Science Benchmark Clarification, Instruction, and Assessment

Strand: IV. Use Scientific Knowledge from the Physical Sciences in Real-World Contexts

Content Standard: 1. All students will measure and describe the things around us; explain what the world around us is made of; identify and describe forms of energy; and explain how electricity and magnetism interact with matter. (Matter and Energy)

Benchmark
Analyze properties of common household and agricultural materials in terms of risk/benefit balance (SCI.IV.1.HS.1).

Benchmark Clarification
Common household and agricultural materials (bleaches, drain cleaners, detergents, lubricants, fertilizers, herbicides, and pesticides) have both benefits and risks. These risks and benefits may be evaluated using criteria such as: safety, human health, environment, politics (governmental), and economics.

Students will:

- Evaluate the benefits of common household or agricultural materials by using a risk/benefit analysis (*link to Glossary*) that utilizes these criteria

Risk/Benefit analysis: weighing potential desirable and undesirable results

Key Concepts (voc.)
Risk/Benefit analysis

Real-World Context

- herbicides
- refrigerants
- fertilizers
- detergents

Instructional Example SCI.IV.1.HS.1

Benchmark Question: How do we describe the things around us?
Focus Question: What are the risks and benefits of using an everyday household product?

After a classroom discussion of risk/benefit analysis clarifying the criteria of safety, human health, environment, politics, and economics, students will work in small groups to research a common household product. Once they have completed their research, they will conduct a risk/benefit analysis to determine whether or not the product should be used. Each group will justify their position in a classroom presentation.

Constructing: (*link to SCI.I.1.HS.4*), (*link to SCI.I.1.HS.5*).

Reflecting: (*link to SCI.II.1.HS.1*), (*link to SCI.II.1.HS.5*), (*link to SCI.II.1.HS.6*).

Resources/References:

Webliography.
http://mtn.merit.edu/mcf/SCI.IV.1.HS.2.html/

Environmental Risk Sciences.
http://www.erisk.com/

EPA Recycling Information.
http://www.epa.gov/epaoswer/non-hw/recycle/index.htm/

Classroom Assessment Example SCI.IV.1.HS.1

Students will produce a written risk/benefit analysis of a product selected by the teacher using each of the five established criteria: safety, human health, environment, politics, and economics.

(Give students rubric before activity.)

Scoring of Classroom Assessment Example SCI.IV.1.HS.1

Criteria	Apprentice	Basic	Meets	Exceeds
Explanation of the risks and benefits of the product	Explains accurately a risk and benefit for one or two of the criteria.	Explains accurately a risk and benefit for three or four of the criteria.	Explains accurately one risk and one benefit for all five of the criteria.	Explains accurately more than one risk and more than one benefit for each of the five criteria.

Strand: IV. Use Scientific Knowledge from the Physical Sciences in Real-World Contexts

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Benchmark
Identify properties of common families of elements (SCI.IV.1.HS.2).

Benchmark Clarification
When elements are listed in order by the masses of their atoms, the same sequence of properties appears over and over. The intent is not for students to relate this order to electron configuration but to focus on the periodic table and look for recurring patterns.

These patterns are called families, and the elements in each family have common physical properties or characteristics such as state, conductivity, metal, non-metal, and chemical properties (such as reactivity, which is the tendency to combine with atoms of a different substance).

- Metals are generally solids, and excellent conductors of heat and electricity
- Non-metals include both solids and gases and are generally poor conductors of heat and electricity
- A third group of elements possesses properties of both metals and non-metals.

Common properties are found under Real-World Contexts.

Students will:

- Describe the common physical properties of common families/columns of the periodic table
- Recognize the characteristics and general categories/ families of elements:

Key Concepts (voc.)
Properties:

- state
- reactivity
- metal/non-metal
- conductivity

Tools:

- various element samples

Real-World Context

Highly reactive metals:

- potassium
- sodium

Less reactive metals:

- calcium

Highly reactive non-metals:

- chlorine
- fluorine
- oxygen

Almost completely non-reactive gases:

- helium
- neon

Relationships on the Periodic Table of Elements

Instructional Example SCI.IV.1.HS.2

Benchmark Question: How do we describe the things around us?
Focus Question: How are elements classified?

In this strategy, students will classify elements according to their physical and chemical properties.

Students will construct a table using columns with the following headings: name of element, state, luster, conductivity, reaction with water, and reaction with acid.

The teacher will give groups of two to four students eight to ten samples of the same identified elements. Students will examine each sample for the listed properties and will record their observations in the table. Small groups will conduct tests for conductivity, reaction with water, and reaction with acid. Students will respond with “high,” “ low,” or “no.” Groups will compare their results to the element’s position on the periodic table and identify any patterns of organization. They will conclude by answering the question, ”How is the periodic table organized?” They will share their findings with the class.

Note: Use a battery powered conductivity tester from a science supply catalog.

Constructing: (*link to SCI.I.1.HS.2*), (*link to SCI.I.1.HS.5*).

Reflecting: (*link to SCI.II.1.HS.1*).

Resources/References:

Webliography.
http://mtn.merit.edu/mcf/SCI.IV.1.HS.2.html/

Safety recommendations.
http://www.flinnsci.com/

Classroom Assessment Example SCI.IV.1.HS.2

Given an element and a periodic table, students will predict the properties they would expect the element to have and explain why. Possible properties include the following: reactivity, state, metal, non-metal, conductivity.

(Give students rubric before activity.)

Scoring of Classroom Assessment Example SCI.IV.1.HS.2

Criteria	Apprentice	Basic	Meets	Exceeds
Prediction of properties	Identifies correctly one property.	Identifies correctly two properties.	Identifies correctly three properties.	Identifies correctly four or more properties.
Reasons for prediction	Gives the correct reason for one property.	Gives the correct reason for two properties.	Gives the correct reason for three properties.	Gives the correct reason for four or more properties.

Strand: IV. Use Scientific Knowledge from the Physical Sciences in Real-World Contexts

Content Standard: 1. All students will measure and describe the things around us; explain what the world around us is made of; identify and describe forms of energy; and explain how electricity and magnetism interact with matter. (Matter and Energy)

Benchmark
Explain how elements differ in terms of the structural parts and electrical charges of atoms (SCI.IV.1.HS.3).

Benchmark Clarification
Each element is defined by its unique number of protons, which equals the number of electrons in a neutral atom.

Atoms are comprised of two major regions, a dense, central nucleus and a low density electron cloud.

The nucleus is made of protons and neutrons that comprise most of the mass of the atom. The protons have a positive charge and the neutrons have no charge (are neutral).

The electron cloud surrounds the nucleus and makes up the majority of the volume of the atom. The electron cloud is comprised of electrons that move rapidly around the nucleus. They have very little mass and are negatively charged.

The attractive force between the positively charged nucleus and the negatively charged electrons holds the atom together.

See SCI.IV.3.MS.3 (*link to SCI.IV.3.MS.3*).
Students will:
- Recognize that elements differ in their numbers of protons

Key Concepts (voc.)
Parts of atoms:
- nucleus
- electron cloud

Subatomic particles:
- proton
- neutron
- electron

Electrical charges:
- positive
- negative
- neutral

Real-World Context
All elements

Instructional Example SCI.IV.1.HS.3

Benchmark Question: What makes up the world around us?
Focus Question: How do the atoms in one element differ from those in another element?

After a classroom discussion about atomic numbers and mass numbers and their relationship to subatomic particles, the teacher will guide students in creating a model of an element. The teacher will use students as protons, neutrons, and electrons.

"Neutrons," labeled with zeros, sit on the floor in the middle of the room. "Protons," labeled with a positive symbol, stand among the neutrons in the middle of the room. "Electrons," labeled with a negative symbol, walk in a random pattern around the nucleus (protons and neutrons).

Students will relate the number of protons to the number of electrons in a neutral atom and will explain how the elements differ (different numbers of protons).

After the modeling, students will write a summary of atomic numbers and mass numbers and their relationship to subatomic particles.

(**Extension:** The teacher can name an element, then students can use a periodic table to find relevant information and can assume their roles in the atom.)

Constructing: (*link to SCI.I.1.HS.4*).

Reflecting: (*link to SCI.II.1.HS.2*).

Resources/References:

Webliography.
http://mtn.merit.edu/mcf/SCI.IV.1.HS.3.html/

Elements, Atoms, and the Periodic Table.
http://www.biologylessons.sdsu.edu/classes/lab2/map.html/

Periodic Table.
http://www.Colorado.EDU/physics/2000/applets/a2.html/

Periodic Table of Elements.
http://pearl1.lanl.gov/periodic/default.htm

Structure of the atom.
http://www.nyu.edu/pages/mathmol/textbook/middle_home.html/

Classroom Assessment Example SCI.IV.1.HS.3

Students will use diagrams to explain the subatomic structure of an atom of a given element.

(Give students rubric before activity.)

Scoring of Classroom Assessment Example SCI.IV.1.HS.3

Criteria	Apprentice	Basic	Meets	Exceeds
Correctness of explanation-relative mass	Explains correctly the relative mass of one subatomic particle.	Explains correctly the relative mass of two subatomic particles.	Explains correctly the relative mass of three subatomic particles.	Explains correctly the relative mass of three subatomic particles and describes the relationship to other masses.
Correctness of explanation-charge	Explains correctly the charge of one subatomic particle.	Explains correctly the charge of two subatomic particles.	Explains correctly the charge of three subatomic particles.	Explains correctly the charge of three subatomic particles and describes the electrostatic forces between subatomic particles.
Correctness of explanation - location	Explains correctly the location of one subatomic particle.	Explains correctly the location of two subatomic particles.	Explains correctly the location of three subatomic particles.	Explains correctly the location of three subatomic particles and describes the relative size of the nucleus and the electron cloud.
Accuracy of diagram - atomic structure	Draws correctly one subatomic particle.	Draws correctly two subatomic particles.	Draws correctly three subatomic particles.	Draws correctly three subatomic particles and indicates motion of electron(s)with arrows.

Strand: IV. Use Scientific Knowledge from the Physical Sciences in Real-World Contexts

Content Standard: 1. All students will measure and describe the things around us; explain what the world around us is made of; identify and describe forms of energy; and explain how electricity and magnetism interact with matter. (Matter and Energy

Benchmark
Explain how current is controlled in simple series and parallel circuits (SCI.IV.1.HS.4).

Benchmark Clarification
Current is controlled in simple series and parallel circuits. A series circuit has a single pathway for the current. Current in a series circuit is either flowing or not flowing as a result of a switch.

A parallel circuit has multiple pathways for the current to flow. Current can be flowing through some parts of the circuit and not others through the use of switches.

