digital camera
- 100 mL beaker (8)
- distilled water
- stir rod
- coffee filters
- funnel
- pH indicator strips or pH probe

Safety Notes:

Wear gloves throughout the experiment.

Rinse any glassware that will be used in the experiment, using distilled water.

Identify four locations for harvesting soil. Each location should have a different type of soil and different types of plant life.

- Use a digital camera to document the type of plant life growing in each chosen location.
- To harvest a soil sample, use the plastic shovel to dig approximately 10 cm below the soil surface and obtain approximately 300 g of soil.
- Seal each soil sample in a plastic bag and label it. Wear gloves while obtaining the sample.

To determine the pH of the soil samples, create a mixture of soil and distilled water for each sample, using the following procedure:

- Place 40 g of soil in a beaker.
- Add 50 mL of distilled water to the beaker and gently stir the mixture.
- Allow the mixture to rest for 15 minutes.
- Place the coffee filter in a funnel. Place the funnel over a clean beaker and gently pour the mixture through the funnel.
- Use the pH indicator strips or the pH probe to determine the pH of the resulting liquid.
- Repeat for the other three soil samples.

Make qualitative observations about the composition of each soil type by direct examination of each sample. Make observations about type of plant growth from direct observation of the digital photographs.

All data should be recorded in a table, as in the table shown:

Soil Sample	Soil Type	Plant Growth	pH
Sample 1			
Sample 2			
Sample 3			
Sample 4			

Discuss the following questions after completion of the entire activity:

- *Which soil samples are the most acidic? The most basic?*
- *What are the relationships between soil type, plant type, and soil pH in the tested samples?*
- *How can knowledge of soil pH be useful in agriculture?*
- *How might soil be used to counteract the negative effects of acid rain?*

UNIT 5: CHARGE

This unit is built on the understanding that electricity involves charged particles and that it may build up (static) or flow (current). This understanding is expanded to include the relationship of electricity to magnetism and to conductivity of solutions. Students will investigate the properties of static and current electricity as well as applications of electromagnetism.

AREAS OF FOCUS

- Electric current is the result of the motion of charged particles across a conductor. (SPS10)
- Friction forces can cause the accumulation of an unbalanced amount of charged particles on the surface of an object. (SPS10)
- The voltage created between two objects due to the presence of an unbalanced charge may create an electric spark or shock. (SPS10)
- Electrons can be transferred from one charged conductor to another by physical contact. (SPS10)
- When a charged object is moved into proximity to a conductor, the conductor is charged by induction. (SPS10)
- An electric current requires a complete circuit and a voltage source. (SPS10)
- The amount of current that flows in a circuit depends on both the resistance of the circuit and the voltage of the source. (SPS10)
- In a series circuit, the same amount of current flows through all the components. (SPS10)
- In a parallel circuit, the voltage drop across each component is equal and is also equal to the voltage of the power source. (SPS10)
- In a direct-current circuit, the electrons flow in only one direction. (SPS10)
- In an alternating current, the motion of the electrons alternates back and forth, due to the changing polarity of the voltage source. (SPS10)
- Charges in motion generate magnetic fields. (SPS10)
- Variable magnetic fields induce currents in a circuit. (SPS10)
- A moving electrical charge, or current, in a magnetic field experiences a force. (SPS10)

KEY IDEAS

The word **electricity** sounds very much like *electron*. The similarity between the words is no accident. Recall that electrons are negatively charged particles, while protons are positively charged particles. When like charges come near each other, the charges repel each other. When opposite charges come near each other, the charges attract each other. **Static electricity** results from the buildup of electric charges on an object. The buildup of charges can be caused by friction, conduction, or induction.

- Rubbing two objects together can cause the electric charges on the objects to separate. The charging that results is due to **friction**. In this process, only electrons can be transferred from one object to another object. One object will become negatively charged as it gains electrons, while the other object will become positively charged as it loses electrons.