Fuses and circuit breakers act as safety switches by cutting off a circuit in the case of too much current flowing through it. Excessive current causes wiring to overheat, which can result in a fire.

Students will
- Construct simple series circuits and parallel circuits using wires, bulbs, motors, switches, and batteries
- Explain how fuses and circuit breakers act as safety switches

Key Concepts (voc.)
- single path
- multiple path
- switches
- fuses
- circuit breakers
- power supply
- batteries
- household current
- motors
- bulbs
- circuit diagrams

Real-World Context
- basic household wiring
- automobile wiring
- flashlights
- tree lights
- power lines
- electrical conductivity testing

Instructional Example SCI.IV.1.HS.4

Benchmark Question: How do electricity and magnetism interact with matter?
Focus Question: How is current controlled in simple series and parallel circuits?

As an introduction to parallel and series circuits, the teacher will give students bulbs, some wire, switches, strings of Christmas lights, and dry cells (batteries). Students will design and construct two circuits: one circuit has switches that turn off all lights when open and one circuit has switches that control individual lights. During a class discussion, students will draw conclusions from what they have observed and will explain how the circuits work. Students will distinguish between series and parallel circuits and will draw diagrams in their journals.

Constructing: (*link to SCI.I.1.HS.1*), (*link to SCI.I.1.HS.2*).

Reflecting: (*link to SCI.II.1.HS.1*).

Resources/References:

Webliography.
http://mtn.merit.edu/mcf/SCI.IV.1.HS.4.html/

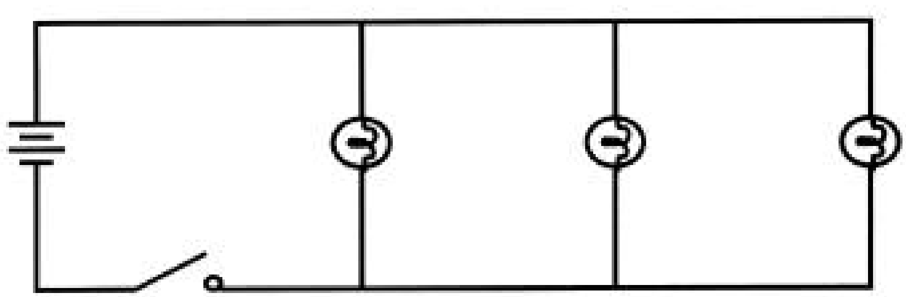
Basic electricity.
http://www.yeg.co.uk/fun/basic_electricity/welcome.shtml/

Fundamentals of electricity.
http://www.vvm.com/~radioray/html/e101-1.htm/

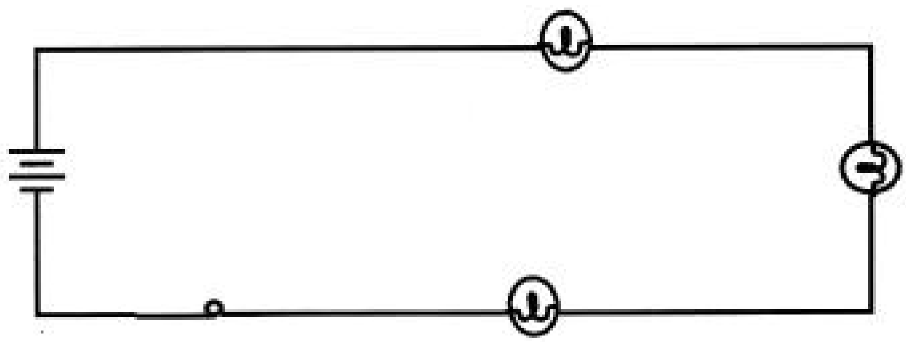
Voltage circuit simulator.
http://www.yeg.co.uk/fun/voltage/welcome.shtml/

Given four <u>circuit diagrams</u>, label each as a simple series, parallel, open (incomplete) or closed circuit and explain the reason for the labeling.

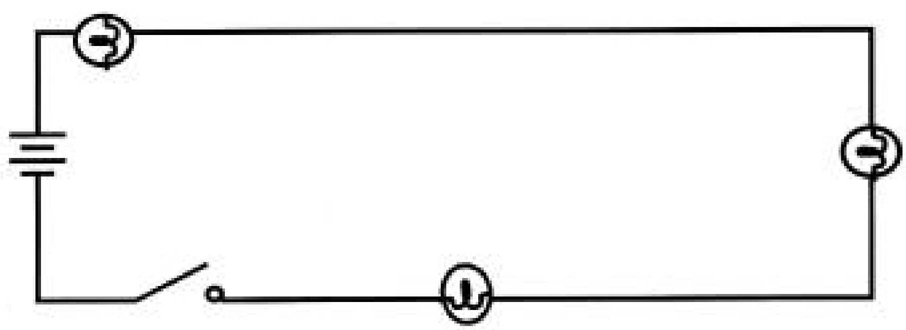
A.



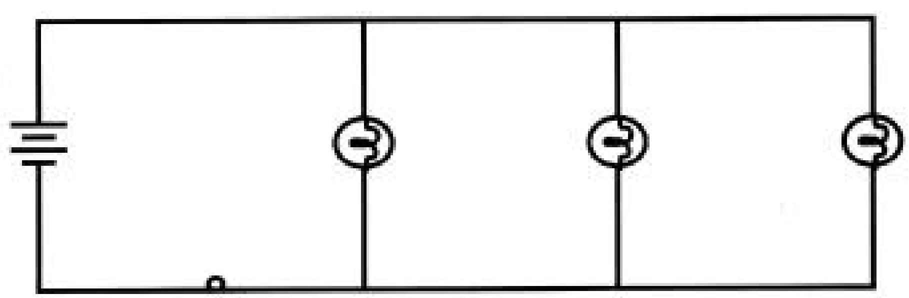
B.



C.



D.



Scoring of Classroom Assessment Example IV.1.HS.4

Criteria	Apprentice	Basic	Meets	Exceeds
Correctness of labels	Labels one diagram correctly.	Labels two diagrams correctly.	Labels three diagrams correctly.	Labels all diagrams correctly.
Correctness of explanation	Explains one reason correctly.	Explains two reasons correctly.	Explains three reasons correctly.	Explains all reasons correctly.

Strand: IV. Use Scientific Knowledge from the Physical Sciences in Real-World Contexts

Content Standard: 1. All students will measure and describe the things around us; explain what the world around us is made of; identify and describe forms of energy; and explain how electricity and magnetism interact with matter. (Matter and Energy)

Benchmark
Describe how electric currents can be produced by interacting wires and magnets, and explain applications of this principle (SCI.IV.1.HS.5).

Benchmark Clarification
Electric currents can be produced by interacting wires and magnets. This principle is applied to electric generators where the direction of the current flow in a wire changes as a magnetic field reverses.

This type of current is called alternating current (AC) because the current changes direction. Another type of current is direct current (DC), where the current flows in one direction only.

Students will:
- Explain how a wire moving through a magnetic field creates an electric current in the wire

See (*link to SCI.IV.3.MS.4*).

Key Concepts (voc.)
- current flow and direction
- magnetic fields

Real-World Context
- generators
- alternating current
- direct current

Instructional Example SCI.IV.1.HS.5

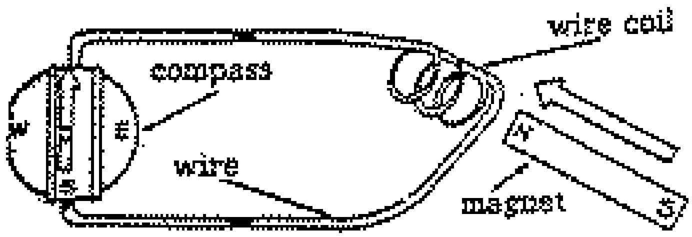
Benchmark Question: How do electricity and magnetism interact with matter?
Focus Question: How can electric currents be produced by interacting wires and magnets?

Following a class discussion about how an electrical current is produced, the teacher will perform the following demonstration and introduce the concept of a magnetic field producing an electric current:

Procedure:

1. Wrap 0.5 m of wire around a compass (top to bottom).
2. Attach the loose ends of the wire to a dry cell (battery) and observe the needle in the compass.
3. Discuss that the needle moves because electricity is moving through the wire and creates a magnetic field that interacts with the needle.
4. Make a coil of wire by wrapping approximately two m of wire several times around a plastic bottle with the top and bottom removed.
5. Remove the dry cell from the ends of the wire around the compass, then twist these ends together with each of the exposed ends of the two m of wire coil around the bottle.

See Compass Galvanometer Diagram below:



6. Place this set-up on an overhead projector to project onto a screen.
7. Take a bar magnet and quickly pass it back and forth through the center of the bottle with the coil; observe the compass needle.
8. Have students pair up, discuss, and then create a written description of what they think is happening.
9. Have students share their ideas with the class and debate which pairs have the most accurate ideas.

Constructing: (*link to SCI.I.1.HS.5*).

Reflecting: (*link to SCI.II.1.HS.1*).

Resources/References:
Webliography http://mtn.merit.edu/mcf/SCI.IV.1.HS.5.html

Fundamentals of electricity
http://www.vvm.com/~radioray/html/e101-1.htm.

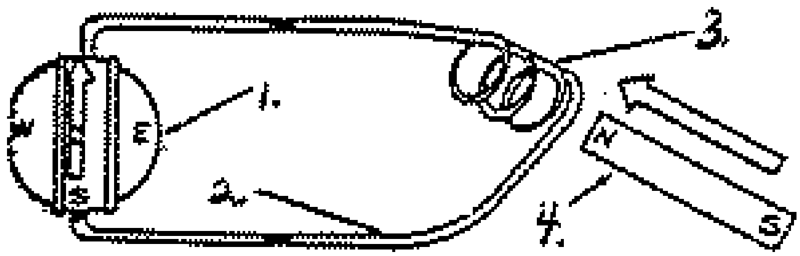
*Michigan Operation Physics***.**
Simple electric motor
http://members.tripod.com/simplemotor/

Classroom Assessment Example SCI.IV.1.HS.5

Students will label the Compass Galvanometer Assessment Diagram below and list the sequence of events in the process shown. Students may include the following steps:

1. Magnetic field from bar magnet causes current to flow in wire.
2. Current flow produces a magnetic field.
3. Generated magnetic field moves the compass needle.

(Give students rubric before activity.)



Scoring of Classroom Assessment Example SCI.1.HS.5

Criteria	Apprentice	Basic	Meets	Exceeds
Accuracy of labels	Labels correctly one part.	Labels correctly two parts.	Labels correctly three parts.	Labels correctly four or more parts.
Correctness of explanation of process	Describes one step correctly.	Describes two steps correctly.	Describes three steps correctly.	Describes three steps correctly and relates to alternating current and/or movement of electrons.