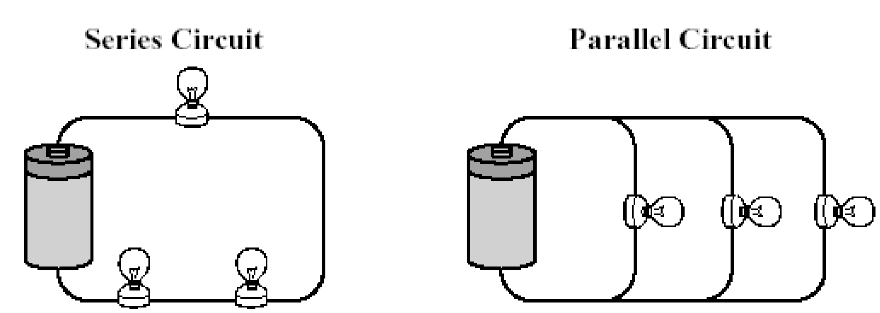
- In **conduction**, electrons flow through one object into another by direct contact. Silver, copper, aluminum, and magnesium are examples of good conductors. These materials allow electrons to flow freely.
- **Induction** involves electrons being rearranged. No contact need occur between two objects for induction to take place. A neutral object only needs to approach a charged object. For example, a negatively charged rubber rod picks up tiny slips of paper by induction. The electrons on the parts of the paper nearest the rod are pushed away, leaving positive charges. Because the positive charges are closer to the negatively charged rod, the slips of paper are attracted to the rod.

Electric charges leave a charged object during an **electric discharge**. Lightning is probably the most dramatic example of an electric discharge. The repulsion and attraction of particles can be described in terms of **electric fields**. An electric field is the area in which the electric force is noticeable. The strength of the electric field depends on the distance from the charged particle.

Electric current results from the movement of electric charges. A **circuit** is a complete, closed path for electron flow. A simple circuit consists of a source of electrons (such as a battery), a resistance or load, conducting wires, and a switch. In a battery, electrical energy is produced by a chemical reaction. When charged particles flow through the wire in a circuit, an **electric current** (*I*) results. The current is measured in amperes (*A*). The electron is the charged particle that most likely moves through the circuit. To get electrons flowing through a circuit, a voltage (*V*) is applied. **Voltage**, which is measured in volts (*V*), is the potential difference in electrical potential energy between two places in a circuit. In other words, voltage is the energy per unit of charge that causes charges to move. The opposition to current is called **resistance** (*R*), which is measured in ohms (Ω). Light bulbs and resistors are examples of objects with a resistance. Materials like copper that are good conductors of electricity have low resistance. The resistance of a wire depends on the thickness, length, and temperature of the wire. Insulators keep electrons from flowing easily. Although electrons move one way through a wire, the current, by convention, is the relative movement of a positive charge. Electrons flow opposite the direction of the current.

Charges can move through a circuit continuously in the same direction, producing a **direct current**, or **DC**. Electrons can also change direction, moving back and forth in cycles. This kind of current is known as **alternating current**, or **AC**. Batteries, such as those found in cars, produce DC, while a gasoline-driven generator usually produces AC.

When the electric charges in a circuit have only one path in which to flow, the circuit is called a **series circuit**. If the circuit has different branches in which the electric charges can flow, the circuit is called a **parallel circuit**. Parallel circuits are used in houses. The following box shows examples of these circuits:



An electric current will also produce a magnetic field. A **magnetic field** is a region around a magnet or current-carrying wire where magnetic forces can be measured. **Magnetism** is the force of attraction or repulsion that is produced by an arrangement of electrons. Magnets have two poles: a north pole and a south pole. *Unlike* magnetic poles attract each other, while *like* magnetic poles repel each other. Groups of atoms with magnetic poles aligned are called **magnetic domains**. Materials with most of these domains lined up are considered magnetized. When a metal bar or another object is composed of stable magnetic domains, a **permanent magnet** results.

When an electric current is used to produce a magnetic field in a coil of wire, the coil becomes an electromagnet. A rotating electromagnet is used in **electric motors** to convert electrical energy to mechanical energy.

When a magnet is moved near a wire, an electric current is generated. This process, called **electromagnetic induction**, is used to operate a **generator**. A generator is a device that converts mechanical energy to electrical energy. In a commercial generator, an electric current is produced when a large coil of wire is rotated in a strong magnetic field.

SAMPLE ITEMS

Item 17

As wet clothes tumble in a clothes dryer, friction between clothing items can knock electrons from some fabrics onto others, creating a static charge. This static electricity can discharge when the dry clothes are taken out of the dryer, sometimes causing unpleasant small shocks. The use of dryer sheets can reduce or eliminate this build-up of static electricity in the dryer.

Which hypothesis offers the BEST explanation for how dryer sheets reduce or eliminate static electricity?

A. Dryer sheets are coated with chemicals with a negative charge. These negative charges balance the negative charges that result from friction between the clothes.

B. Dryer sheets are coated with chemicals with a positive charge. These positive charges balance the negative charges that result from friction between the clothes.

C. Dryer sheets slide in between the clothing in the dryer, keeping the fabrics from touching each other. This eliminates the possibility of static electricity occurring due to friction.

D. Dryer sheets coat the inside surface of the dryer with chemicals. These chemicals make the clothes slippery, so they do not rub against each other, and therefore static electricity cannot build.

Item 18

A student performs an experiment on two isolated conducting spheres, A and B. Sphere A is positively charged, and sphere B is electrically neutral. The steps of the experiment are the following:

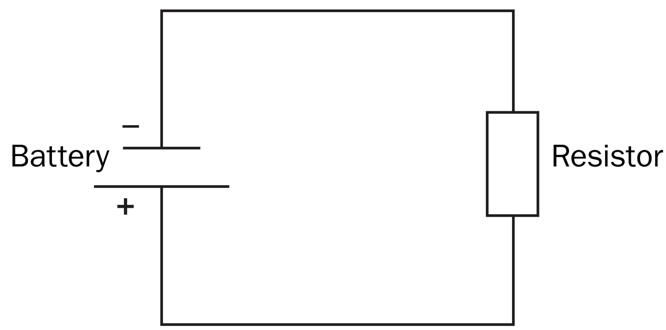
Step 1	The two spheres are brought into contact with one another for several seconds and then separated.
Step 2	Sphere B is brought into contact with a ground for several seconds and then the ground is removed.
Step 3	The two spheres are brought into contact with one another for several seconds and then separated.

What are the charges on the spheres following this experiment?

A. Sphere A and sphere B are positively charged.
B. Sphere A and sphere B are electrically neutral.
C. Sphere A is positively charged, and sphere B is electrically neutral.
D. Sphere A is electrically neutral, and sphere B is positively charged.

Item 19

The following simple circuit consists of a battery and one resistor, connected by ideal wires.



If the value of the resistor is replaced with another resistor that has a resistance of four times the initial value, how does the flow of electrons through the wire change?

A. reduced by a factor of 4
B. reduced by a factor of 2
C. increased by a factor of 2
D. increased by a factor of 4

Item 20

A permanent magnet is passed through a loop of wire. When is the electric potential difference in the loop the GREATEST?

A. when the permanent magnet is held far away from the loop of wire
B. when the permanent magnet is passed slowly through the loop of wire
C. when the permanent magnet is passed quickly through the loop of wire
D. when the permanent magnet is held still in the middle of the loop of wire

ADDITIONAL SAMPLE ITEM KEYS

Item	Standard/ Element	Characteristics of Science Standard/ Element	DOK Level	Correct Answer	Explanation
1	SPS5a	SCSh3a	1	B	The correct answer is choice (B) The average speed of the molecules decreases because they have lower energy in the liquid state. A substance loses energy as it changes from a gas to a liquid. The loss in energy causes the molecules to slow down. Choice (A) is incorrect because the average speed of the molecules decreases when a substance changes from a gas to a liquid. Choices (C) and (D) are incorrect because molecules in a liquid have less energy than those in a gas.
2	SPS8a	SCSh5e	2	D	The correct answer is choice (D) 12 km/hr in the direction of the path. To find velocity, divide the distance traveled (6 kilometers) by the time (0.5 hr). The answer is 12 km/hr. Choice (A) is incorrect because the runner has a finite speed. Choices (B) and (C) are incorrect because the runner travels at a faster rate than either of these velocities.
3	SPS8b	SCSh3e	2	C	The correct answer is choice (C) speed increases, acceleration remains constant. Since the only force acting on the marble is the constant force of gravity, the acceleration of the object will also be constant. A constant acceleration causes the speed to increase at a constant rate. Choices (A) and (B) are incorrect because a constant force will result in a constant acceleration. Choice (D) is incorrect because only the acceleration remains constant, while the speed increases.