Strand: IV. Use Scientific Knowledge from the Physical Sciences in Real-World Contexts

Content Standard: 2. All students will investigate, describe, and analyze ways in which matter changes; describe how living things and human technology change matter and transform energy; explain how visible changes in matter are related to atoms and molecules; and how changes in matter are related to changes in energy. (Changes in Matter)

Benchmark
Explain chemical changes in terms of the breaking of bonds and the rearrangement of atoms to form new substances. (SCI.IV.2.HS.1).

Benchmark Clarification
Bonds (attachments or connections) between atoms break, and the atoms move around and rearrange into new substance(s) with new bonds.

The substance(s) that undergo the change are called reactants, and the substances that are formed are called the products. The numbers and kinds of atoms present in the reactants are the same as in the products (only the arrangement has been changed).

Reaction rates can be increased by increasing temperature, surface area, and/or concentration.

Types of bonds (ionic and covalent) are not emphasized, because they are not considered critical to scientific literacy.

Students will:

- Describe chemical changes as groups of atoms rearranging to form different substances

Key Concepts:

- atom
- molecule
- ion
- bond
- reactant
- product
- conservation of mass

Specific chemical reactions:

- burning paper or wood
- rusting iron
- formation of sugars during photosynthesis

Rate of reaction:

- temperature
- surface area
- concentration

See Structure of the atom.(*link to SCI.IV.1.HS.3*).

Real-World Context
Examples of chemical changes (*link SCI.IV.2.MS.2*)

Instructional Example SCI.IV.2.HS.1

Benchmark Question: How does matter change?
Focus Question: How does matter change in chemical changes?

After the teacher demonstrates, describes, and models a chemical change, students will perform a chemical change in small lab groups. The groups will model the chemical change using colored mini marshmallows and toothpicks. The following is a suggestion of an appropriate chemical change investigation for students:

<u>The Rusting of Iron (Oxidation)</u>

1. Rinse a small marble-sized sample of steel wool (Fe) in a dish of dilute HCl (0.1M).
2. Place the sample in the bottom of a test tube and invert the test tube. The steel wool should fit snugly enough into the tube so that it doesn't fall out.
3. Fill a small beaker (approx. 250 ml) with water to a depth of about two cm.
4. Place the inverted test tube into the beaker with the water.
5. Let this stand for an hour or overnight.
6. Observe the water level and the steel wool. The water level in the tube should rise as a result of oxygen (O_2) leaving the gaseous state and combining with iron (Fe) and forming the solid rust (Fe_2O_3).
7. Discuss the following reaction that occurs:

$$4Fe + 3O_2 \rightarrow 2Fe_2O_3$$

8. Groups should use one color of marshmallow for iron, another for oxygen, and construct a model with toothpicks (for bonds) to represent the reaction.

Small groups will describe the chemical change in writing and will share this writing with other groups and classes.

Constructing: (*link to SCI.I.1.HS.1*), (*link to SCI.I.1.HS.2*), (*link to SCI.I.1.HS.5*).

Reflecting: (*link to SCI.II.1.HS.1*).

Resources/References:

Webliography.
http://mtn.merit.edu/mcf/SCI.IV.2.HS.1.html/

Atoms, molecules and chemical reactions.
http://step.sdsc.edu/projects95/ATOM.PROGRAM/Atoms.html/

Chem 4 Kids".
http://www.chem4kids.com/map.html/

Chem Web Online Introduction to Chemistry.
http://library.advanced.org/10429/

Classroom Assessment Example SCI.IV.2.HS.1

Students will illustrate and explain the rearrangement of atoms in the formation of new substances in one or more of the following chemical changes:

$NaOH + HCl \rightarrow NaCl + H_2O$

(Give students rubric before activity.)

Scoring of Classroom Assessment Example SCI.IV.2.HS.1

Criteria	Apprentice	Basic	Meets	Exceeds
Accuracy of illustration	Illustrates inaccurately the arrangement of atoms in reactants and products or provides no illustration.	Illustrates accurately the arrangement of atoms in products *or* reactants.	Illustrates accurately the arrangement of atoms in products *and* reactants.	Illustrates accurately the arrangement of atoms in products and reactants and shows the breaking and forming of bonds to form new substances.
Correctness of explanation	Explains incorrectly or fails to explain at all.	Explains in a vague and/or incomplete manner.	Explains and mentions breaking of bonds and rearrangement of atoms to form new bonds and new substances.	Explains and mentions breaking of bonds and rearrangement of atoms to form new bonds and new substances. Gives an additional explanation of a chemical change.

Strand: IV. Use Scientific Knowledge from the Physical Sciences in Real-World Contexts

Content Standard: 2. All students will investigate, describe, and analyze ways in which matter changes; describe how living things and human technology change matter and transform energy; explain how visible changes in matter are related to atoms and molecules; and how changes in matter are related to changes in energy. (Changes in Matter)

Benchmark
Explain why mass is conserved in physical and chemical changes (SCI.IV.2.HS.2).

Benchmark Clarification
Because atoms are not created or destroyed during physical changes and chemical changes, the mass of material before the change is equal to the mass after the change.

See Physical changes **(***link to SCI.IV.2.MS.3*).
See Chemical changes(*link to SCI.IV.2.HS.4*).

Students will:
- Recognize that the mass before and after physical and chemical changes is equal
- Explain how the number and kinds of atoms before the changes are the same as after the changes

Key Concepts (voc.)
- atom
- molecule
- mass

Real-World Context
Common physical and chemical changes including matter cycles in ecosystems

Instructional Example SCI.IV.2.HS.2

Benchmark Question: How does matter change?
Focus Question: How is mass conserved in physical and chemical changes?

Students will perform a chemical change and a physical change in small lab groups. They will weigh and compare the masses of reactants and products in each case. Working in these same small groups, students will write summaries comparing the masses of products and reactants. Groups will share their summaries with the class.

Changes might include the following: Physical change: Melting ice cube, tearing paper, breaking beaker.

Chemical change: Burning, rusting, forming a precipitate. See (*link to IV.2.HS.1*).

Constructing: (*link to SCI.I.1HS.1*), *(link to SCI.I.1.HS.2), (link to SCI.I.1.HS.3)*

Reflecting: (*link to SCI.II.1.HS.3*).

Resources/References:

Webliography.
http://mtn.merit.edu/mcf/SCI.IV.2.HS.2.html/

Conservation.
http://tqd.advanced.org/3042/conservation.html/

Classroom Assessment Example SCI.IV.2.HS.2

Given the mass data of reactants, students will predict the total mass of the products and explain the prediction by using the concept of conservation of mass.

(Give students rubric before activity.)

Scoring of Classroom Assessment Example IV.2.HS.2

Criteria	Apprentice	Basic	Meets	Exceeds
ccuracy of rediction	Gives incorrect prediction of total mass.	Gives correct prediction of total mass.	Gives correct prediction of total mass that relates to explanation.	Gives correct prediction of total mass that relates to explanation and a description of what happening at the atomic level.
orrectness of xplanation	Gives incorrect explanation of conservation of matter with many misconceptions.	Gives correct explanation of conservation of matter with some misconceptions.	Gives correct explanation of conservation of matter with a few misconceptions.	Gives correct explanation of conservation of matter with no misconceptions.

Strand: IV. Use Scientific Knowledge from the Physical Sciences in Real-World Contexts

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Benchmark
Contrast nuclear fission, nuclear fusion, and natural radioactivity (SCI.IV.2.HS.3).

Benchmark Clarification
Nuclear change occurs when the nucleus of one atom changes, resulting in an atom of a different element. When this occurs, highly energetic particles/radiation are given off.

In nuclear fission, the nucleus of heavy atoms split into lighter atoms. In nuclear fusion, the nucleus of light atoms fuse into heavier atoms.

Most elements have two or three isotopes (*link to Glossary*). Some are stable, meaning the nucleus doesn't change. Others are unstable, meaning the nucleus decays, resulting in one or more different elements. This type of decay is called natural radioactivity.

Students will:

- Recognize that nuclear force holds the nucleus together

See Structure of the atom (*link to SCI.IV.1.HS.3*).

Isotopes: forms of the same element with differing numbers of neutrons

Key Concepts (voc.)

- nucleus
- nuclear change
- force that holds nucleus together
- nuclear energy
- stable and unstable isotopes

Properties:

- mass
- element
- radioactivity

Real-World Context

- nuclear power plants
- nuclear energy from the Sun
- natural radioactive decay
- use of radiation and radioactive isotopes in medicine

Instructional Example SCI.IV.2.HS.3

Benchmark Question: How does matter change?
Focus Question: How are nuclear fusion, nuclear fission, and radioactivity different?

Students will take notes from a teacher-led presentation of characteristics unique to nuclear fusion, nuclear fission, and radioactivity. Working in small groups, students will use their notes, text, and other resources such as library books and the internet to create a Venn diagram. The diagram will show how these three processes are similar as well as different. Students will draw diagrams to explain how one of the three processes occurs from beginning to end.

Students will share their diagrams with others in a small group. They will evaluate the accuracy of each diagram and present the most accurate diagram to the class.

As a follow-up, students will research the following scientists and place them into the proper sections of the Venn diagram based upon their contributions to key concepts in nuclear fusion, nuclear fission, and radioactivity:

<u>Lise Meitner</u> (*link to Biography*)
Lise Meitner (1878 – 1968)
ONE OF THE FIRST GREAT WOMEN PHYSICISTS

Lise Meitner was born in Vienna, Austria in 1878. Her father was a lawyer and able to provide well for the family, so-even though a girl-Lise was furnished with an excellent education. She attended the Academic High School in Vienna, and read about Marie Curie and her work with radioactivity in isolating radium. Intrigued, Meitner decided to study mathematics and physics so she, too, could become a physicist.

In 1902, she began her studies in theoretical physics with Ludwig Boltzmann. Although the concept that matter was composed of atoms was not generally accepted in that day, Professor Boltzmann was an early and enthusiastic proponent of the concept. Soon after the discovery of radium, physicists were able to prove that atoms and even sub-atomic particles existed. It was an eventful and exciting time.

In 1906, she received her doctorate and went on to the University of Berlin. It was here that Dr. Meitner met and began collaborating with a young chemist, Otto Hahn, who later won the Nobel Prize in Physics. Hahn worked at the Emil Fischer Institute, which barred women from working there. But Dr. Hahn finally convinced the authorities to allow Dr. Meitner to work with him. She was given a carpenter shop on the first floor to use as a laboratory. Not only was this shop difficult to equip, but its size and the lack of full cooperation from the Institute's administration limited her work to chemical research.

In 1921, the Kaiser Wilhelm Institute for Chemistry was opened as part of the University of Berlin. This afforded opportunities for both Dr. Meitner, who became an assistant to Max Planck at the University's Institute for Theoretical Physics, and Dr. Hahn, who was made a member of the staff. Dr Meitner was soon recognized for her work, and was asked to organize and become the head of a new Physics Department at the Institute. This gave her unlimited opportunity to meet and work with the greatest scientific minds of the time.

She continued her collaborative work with Dr. Hahn, and in 1917, they discovered the rare radioactive element protactinium. Dr. Meitner also did extensive work on her own, especially studying beta rays. She was the first to conclude that the emission of radiation follows, rather than precedes, the emission of the particles in the process of disintegration of radioactive materials.

In 1924, she was awarded the Liebnitz Medal of the Berlin Academy of Sciences, and the Lieber Prize of the Austrian Academy of Sciences in the following year. In 1926, she was appointed Professor Extraordinary at the University of Berlin. She continued in this position until Adolph Hitler's anti-Jewish activities forced her to flee for her life.

Although the workings of nuclear fission were known to many enslaved Jewish scientists who were unable to escape Hitler's decrees, they did not reveal their secrets. If they had, it is likely that Hitler's military would have had the atomic bomb before the U.S. Ironically, the Jewish scientists who were able to escape Hitler's grasp formed the basis of the scientific group in the U.S. which developed the atomic bomb, ending the war Hitler had begun.

Just prior to escaping Germany, Dr. Meitner and Dr. Hahn found a new group of radioactive substances (transuranium elements, such as barium and krypton) that could not be identical to any element just below uranium in the Periodic Table. These experiments revealed that they had, in fact, split the uranium atom—something she called atomic fission. Thirteen months later, an atomic chain reaction was produced at Columbia University making possible the first atomic bomb.

Only July 13, 1938, Dr. Meitner received a forged set of documents and escaped with Dr. Coster to the Netherlands. At the age of 59, she was again starting over in a new country. One month later, Dr. Meitner moved to Stockholm, Sweden, where she began work at the Physical Institute of the Academy of Sciences. Dr. Meitner remained at the Institute, and as a member of the Atomic Research Staff of the University of Stockholm, until she retired.

Dr. Lise Meitner lived at a time in which she was severely discriminated against because of her gender and religion. But, her inquiring mind, tremendous intellectual abilities, and the help of some of the greatest thinkers of her day, permitted her to overcome discrimination and become one of the most distinguished theoretical physicists to date. She not only made many scientific discoveries on her own, but also helped a number of others achieve greatness.

By the time of her death on April 12, 1989, Dr. Meitner had been the only living woman member of the Swedish Academy of Sciences, who had received the City of Vienna's Prize in Science (1947); was awarded the Max Planck Medal (1949), and also had been given honorary doctorates in science from Syracuse, Rutgers, Smith, and Adelphi Universities.

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Albert Einstein (*link to Biography*),

Albert Einstein (1879 – 1955)
CONCEPTUALIZED THE THEORY OF RELATIVITY

Dr. Albert Einstein was born the son of an electrical engineer on March 14, 1879, in Ulm, Germany. His scientific curiosity began by age five as he pondered the invisible force which directed the needle of a compass given to him by his father. But, he showed little academic promise at the Catholic state school he was forced to attend, and was unable to speak very well at the age of nine. His teachers said he was mentally slow, unsociable, and "adrift forever in his foolish dreams." Unaffected by these criticisms, Einstein took refuge in a sea of books and learned to play the violin. These solitary pursuits brought him great joy.

One day, Einstein's teacher brought to class a large nail she said was from the crucifixion of Jesus. As the only Jewish boy, all eyes turned to him as if he and his religious ancestors were directly responsible. Einstein did not understand this senseless hatred, and he ran from the room, returning to his books for comfort. This incident stayed with him throughout his lifelong fight against prejudice.

At the age of 12, Einstein's life changed dramatically when he discovered Euclidean geometry. By age 16, he had also become proficient in differential and integral calculus.

In the 1880's, Einstein's family moved to Switzerland. Even so, he continued to be unhappy in school and was soon expelled because his rebellious attitude hurt the morale of fellow classmates. He then tried to enter the Federal Institute of Technology in Zurich. Even though Albert's knowledge of mathematics was superior to most, his knowledge in other areas was greatly lacking and he failed his first attempt at taking the university entrance examination. Later, in 1896, he was admitted to the Institute. At first he wanted to become a mathematics teacher, but soon realized that his greatest interests lay in experimental and theoretical physics.

Einstein passed his university examinations in 1900, and was given a teaching certificate – but not a teaching job as was usual at that time. Anti-Semitism was growing, and as a Jew, he was denied any job with status attached to it. After several years of unsuccessfully searching for a teaching position, he accepted a job as a technical expert, third-class, in a patent office.

Bored, Einstein began experimenting with complicated mathematical formulas. With a pencil in hand, he built a laboratory in his mind. Those calculations were basis of his doctoral dissertation which he completed at age 26. They also were his first steps in formulating a theory which shook the foundations of science.

Einstein had long searched for a general principal which would explain a paradox that occurred to him when he was 16 – if someone runs alongside a train at the same speed, as the train, it appears to be at rest. But, if it were possible to run alongside a ray of light, the ray of light – an oscillating electromagnetic wave – would not appear to be at rest. Therefore, everything in the universe was actually in motion. Speed and direction are relative, and only measured relative to other objects. Einstein then concluded that space and time were also relative. The only thing that was not relative was the speed of light.

In short, he stated that, no matter how fast an observer is traveling, he or she must always observe the velocity of "c" as the speed of light. He also hypothesized that, if an observer at rest and an observer moving at a constant velocity perform the same experiment, they must get the same results. These two considerations were the basis of Einstein's "Special Theory of Relativity." He went on to prove that this theory predicted energy "E" and mass "m" are interconvertible – thus "$E=mc^{2}$. This formula gave a remarkable new picture of the universe.

The Special Theory of Relativity challenged long-held views of time and space. Always before, scientists had believed that mass, length, and time was absolute and unvarying. Einstein demonstrated that they were dependent on the relative motion between the observer and what is being observed. In 1907, he proved his entire quantum hypothesis by showing that it accounted for the low-temperature behavior of specific heat in solids.

In 1909, he was made an associate professor at the University of Zurich, and a full professor two years later. A year-and-a-half after that, he became a full professor at the Federal Institute of Technology. Einstein was rapidly advancing. He had become so well known within the scientific community that, in 1913, Max Planck and Walter Nernest asked him to accept a research professorship at the University of Berlin. To further entice Einstein, Planck also offered him full membership in the Prussian Academy of Science. In 1914, Einstein accepted and remarked, "The Germans are gambling on me as they would on a prize hen. I do not really know myself whether I shall ever lay another egg."

By 1915, Einstein had refined his General Theory of Relativity which described the structure of space. He maintained that the universe contained a continuum of space and time in the form of a complicated four-dimensional curve. Unlike Newton, Einstein proved that gravity was created by a localized bending of space caused by the presence of large masses such as planets and stars. In addition, he demonstrated that the shortest distance between two points in space was not a straight line, but a curved line – light is modified by the objects it encounters as it travels from one point to the next.

In 1919, the light of a solar eclipse was independently measured at two observatories. Einstein predicted that light rays which passed near the sun would, because of the intense gravitational waves. He also suggested that the universe is static and uniformly filled with a finite amount of matter; and although finite, it has no beginning or end point. The proof of his predictions, published in 1915, caused a great fury in the scientific world.

In 1920, Einstein was appointed to an honorary lifelong professorship at the University of Leiden. A year later, he was awarded the Nobel Prize for his famous 1905 equation for the photelectric effect.

During 1921-22, Anti-Semitic attacks on Einstein were renewed. Even Nobel Prize-winning physicists Philipp Leonard and Johannes Stark were known to criticize Einstein's theory of relativity as "Jewish physics." This Anti-Semitic prejudice increased rapidly with the rise of Nazi Germany. It was during this period that Einstein took a public stand against Anti-Semitism. For two years he and Chiam Weizmann, the future first president of Israel, traveled worldwide to gain support for establishing Palestine as a Jewish homeland.

In 1924, S. N. Bose, with Einstein's help, developed Bose-Einstein statistics. This soon led to Einstein's famous wuantum theory of an ideal gas. Around this same time, he was offered an honorary vice presidency of the Mark Twain Society. When he found that they also had offered a similar position to Italian dictator Benito Mussolini, however, he flatly refused. Shortly thereafter, he found his name high on a list of people who were to be assassinated by the Nazis, and moved to Holland. But, he found that formerly tolerant nation also to be rife with Anti-Semitism and a fear of Nazi Germany. In 1932, Einstein moved to the United States.

Adolf Hitler then told Einstein that he would overlook the fact that he was Jewish, and asked him to return to Germany. When Einstein refused, Hitler reversed himself, insisted that no Jew could have formulated the Theory of Relativity immediately revoked his German citizenship, and place a price of 20,000 marks on his head. At the same time, Einstein resigned from the Prussian Academy of Science because of their Anti-Semitism, and was expelled from the Bavarian Academy of Science.

A year later he was appointed a life member of the Institute for Advanced Studies at Princeton University in New Jersey, and actively continued his work there until 1939. At that time, American scientists were becoming concerned that the Relativity Theory (which showed that mass could be converted directly to energy) could be used by German scientists to build a new "super weapon." With the threat of a world war looming, Einstein wrote to President Roosevelt, a suggesting that the U.S. develop a counter weapon in hopes it could be used to prevent war. The counter weapon's development was begun, but rather than used to deter a war, it was used to end one. In 9145, despite Einstein's appeals, an atomic bomb was dropped over Hiroshima, Japan.

Einstein spent his last years in semi-retirement at Princeton and continued to work and teach until 1945, when he retired and was made a professor emeritus. Between that time and his death in 1955, Einstein became a strong advocate of a world government as the only practical way to achieve peace.

Dr. Albert Einstein's legacy is unending. He gave science an entirely new understanding of the universe. He fought against religious prejudice and war. And the lived a full life – a life spent in the service of others.

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Enrico Fermi (*link to Biography*),
Enrico Fermi (1901 – 9154) FIRST TO CREATE NUCLEAR FISSION

Winner of the 1938 Nobel Prize in nuclear physics, Enrico Fermi was born in Rome, Italy, in 1902. He grew up during troubled times of great economic, political, and religious strife. Even so Fermi earned his doctorate degree at the University of Pisa in 1922 – only a few months before the dictator Benito Mussolini seized power.