Item	Standard/ Element	Characteristics of Science Standard/ Element	DOK Level	Correct Answer	Explanation
4	SPS8b	SCSh7b	3	C	The correct answer is choice (C) A book placed beside you on the back seat of a car slides to the floor as the car stops suddenly. Newton's first law of motion can be stated as an object in motion tends to stay in motion and an object at rest tends to stay at rest. When the car stops suddenly, the book continues to move forward and falls to the floor. Choice (A) is an example of unbalanced forces. Choice (B) is an example of Newton's second law of motion. The professional baseball player uses more force and so the acceleration of the ball is greater. Choice (D) is an example of Newton's third law. The force of the stone with greater mass is greater than that of the less massive stone.
5	SPS7c	SCSh5e	2	B	The correct answer is choice (B) 418.4 J. To calculate the heat gained, the mass of the sample should be multiplied by the specific heat capacity and the change in temperature. This would be 4.184 x 10.00 x (32.00 – 22.00) which equals 418.4 J. The other answers are incorrect because they do not equal this value.
6	SPS7a	SCSh3e	2	B	The correct answer is choice (B) As it travels downward, it gains kinetic energy and loses gravitational potential energy. This energy is converted into kinetic energy, causing the object to speed up. Choices (A) and (C) are incorrect because the object loses gravitational potential energy as it falls. Choice (D) is incorrect because the object gains kinetic energy as it continues to fall.

Item	Standard/ Element	Characteristics of Science Standard/ Element	DOK Level	Correct Answer	Explanation
7	SPS8e	SCSh5e	2	B	The correct answer is choice (B) 40 J. To find the work done on the box, calculate the force applied to the box times the distance it was applied. The force applied is the force in opposition to gravity, which is 20 N. It was applied over a distance of 2 m. 2 m times 20 N is 40 J. The other answers are incorrect because they do not equal 40 J.
8	SPS9c	SCSh7a	2	D	The correct answer is choice (D) Radiation from the Sun reaches Earth. Electromagnetic radiation can travel through the vacuum of space. Choice (A) involves sound waves, which are mechanical waves and require a medium. They can travel through walls. Choice (B) refers to light, which is an electromagnetic wave, but it needs to reflect off matter to be seen by human eyes. Choice (C) is incorrect because although X-rays are electromagnetic waves, this is an example of them traveling through a medium.
9	SPS1a	SCSh3e	2	A	The correct answer is choice (A) an ion of calcium. An atom's identity is determined by the number of protons contained in the nucleus. Since there are 20 protons, the atom is calcium. Since there is an uneven number of protons and electrons, the atom is an ion. Choice (B) is incorrect because the number of protons corresponds to an atom of the element calcium, not potassium. Choices (C) and (D) are incorrect because they are not neutral atoms, since they contain an unequal number of protons and electrons.

Item	Standard/ Element	Characteristics of Science Standard/ Element	DOK Level	Correct Answer	Explanation
10	SPS3c	SCSh5e	2	A	The correct answer is choice (A) 32.0 g. Taking the days and dividing by the half-live gives a value of 3. Since three half-lives have passed, one-eighth ($1/2^3$) of the sample remains. 256.0 g divided by 8 yields 32.0 g. The other answers are incorrect because they do not equal this value.
11	SPS4b	SCSh3a	2	D	The correct answer is choice (D) They have the maximum possible number of electrons in their outermost shell. The noble gases, including neon, argon, and krypton, are group 18 elements, which means that they have the maximum number of valence electrons. Therefore, these elements tend to be chemically inert. Choice (A) is incorrect because the noble gases are stable elements. Choice (B) is incorrect because the noble gases are reasonably plentiful elements. Choice (C) is incorrect because the noble gases do not readily give up their valence electrons.
12	SPS4a	SCSh3e	2	A	The correct answer is choice (A) metals and nonmetals are likely to be oppositely charged. An ionic bond is formed between oppositely charged ions; Based on their placement on the periodic table, metals and nonmetals are likely to become oppositely charged. Metals tend to lose electrons and become positively charged ions, and nonmetals tend to gain electrons and become negatively charged ions. Choice (B) is incorrect because this is a description of a covalent bond. Choices (C) and (D) are incorrect because both metals and nonmetals are considered reactive.

Item	Standard/ Element	Characteristics of Science Standard/ Element	DOK Level	Correct Answer	Explanation
13	SPS1a	SCSh3e	2	C	The correct answer is choice (C) Atom 2 and Atom 3. Isotopes of the same atom have the same number of protons and different numbers of neutrons. Since Atoms 2 and 3 both have 6 protons, they are isotopes of each other. Choices (A) and (D) are incorrect because these atom pairs have the same number of neutrons, but a different number of protons. Choice (B) is incorrect because the two atoms have a different number of protons. Therefore, they are different elements.
14	SPS2b	SCSh5e	2	B	The correct answer is choice (B) Al_2O_3. Due to the number of valence electrons, aluminum forms the ion Al^{3+} and oxygen forms the ion O^{2-}. Two aluminum ions will give up a total of six electrons while three oxide ions accept a total of six electrons. These ions join together to form the ionic compound Al_2O_3. Choice (A) is incorrect because two oxide ions can accept only four electrons; but the two aluminum ions need to give up six electrons in all. Choices (C) and (D) are incorrect because three aluminum ions would give up nine electrons, and there are insufficient oxygen atoms to accept that many electrons.
15	SPS2e	SCSh5e	2	D	The correct answer is choice (D) 4, 3, 2. Four Fe combine with three O_2 to yield two Fe_2O_3. Choice (A) is incorrect because the coefficients 2, 1, 2 result in an unbalanced number of both Fe and O. Choice (B) is incorrect because the coefficients 2, 3, 2 result in an unbalanced number of Fe atoms. Choice (C) is incorrect because the coefficients 4, 1, 2 result in an unbalanced number of O atoms.

Item	Standard/ Element	Characteristics of Science Standard/ Element	DOK Level	Correct Answer	Explanation
16	SPS6a	SCSh3e	2	C	The correct answer is choice (C) the water. The solvent is the component of the solution that dissolves the other components. Choices (A) and (B) are incorrect because the salt and sugar are both solutes. Choice (D) is incorrect because the mixture of the salt, sugar, and water is called a solution.
17	SPS10a	SCSh3a	2	B	The correct answer is choice (B) Dryer sheets are coated with chemicals with a positive charge. These positive charges balance the negative charges that result from friction between the clothes. Because the charges balance, there is no build-up of static electricity, even though there is still friction between the clothing items. Choice (A) is incorrect because negative charges do not balance negative charges. Choice (C) is incorrect because the clothes still touch each other, even in the presence of a dryer sheet. Choice (D) is incorrect because dryer sheets pass charges to the clothes; the dryer sheets do not work by passing chemicals to the inside of the dryer.
18	SPS10a	SCSh5e	3	A	The correct answer is choice (A) Sphere A and sphere B are positively charged. Sphere A initially has a positive charge. During Step 1, this charge becomes distributed equally between both spheres, resulting in sphere B also having a positive charge, though both have a smaller magnitude of charge than sphere A originally carried. During Step 2, sphere B is grounded and its charge is reduced to 0. During Step 3, the remaining charge on sphere A is again distrubuted equally between both spheres, resulting again in a (smaller) positive charge on the two spheres. Choice (B) is incorrect because there is still a finite amount of charge on the spheres at the end of the experiment. Choices (C) and (D) are incorrect because neither sphere will be electrically neutral at the end of the experiment.

Item	Standard/ Element	Characteristics of Science Standard/ Element	DOK Level	Correct Answer	Explanation
19	SPS10b	SCSh5e	3	A	The correct answer is choice (A) reduces by a factor of 4. The rate at which electrons flow is the current in the circuit, which is governed by the mathematical relationship $V=IR$. Since the battery is the same, the potential difference across the resistor (V) remains constant. Since the resistance (R) is increased by a factor of 4, the current (I) must be reduced by a factor of 4 in order for the product of I and R to remain equal to V. Choice (B) is incorrect because the current is reduced by a factor of 4, not 2. Choices (C) and (D) are incorrect because the value of the current decreases rather than increases.
20	SPS10c	SCSh3a	2	C	The correct answer is choice (C) when the permanent magnet is passed quickly through the loop of wire. Electromagnetic induction is defined by Faraday's law, which states that the magnitude of the potential difference induced in a coil of wire is directly proportional to the rate at which the magnetic field inside the loop is changing. When the permanent magnet is passed quickly through the loop, the magnetic field through the loop is changing at the largest rate. This will produce the greatest potential difference in the loop of wire. Choices (A) and (D) are incorrect because a constant magnetic field will not induce any potential difference in the coil of wire. Choice (B) is incorrect because passing the permanent magnet slowly through the loop of wire will induce only a small potential difference in the wire.

Study/Resource
Guide for Students
and Parents
Physical Science
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