Throughout his tudies, Fermi was extremely interested in the behavior of electrons in solid materials. He went to Germany to work under Bron, later returning to Italy where he became professor of physics at the University of Rome in 1926.

His interests in sub-atomic particles became even greater with Chadwick's 1932 discovery of the neutron. Germi's mathematics demonstrated the neutron's existence and measured its emission. As part of this work, Fermio calculated the nature of weak interaction among neutrons – and later also calculated strong interaction.

Fermi's important mathematical calculations made possible new types of nuclear reactions. He discovered that neutrons were more effective when they had a lesser change, and he noticed that they were also more effective in generating nuclear reactions if they first passed through water or paraffin.

This finding was important because, when a neutron is absorbed by the nucleus of another atom, the newly-formed nucleus can emit a beta particle and become an atom of the next higher element on the periodic table. IN 1934, Fermi conjectured that he could bombard uranium with neutrons to form an artificial element above uranium on the periodic table – a trans-uranium element which he called uranium X. What Fermi had actually done, however, was create nuclear fission, and he was awarded the Nobel Prize in 1938 for his experiments.

While this work was going on, the dictator Mussolini had increased his hold over Italy and combined forces with German dictator Adolph Hitler. Hitler's anti-Jewish control was rapidly increasing in Europe, and the Italian government passed many anti-Jewish laws. When Fermi refused to wear a Fascist uniform or give a Fascist salute at award ceremonies, this made his anti-Fascist views public and he was attacked by the Italian press. And, because Fermi's wife was Jewish, they could not return to Italy. After a short stay in Stockholm, Sweden, where he accepted the Nobel Prize, Fermi moved permanently to the U.S., and became a citizen in 1944.

Here, Fermi and a well-known scientist named Szilard began collaborating. They speculated that neutrons could be emitted in uranium fission, which would cause other uranium atoms to also undergo fission and produce more neutrons. These would collide with more atoms to create a nuclear chain reaction. This type of reaction would produce tremendous amounts of energy in only a fraction of a second.

Meanwhile, world powers were conducting research to find a "super weapon" which would give them control over the outcome of World War II. The Manhattan Project was established at the University of Chicago, Illinois in an effort to develop a structure in which a nuclear reaction could be produced. Fermi was put in charge of the building which housed the Project. He soon discovered that graphite would slow down the activity of neutrons better than the paraffin he used earlier. Because the slowed neutron could be more readily absorbed by uranium atoms, nuclear fission was made easier.

The first nuclear reactor was made of uranium and uranium oxide piled up with graphite blocks. It also contained cadmium
rods, used to absorb neutrons until they were needed to start a nuclear reaction. At 3:45 p.m. on December 2, 1942, cadmium rods were withdrawn from the nuclear pile and the chain reaction became self-sustaining – the nuclear age began with this first chain reaction.

IN a little more than tow-and-a-half years, enough was known about fission reactions for the first atomic bomb to be developed, which was used to devastate the Japanese cities of Hiroshima and Nagasaki. The world had never witnessed such widespread destruction from a single weapon. Shortly after Nagasaki was bombed, the Japanese surrendered and the last part of World War II was over.

Like many of the Manhattan Project team who knew how powerful nuclear explosions could be, Fermi opposed further development of atomic bombs. Even so, nuclear reactions were refined to create nuclear fusion – the basis for the even more powerful H-bomb. Fortunately, none have been used in armed conflicts so far.

When the Manhattan Project was completed, Fermi became a professor at the Institute for Nuclear Studies, University of Chicago, where he worked until he retired. Many of his students later went on to make great discoveries themselves, including Gell-Mann, Chamberlain, Lee, and Yang.

On November 28, 1954, before Fermi could see nuclear reactions put to peaceful use, he died of stomach cancer. Fermium, discovered a year after his death, was named for Fermi as a lasting tribute to the "Father of Nuclear Fission".

Marie Curie (*link to Biography*),
Marie Sklodowska Curie (1867 – 1934) WINNER OF TWO NOBEL PRIZES

Marie Sklodowska was born in Warsaw, Poland, November 7, 1867. She demonstrated academic excellence throughout her early schooling, and was awarded a gold medal upon completing her high school studies in 1883.

Although she was considered brilliant, girls were not allowed to attend universities in Russian-dominated Poland. Dejected, she spent a year in the country with friends. Upon her return, she began to tutor students to earn a living and also became associated with the "Floating University" – a group of young men and women who tried to quench their thirst for knowledge in semi-secret meetings.

IN 1886, she became governess to a family in Szczuki, Poland, but this only served to fuel her hunger for knowledge and she was determined to continue her studies at a university. Fortunately, one of Marie's sisters was studying medicine in Paris, France, at the time, so Marie joined her there.

After her graduation in physics from the Sorbonne, Marie began looking for a laboratory where she could continue her research on measurement of the magnetic properties of steel alloys. A friend suggested that she speak with a young professor, Pierre Curie, at the School of Physics and Chemistry of the University of Paris. Although Marie returned to Poland during that summer, Pierre convinced her to return to Paris and they were married a year later.

Early in their work together, the Curies were intrigued with the radiation which was emitted from uranium compounds. In searching for its source, they turned to pitchblende, a mineral which was known to contain uranium. During their four years of research, however, the two were forced to spend their entire savings to buy enough pitchblende to complete their experiments. by 1887, Madame Curie had completed two additional university degrees, a fellowship, a paper on the magnetization of tempered steel, and given birth to their first daughter, Irene.

The Curies set up their laboratory in a courtyard shed at the School of Physics and Chemistry. Soon, the news of the discovery of radiation reached them. They became virtually obsessed in their search for the mysterious element which would account for the earlier differences in radioactivity they had found. Marie discovered that, although radiation emitted from thorium was similar to that of uranium, pitchblende contained more radioactivity than could be explained by the combination of the uranium and thorium which it contained. They believed the pitchblende contained another element which they had not yet found, and called it "radium." During this time, she also coined a new word to describe the emitted radiation, "radioactivity."

After four years, their exhaustive work and near-starvation paid off – they were able to produce a tenth of a gram of radium. Within six months, the Curies had written two papers on their discoveries. The first, which announce the discovery of an entirely new radioactive element (polonium, named after Marie's homeland), was presented to the French Academy of Sciences. The second paper proclaimed the discovery of radium, which they found to be two million times more radioactive than uranium. It also noted that radiation made air a conductor of electricity, and by ionizing the gas molecules, caused phosphorescent substances like zinc sulfide to glow brightly.

During those years, they jointly or separately published another 30 scientific papers. Among them was one which reported that diseased tumor-forming cells were destroyed faster than healthy cells when exposed to radium. This finding went unnoticed until World War I, and continues to be the basis of much work in radiology today.

Suddenly, the scientific world began taking note. In November, 1903, the Royal Society in London gave Marie and Pierre Curie the Davy Medal, one of their highest awards. Within a month, word came that A. H. Becquerel and the Curies were to be jointly awarded the Nobel Prize for physics. Unfortunately, the Curies were too ill and exhausted to travel to Stockholm to accept the award.

Even French scientists began to take note, and created a chair in physics at the University of Paris. A few months later, Marie Curie was appointed director of research for physics. In 1904, the Curies had their second daughter, Eve. A year later, Pierre Curie, who had previously been rejected for membership, was finally elected to the French Academy of Sciences.

At their new academic posts, the Curies feverishly renewed their research on radium atoms. However, tragedy struck in 1906 when Pierre was run over and killed by a heavy carriage. Two weeks later, Marie was asked to take over her husband's post – the first time a woman had ever been named a professor. Without time to mourn, and now the single mother of two children, Marie Curie undertook the task of leading the scientific world with her research.

In 1911, the French Academy of Sciences voted down her membership, but 11 months later she was awarded the Nobel Prize in chemistry – becoming the first person to ever receive two Nobel Prize science laureates. That same year, Madame Curie was also elected a permanent member of the Solvay Conferences in physics, and offered the directorship of the new Institute of Radioactivity in Warsaw.

Curie turned down the Warsaw offer and remained in Paris because the Pasteur Institute convinced her to stay by promising to establish the Paris Institute of Radium. This joint effort of the Pasteur Institute and the Sorbonne was dedicated in July, 1914.

World Ward I also broke out at the time. IN an effort to apply her talents to medicine, Madame Curie spent most of the next four years equipping automobiles with X-ray apparatus. By the end of the war, these cars became known as "little Curies."

After the war in 1919, Marie Curie began work at the Institute of Radium, and her daughter Irene – a talented physicist in her own right – was appointed her laboratory assistant. Two year later, she published her book, La Radiologie et la guerre, which gave a full account of the gains made in radiology during the war.

Soon afterward, Mrs. William B. Meloney, editor of a large New York magazine, visited Madame Curie to tell her that she was an inspiration to the women of the United States. However, her attention was focused on raising funds to buy for research purposes some of the exceedingly expensive element, radium. Within a year, Mrs. Meloney had raised $100,000 and purchased some radium. Madame Curie collected this gift from U. S. President Warren G. Harding at the White House.

During the last years of her life, Madame Curie continued her work at the Institute of Radium, which became a major center for research in nuclear physics and chemistry. During this time, she pioneered many of the earliest medical applications of X-rays and radium. The techniques which resulted were quickly adopted in the treatment of cancer.

Unfortunately, Marie Curie was unaware of what the years of research to help mankind had done to her own body. Constant exposure to radioactive elements began to negatively affect her blood chemistry. Even so, with great support from her daughter Eve, she completed her last book, Radioactivite. On July 4, 1934, Marie Curie died of leukemia.

Marie Sklodowska Curie is remembered for more than her many extraordinary accomplishments in physics and chemistry. She was a symbol of commitment, dedication, and strength, having faced and overcome overwhelming prejudice because she was female. She was often poor because of the high costs of her research, and things were especially difficult after Pierre's death as she raised her children alone.

But, regardless of the obstacle, Madame Curie overcame it. Perhaps Albert Einstein best described this brilliant woman. “Marie Curie is, of all celebrated beings,” he said, “the only one whom fame has not corrupted.”

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Chien Shiung Wu (*link to Biography*),

Chien-Shiung Wu (1915 -) FIRST WOMAN PHYSICS TEACHER AT U.S. UNIVERSITY

Chien-Shiung Wu was born in 1912 in Liu Ho, a small town near Shanghai, China. She first attended school in Liu Ho, where her father was the principal. After she completed all the schooling available in her village, Wu was sent to Soochow for high school. There, she began to study the English language and decided to become a physicist because she enjoyed mathematics and Science. Next, she enrolled in the National Central University at Nanking. She took all of the math and physics courses available, and graduated with a science degree in 1936.

At that time, no advanced degrees in physics were offered in China, so Chien-Shiung Wu persuaded per parents to let her go to graduate school in the United States. In 1936, she arrived at the University of California at Berkeley to study under Dr. Ernest Lawrence, who had just made director of the radiation laboratory there. Son after, he began developing his noted atom smashing cyclotron. He also began his research of atomic structure and transmutations for which he was awarded the Nobel Prize in Physics. Studying under such a great scientist made this a particularly inspiring time for Wu.

Her excellent work was soon noticed, and she was given a teaching assistantship which continued through her graduation with a Ph.D. in nuclear physics in 1940. Dr. Wu’s researchfor her doctoral dissertation had two parts – she worked with X-radiations from beta decay, perfected new ways to separate two types of rays during disintegration, and also focused on establishing two complete chains of radioactive decay with half lives. Here, she collaborated with Dr. E. Serg, but this work was not allowed to be published until after World War II was over. Soon, she was elected to Phi Beta Kappa (a prestigious national honor society) for her outstanding graduate work, and began work with Dr. Lawrence as his research assistant.

In 1942, Dr. Wu taught physics at Smith College. At the age of 21, after only a year at Smith, Princeton University asked her to teach nuclear physics to their students. But, within a few months she was called to work on the Manhattan Project at Columbia University – the project responsible for developing the atomic bomb. IN 1944 she was made a member of the scientific staff of the Division of War Research at Columbia. Most of her work there was spent developing devices which could detect and measure radiation.

Immediately following the end of World War II, Dr. Wu became a research associate at Columbia, where she found new ways to study the shapes of the beta spectra and the interaction of beta decay. To do this, she invented a technique which used a magnetic spectrometer into which a scintillation counter and a beta detector had been built. The results of her experiments gave proof of the Fermi theory of beta decay, and won her a promotion to associate professor of physics in 1952.

In 1956, two Chinese-American physicist colleagues, Professors Tsung Dao Lee of Columbia and Chen Ning Yang of the Institute for Advanced Study at Princeton, wrote a paper which questioned a principal of parity which had been an accepted truth in physics since its conception 30 years earlier. They noted that there were great differences between what actually happened when K-mesons (discovered in 1952) disintegrated and what, according the theory, should have happened. Lee and Yang purposed that these questions be cleared up by experimenting with pi and muon mesons and with beta rays. They later won a Nobel Prize for this theoretical work, but it was Dr. Wu who conducted the experiments with beta rays.

The results of her experiment clearly showed that the number of electrons emitted in the opposite direction of the rotation of the nucleus was far greater than the number emitted in the same direction. Thus, the direction of the emitted electrons is predetermined to be in the opposite direction of the rotation of the nucleus. Not only did her experiments prove that the motion of emitted electrons is the opposite of what was formerly thought, but they also liberated thinking about the structure of the physical world. Later, in 1958, for her outstanding work in this field, Dr. Wu was given an honorary doctorate in science from Princeton University, the first ever given to a woman.

In 1963, Dur. Wu again collaborated with Professor Lee and L. W. Mo, another research physicist. Her experiments clearly proved a new fundamental theory in nuclear physics – the theory of conservation of vectory current. This gave rational understanding to the lack of renormalization of the vector current in beta decay, the basis of the universal Fermi interaction. Dr. Wu then went on to perform other research which led her to determine the masses and magnetic moments of particles to a very high precision.

Dr. Chien-Shiung Wu has continued her research and teaching to date, and received many awards and memberships which recognize her merit. She was awarded the first Michael I. Pupin Chair in Physics, elected to the National Academy of Sciences, served as president of the American Physical Society, joined the American Academy of Arts and Sciences, made a fellow of the American Association for the Advancement of Science, received the Research Corporation Award, and the Comstock Award of the National Academy of Sciences. She also received the Scientist of the Year award from Industrial Research Magazine, the National Science Medal, the Wolf Prize in Physics from the Wolf Foundation in Israel, and was elected to the Academia Sinica (the Academy of Sciences of China).

Dr. Wu has shown that great obstacles such as gender, race, culture, and language can be overcome in order to succeed as a preeminent and respected scientist in her chosen field.

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and Shirley Ann Jackson (*link to Biography*)

Shirley Ann Jackson (1946 -)
FIRST BLACK WOMAN TO EARN A PH.D IN PHYSICS

The first black woman in the United States to receive a doctorate in physics, Shirley Ann Jackson was born in Washington, D.C., August 5, 1946. Her enjoyment of mathematics – along with strong encouragement from her parents and scientific events like the launching of the Soviet Sputnik satellite – helped her achieve her dream of becoming a theoretical physicist.

Jackson was offered many academic scholarships after graduating from high school. She decided to attend the Massachusetts Institute of Technology (MIT), even though she would be one of only 15 Black students, and the only Black to study theoretical physics. Here, she joined the Delta Sigma Theta sorority and served as president for two years, following in the footsteps of her role models – Mrs. Frankie Freeman, a member of the U.S. Civil Rights Commission; and Dr. Jean Noble, a professor of psychology at New York University.

While at MIT, Jackson also helped organize the Black Student Union, which she co-chaired for two years. She set up recruiting committees, and got a commitment from MIT to make enrollment requirements more flexible, and to admit more Black students. Jackson received her undergraduate degree in 1968.

Although she was accepted by graduate schools of may other prestigious universities, Jackson remained at MIT to complete her doctorate. She studied theoretical solid state physics and investigated the fundamental interaction between basic parts of matter. She received her Ph.D. in 1973.

Next, Dr. Jackson was awarded a post-doctoral fellowship in theoretical physics at the Fermi National Accelerator Laboratory in Batavia, Illinois. In 1974, she was appointed to the post of Visiting Science Associate at the European Organization for Nuclear Research, and remained there until 1975. Later that year, she returned to the Fermi Laboratory to spend a year as a research associate in theoretical physics. Dr. Jackson then moved to California to work at the Stanford Linear Accelerator Center and the Aspen Center for Physics.

In 1978, she was appointed to the technical staff at Bell Telephone Laboratories, where she continues to work in theoretical physics. Dr. Jackson's primary focus is conducting research on the Landau theories of change density waves in one and two dimensions, two dimensional yang-mills gauge theories, and neutrino reactions. In particular, she is involved in trying to explain one of the most troubling questions in physics today – what force holds the components of the hadron proton and neutron together? Answering this question will lead physicists to understand the fundamental interaction between the basic constituents of matter when they interact with high energy, this finding could well prove to be as important as the first splitting of the atom.

As a Black woman, Dr, Jackson has overcome many obstacles in the primarily White male field of theoretical physics. She has earned a large number of awards and has served as a member of many noteworthy organizations. These include the Candace Award, National Coalition of 100 Black Women; MIT Educational award; Board of Trustees, Lincoln University; Nuclear Regulatory Commission – National Academy of Sciences; and Sigma Xi, Also, the New York Academy of Sciences; Scholar, martin Marietta Aircraft Corporation; National Science Foundation Traineeship; and the Outstanding Young Women of America Award, received in both 1976 and 1981.

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Constructing: (*link to SCI.I.1.HS.4*).

Reflecting: (*link to SCI.II.1.HS.4*), (*link to SCI.II.1.HS.7*).

Resources/References:

Webliography.
http://mtn.merit.edu/mcf/SCI.IV.2.HS.3.html/

Nuclear fusion.
http://www.sasked.gov.sk.ca/docs/physics/u8c3phy.html/

Nuclear reactions.
http://theory.uwinnipeg.ca/physics/nucl/node5.html/

Classroom Assessment Example SCI.IV.2.HS.3

Students will write essays contrasting the three processes of nuclear fusion, nuclear fission, and natural radioactivity over time. In their essays, students will describe the contributions of each of the following scientists to our understanding of nuclear fusion, nuclear fission, and natural radioactivity: Lise Meitner, Albert Einstein, Enrico Fermi, Marie Curie, Chien Shiung Wu, and Shirley Ann Jackson.

(Give students rubric before activity.)

Scoring of Classroom Assessment Example SCI.IV.2.HS.3

Criteria	Apprentice	Basic	Meets	Exceeds
Accuracy of contrast	.Fails to contrast any process.	Contrasts clearly one of the three processes.	Contrasts clearly two processes.	Contrasts clearly all three processes.
Accuracy of description	Clearly describes the contributions of one scientist.	Clearly describes the contributions of two scientists.	Clearly describes the contributions of three scientists.	Clearly describes the contributions of four or more scientists.

Strand: IV. Use Scientific Knowledge from the Physical Sciences in Real-World Contexts

Content Standard: 2. All students will investigate, describe, and analyze ways in which matter changes; describe how living things and human technology change matter and transform energy; explain how visible changes in matter are related to atoms and molecules; and how changes in matter are related to changes in energy. (Changes in Matter)

Benchmark
Describe energy transformations involved in physical, chemical, and nuclear changes, and contrast their relative magnitudes (SCI.IV.2.HS.4).

Benchmark Clarification
Physical, chemical, and nuclear changes are accompanied by changes in energy. Energy exists in different forms: potential (energy due to position), kinetic potential (energy of motion), heat, light, electrical, chemical, sound

Energy can change its form at any time during everyday physical and chemical changes, but it can never be created or destroyed.

Only in nuclear changes are energy and matter not conserved. During these changes, some matter is converted into energy or energy into matter according to Einstein's equation, $E = mc^2$ (energy = mass times the square of the speed of light).

Because matter and energy can be converted from one to the other, the total amount of matter and energy in the universe remains constant and unchanged.

Students will
- Compare the amount of energy associated with nuclear, chemical and physical changes
- Recognize that nuclear changes involve the greatest amount of energy

Key Concepts (voc.)
- potential energy
- kinetic energy
- heat
- light
- electrical energy

- chemical energy
- sound
- temperature changes

Original sources of energy:

- sun
- radioactivity

Conservation of energy

Conservation of mass/energy: $E = mc^2$

See Common energy transformation (*link to SCI.IV.2.MS.4*).

See Nuclear changes (*link to SCI.IV.2.HS.3*).

Real-World Contexts

- common physical changes
- chemical changes
- nuclear changes
- changes of state
- burning
- electrical decomposition of water
- photosynthesis
- cellular respiration
- fireworks and dynamite
- nuclear power
- stars

Instructional Example SCI.IV.2.HS.4

Benchmark Question: How does matter change?
Focus Question: How does energy get transformed in a chemical change?

Working in small lab groups, students will observe photosynthesis in green plants by performing the following steps:

1. Place a sprig of a submerged aquatic plant (e.g., *Elodea anacharis*) in a small test tube.
2. Fill the test tube with water and place inverted into a beaker filled with water. The test tube should still be completely filled with water.
3. Repeat steps one and two for a second test tube.
4. Shine a bright light source on one set-up (e.g., lamp, sunlight) and place the other in a dark location. Let both stand for at least half an hour.

Observe the plants in both test tubes. Small bubbles of oxygen (from photosynthesis in the plant) should be filling the top of the test tube under the bright light, while the one in the dark has few or no bubbles. Students will analyze the results of the experiment and discuss the source of energy required to produce the gas. Using references, each student will diagram the energy transformation in photosynthesis. Each student will write an explanation of the energy transformation in photosynthesis, including the fact that light energy is absorbed and used by photosynthesis to produce the bubbles of oxygen.

Constructing: (*link to SCI.I.1.HS.4*), (*link to SCI.I.1.HS.5*).

Reflecting: (*link to SCI.II.1.HS.3*), (*link to SCI.II.1.HS.6*).

Resources/References:

Webliography.
http://mtn.merit.edu/mcf/SCI.IV.2.HS.4.html/

Energy .
http://tqd.advanced.org/3042/energy.html/

Classroom Assessment Example SCI.IV.2.HS.4

Students will create a storyboard illustrating the energy transformation and the chemical reactions of photosynthesis. They will begin with sunlight and end with stored energy in the new chemical bonds of products.

(Give students rubric before activity.)

Scoring of Classroom Assessment Example SCI.IV.2.HS.4

Criteria	Apprentice	Basic	Meets	Exceeds
Completeness of storyboard illustration	Illustrates incompletely and/or out of sequence.	Illustrates general sequence correctly but lacks detail.	Illustrates complete chemical reaction and energy transformation.	Creates and illustrates complete in-depth storyboard.
Accuracy of explanation	Explains inaccurately and with no details.	Explains accurately but with few details.	Explains accurately and completely with some details.	Explains accurately and completely with many details.

Strand: IV. Use Scientific Knowledge from the Physical Sciences in Real-World Contexts

Content Standard: 2. All students will investigate, describe, and analyze ways in which matter changes; describe how living things and human technology change matter and transform energy; explain how visible changes in matter are related to atoms and molecules; and how changes in matter are related to changes in energy. (Changes in Matter)

Benchmark
Explain changes in matter and energy involving heat transfer (SCI.IV.2.HS.5).

Benchmark Clarification
Heat is a measure of the total kinetic energy of the molecules in a sample.

Heat energy flows from a warmer region to a cooler region by three methods:
- Conduction (direct contact)
- Convection (movement of matter in a fluid)
- Radiation (electromagnetic waves)

Conductors are materials that allow heat to flow through easily; insulators are materials that resist the flow of heat.

As heat is transferred to an object, its temperature, volume, and pressure increase, resulting in expansion (thermal expansion).

Within any real-world system, energy is not perfectly transformed from one form to another. As humans attempt to harness energy to accomplish tasks, they can never have a completely efficient transfer without a conversion of energy to an undesired form (most often heat).

Students will:
- Explain three methods for heat energy flowing from a warmer region to a cooler region

Key Concepts (voc.)
Mechanisms of heat transfer:

- convection
- conduction
- radiation

Conservation of energy, efficiency
Changes in matter related to heat transfer
Changes in temperature, volume, pressure
Thermal expansion
See Thermal expansion (*link to SCI.IV.2.MS.1*).
See Convection (*link to SCI.V.3.HS.3*).

Real-World Context

- convection currents
- lake turnover
- wind
- hot frying pans
- heating and cooling buildings
- heat lamps
- sunlight heating the Earth
- greenhouse effect
- fires for warming

Instructional Example SCI.IV.2.HS.5

Benchmark Question: How are changes in matter related to changes in energy?
Focus Question: How do matter and energy change as a result of heat transfer?

Following a teacher-led discussion of the three methods of heat transfer, students will work in small lab groups and will investigate the three methods of heat transfer by designing and constructing a "box" that minimizes the loss of thermal energy by conduction, convection, and radiation.

1. Using materials of their choice, groups of students will construct boxes of given dimensions (30 cm x 30 cm x 30 cm). Each box must hold an aluminum soda can that in turn holds 100 ml of hot water.
2. Groups will write predictions of how their boxes will minimize thermal energy loss due to conduction, convection, and radiation.
3. The teacher will place 100 ml of hot water into each can.
4. Each group will measure and record its temperature.
5. Groups will place their can of hot water into their box.
6. The boxes should be left standing for thirty minutes.
7. Groups will open their boxes and measure and record the new temperature of the water.

8. Each group will evaluate the success of their project by comparing the heat loss in their box to that of others' boxes.
9. Groups will list three ways they would improve their design based on the results of the tests.
10. Groups will explain the loss of heat in their box by applying the three different methods of heat transfer through writing and drawing.

Constructing: (*link to SCI.I.1.HS.5*).

Reflecting: (*link to SCI.II.1.HS.3*).

Resources/References:

Webliography.
http://mtn.merit.edu/mcf/SCI.IV.2.HS.4.html/

Construct-a-Glove. NSTA Press, 2000.
http://www.nsta.org/

Construct-a-Greenhouse. NSTA Press, 2000.
http://www.nsta.org/

Classroom Assessment Example SCI.IV.2.HS.5

Students will explain the three methods of heat transfer and describe an example of each method from daily life.

(Give students rubric before activity.)

Scoring of Classroom Assessment Example SCI.IV.2.HS.5

Criteria	Apprentice	Basic	Meets	Exceeds
Accuracy of explanation	Explains accurately one method of heat transfer.	Explains accurately two methods of heat transfer.	Explains accurately three methods of heat transfer.	Explains accurately three methods of heat transfer and compares them to each other.
Accuracy of description	Describes no example from daily life.	Describes accurately one example from daily life.	Describes accurately two examples from daily life.	Describes accurately three examples from daily life.

Strand: IV. Use Scientific Knowledge from the Physical Sciences in Real-World Contexts

Content Standard: 3. All students will describe how things around us move and explain why things move as they do; demonstrate and explain how we control the motions of objects; and relate motion to energy and energy conversions. (Motion of Objects)

Benchmark
Analyze patterns of force in the operation of complex machines (SCI.IV.3.HS.1).

Benchmark Clarification
A machine is used to change direction and/or amount of force.

The force that comes out of a machine may be larger or smaller than the force that was put into the machine, depending on the distance through which the forces are expected to act.

Students will:

Investigate the forces in machines
Compare variations in the amount and direction of force applied with the motion that results
Determine that machines change the direction, amount, and distance through which a force acts

Key Concepts (voc.)
Electrical and/or mechanical components of complex machines

Real-World Context
Machines such as:

- bicycles
- automobiles
- electrical motors
- pumps

Instructional Example SCI.IV.3.HS.1

Benchmark Question: How can we control the motion of objects?
Focus Question: Where and how are forces applied in a complex machine?

The teacher will set up several numbered stations with one complex machine per station (e.g., egg beater, pencil sharpener, bicycle, stapler). Students will be assigned a number that directs them to a station. Student groups will discuss the force applied and the direction of that force. They then will draw a diagram of their item that illustrates both the force and direction of application as well as the resulting motion. Each group will explain its diagram to the class.

Constructing: (*link to SCI.I.1.HS.2*).

Reflecting: (*link to SCI.II.1.HS.2*), (*link to SCI.II.l.HS.5*).

Resources/References:

Webliography.
http://mtn.merit.edu/mcf/SCI.IV.3.HS.1.html/

Balmer, Al. M*ouse Trap Cars*: The Secrets to Success. Doc Fizzix, 1998.

Beven, Roy. *Move With Science: Energy, Force & Motion*. ***NSTA, 1998.***
http://www/nsta.org/

Gartrell, Jack. *Methods of Motion*. NSTA, 1998.
http://www.nsta.org/

Classroom Assessment Example SCI.IV.3.HS.1

Students will choose a complex machine and analyze the transfer of force from input to output. Students then will construct a model or draw a diagram of the machine. Each student will explain the analysis of the transfer of force in his or her machine during a presentation to the class.

(Give students rubric before activity.)

Scoring of Classroom Assessment Example SCI.IV.3.HS.1

Criteria	Apprentice	Basic	Meets	Exceeds
Completeness of construction	Gives incomplete model/ diagram with no labels.	Gives complete model/ diagram with few labels.	Gives complete model/ diagram with some labels.	Gives complete model/diagram with all labels.
Correctness of analysis	Identifies correctly the input or output force.	Identifies correctly the initial input and the output force.	Identifies correctly all force transfers within the machine.	Identifies correctly all force transfers as well as the simple machines in the complex machine.

Strand: IV. Use Scientific Knowledge from the Physical Sciences in Real-World Contexts

Content Standard: 3. All students will describe how things around us move and explain why things move as they do; demonstrate and explain how we control the motions of objects; and relate motion to energy and energy conversions. (Motion of Objects)

Benchmark
Explain energy conversions in moving objects and machines (SCI.IV.3.HS.2).

Benchmark Clarification
Changes in the speed of an object or its distance from the Earth always involve energy transformation of some type (e.g., heat, gravitational potential energy, chemical potential energy, electrical, spring potential energy, and radiation) to kinetic energy/ energy of motion.

Machines are energy-conversion devices. No machine is one hundred percent efficient; some energy is transformed into heat as a result of friction. Efficiency here is defined as a ratio of work output over work input and expressed as a percentage.

Students will:
- Identify an example of energy conversion taking place
- Analyze the types of energy conversions taking place in a machine

Key Concepts (voc.)
Types of energy:
- electrical energy
- kinetic energy
- gravitational potential energy
- potential energy in spring
- chemical potential energy
- heat energy
- radiation
- efficiency

See Energy transformations (*link to SCI.IV.2.MS.4*).
See Conservation of energy (*link to SCI.IV.2.HS.4*).
See Energy in physical and chemical changes (*link to SCI.IV.2.HS.4*).

Real-World Context
Simple and complex machines:

- roller coasters
- swings
- pendulums
- elevators
- automobiles
- fans
- motors

Instructional Example SCI.IV.3.HS.2

Benchmark Question: How is motion related to energy and energy conversions?
Focus Question: How do machines convert energy?
The teacher will demonstrate items such as a wind-up toy, glow stick, or a battery-operated fan. Using a cooperative learning technique such as Think-Pair-Share, groups will identify in writing the forms of energy and the energy transfers used in the items the teacher demonstrated. Students then will pair up, come to a consensus, and share/discuss their ideas with the class.

Constructing: (*link to SCI.I.1.HS.2*), (*link to SCI.I.l.HS.4*), (*link to SCI.I.l.HS.5*).

Reflecting: (*link to SCI.II.1.HS.1*).

Resources/References:

Webliography.
http://mtn.merit.edu/mcf/SCI.IV.3.HS.2.html/

Energy transformations on a roller coaster.
http://www.glenbrook.k12.il.us/gbssci/phys/mmedia/energy/ce.html/

Roller coaster activity.
http://www.col-ed.org/cur/sci/sci193.txt/

Classroom Assessment Example SCI.IV.3.HS.2

Students will select a complex machine and create a flow chart or other graphic organizer to depict the forms of energy and energy transformations in its operation.

(Give students rubric before activity.)

Scoring of Classroom Assessment Example SCI.IV.3.HS.2

Criteria	Apprentice	Basic	Meets	Exceeds
orrectness of dentification- forms f energy	Identifies correctly one form of energy present.	Identifies correctly two forms of energy present.	Identifies correctly three forms of energy present.	Identifies correctly four or more forms energy present.
orrectness of lentification -energy ansformations	Identifies correctly one energy transformation.	Identifies correctly two energy transformations.	Identifies correctly three energy transformations.	Identifies correctly four or more energy transformations.

Strand: IV. Use Scientific Knowledge from the Physical Sciences in Real-World Contexts

Content Standard: 4. All students will describe sounds and sound waves; explain shadows, color, and other light phenomena; measure and describe vibrations and waves; and explain how waves and vibrations transfer energy. (Waves and Vibrations)

Benchmark
Relate characteristics of sounds that we hear to properties of sound waves (SCI.IV.4.HS.1).

Benchmark Clarification
We detect frequency (*link to Glossary*) as pitch, hearing high-frequency waves as high-pitched sounds. We detect amplitude (*link to Glossary*) as loudness (volume), hearing larger-amplitude waves as louder sounds.

The velocity of sound waves depends on the medium (material) through which the waves travel. Sound results from the motion of particles (i.e., sound waves are mechanical waves *(link to Glossary*) as sound energy traveling through a medium).

Students will:
- Describe sound waves in terms of frequency and amplitude
- Compare sound waves in terms of frequency and amplitude

Frequency: how many waves pass a particular point in a certain amount of time (usually seconds)
Amplitude: a measure of how far the particles of a medium get moved; also a measure of the amount of energy in a wave

Key Concepts (voc.)
Properties of sounds:
- pitch
- volume

Characteristics of sound waves:
- frequency
- amplitude
- velocity

Real-World Context
Common sounds that vary in pitch and volume
See (*link to SCI.IV.4.E.1*).

Instructional Example SCI.IV.4.HS.1

Benchmark Question: How can we describe sound?
Focus Question: How are the properties of sound waves related to the characteristics of sound?

Students will listen to a musician(s) produce sounds on various instruments.

The teacher will use a ruler to demonstrate variations in frequency (pitch). Placing a ruler flat on a desk so a portion of the ruler extends past the edge of the desktop, the teacher will use a finger to depress and release the end of the ruler while students listen for the effect. The teacher then will increase and/or decrease the amount by which the ruler extends past the edge of the desktop and repeat the demonstration.

After a teacher-led class discussion, students will explain the characteristics of sound waves: frequency, amplitude, velocity, pitch, and volume. Students then will construct a musical instrument in small groups or individually. Each instrument will be demonstrated and students will discuss/share characteristics of sound waves.

Constructing: (*link to SCI.I.1.HS.2*).

Reflecting: (*link to SCI.II.1.HS.3*).

Resources/References:

Webliography.
http://mtn.merit.edu/mcf/SCI.IV.4.HS.1.html/

Car horns.
http://www.eecs.umich.edu/mathscience/funexperiments/agesubject/lessons/beakman/doppler.html/

Interactive Sound Lab.
http://library.advanced.org/19537/java/Beats.html/

Physical Science Activity Manual-Sound.
http://192.239.146.18/resources/Science/PSAM.html/

Classroom Assessment Example SCI.IV.4.HS.1

Students will perform a variety of pitches and volumes to an audience with a constructed instrument. Students will present an explanation of how these sounds are produced in terms of the characteristics of sound (frequency, amplitude, and velocity).

(Give students rubric before activity.)

Scoring of Classroom Assessment Example SCI.IV.4.HS.1

Criteria	Apprentice	Basic	Meets	Exceeds
Effectiveness of construction	Constructs a musical instrument that produces one pitch with high and low volume.	Constructs a musical instrument that produces two pitches with high and low volume.	Constructs a musical instrument that produces at least three different pitches with high and low volume.	Constructs a musical instrument that produces at least three pitches with various sounds and plays a recognizable tune.
Accuracy of explanation	Describes a characteristic of sound with one property.	Describes two characteristics of sound with one property.	Describes clearly each characteristic of sound in terms of pitch and volume.	Explains a sheet of music in terms of the characteristics and properties of sound.

Strand: Use Scientific Knowledge from the Physical Sciences in Real-World Contexts

Content Standard: 4. All students will describe sounds and sound waves; explain shadows, color, and other light phenomena; measure and describe vibrations and waves; and explain how waves and vibrations transfer energy. (Waves and Vibrations)

Benchmark
Explain how we see colors of objects. (SCI.IV.4.HS.2).

Benchmark Clarification
The colors of objects depend on how light waves are reflected (bounce off), absorbed (taken in), transmitted (pass through), scattered (reflected in numerous directions), and/or emitted (produced).

Amplitude is defined as the measure of energy within a wave. With light it is a measure of brightness.

Students will:

- Explain that colors differ as a result of wavelengths of light
- Describe that brightness depends on amplitude

Key Concepts (voc.)
Characteristics of light:

- brightness
- amplitude
- wavelength
- frequency See (*link to SCI.IV.4.HS.3*).

Colors of spectrum (red, orange, yellow, green, blue, indigo, violet)

Ways that objects interact with light:

- emission
- reflection
- absorption
- transmission
- scattering See (*link to SCI.V.4.MS.4*).

Real-World Context
Colored light-reflecting objects:

- books
- clothes
- color photographs

Colored light-transmitting objects:

- stained glass
- cellophane

Colored light-emitting objects:

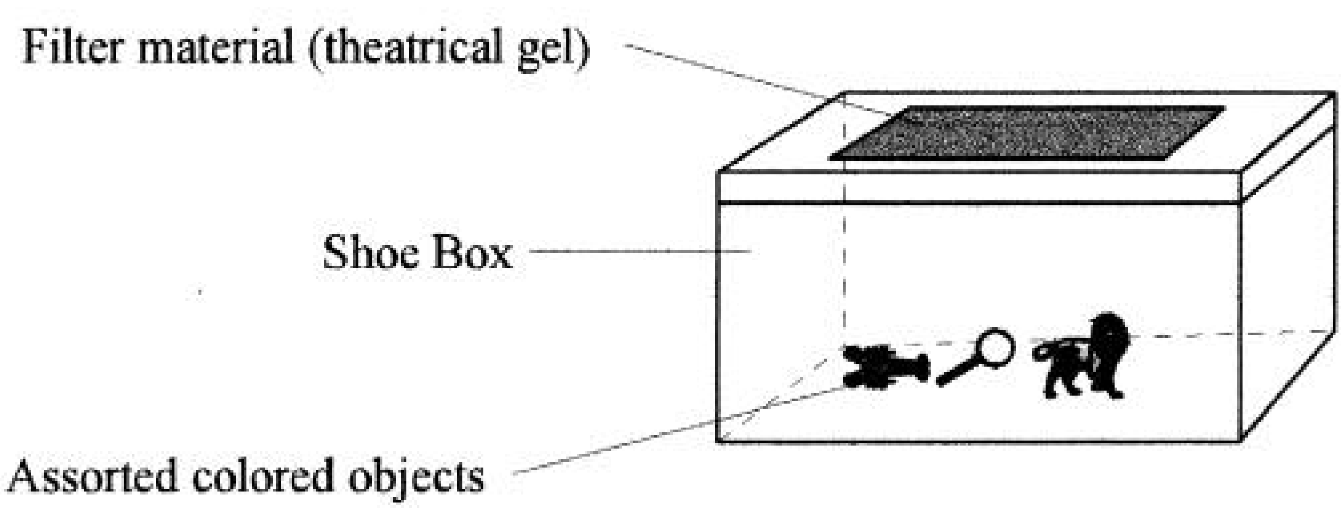
- television
- neon lights

Scattering of light by atmosphere

Instructional Example SCI.IV.4.HS.2

Benchmark Question: How can we describe light?
Focus Question: How do we see colors of objects?

After a discussion of what produces colors of objects, students will perform a small group lab investigation. In groups, students will place various colored objects in a box and predict what color the objects will be when a color filter is placed in a hole on top of the box. Students then will put the color filter over the box, observe what they see, and record the color of the objects. After classroom discussion, each group will write an explanation of how they see colors of objects using the following terms: absorption, reflection, transmission, and scattering. Students also will explain the relationship between wavelength and color.



Constructing: (*link to SCI.I.1.HS.1*), (*link to SCI.I.l.HS.2*), (*link to SCI.I.l.HS.5*).

Reflecting: (*link to SCI.II.1.HS.1*).

Resources/References:

Webliography.
http://mtn.merit.edu/mcf/SCI.IV.4.HS.2.html/

Box (*link*).

CEA light tour.
http://www.cea.berkeley.edu/Education/light/light_tour.html/

Electromagnetic Spectrum.
http://imagers.gsfc.nasa.gov/ems/visible.html/

Visible Electromagnetic Spectrum.
http://fusioned.gat.com/Teachers/Curriculum/Curriculum-HTML/T01-visible-light.html/

Visible Light Rays.
http://imagers.gsfc.nasa.gov/ems/visible.html/

Classroom Assessment Example SCI.IV.4.HS.2

Each student will write an explanation of how we see the colors of objects.
The explanation will include the key terms absorption, reflection, transmission and scattering.
The explanation will include the relationship between wavelength and color.

(Give students rubric before activity.)

Scoring of Classroom Assessment Example SCI.IV.4.HS.2

Criteria	Apprentice	Basic	Meets	Exceeds
Correctness of explanation - color of an object	Uses correctly one key term to explain how the color of an object is seen.	Uses correctly two key terms to explain how the color of an object is seen.	Uses correctly three key terms to explain how the color of an object is seen.	Uses correctly four key terms to explain how the color of an object is seen.
Correctness of explanation - relationship between wavelength and color	Explains that white light is made up of many wavelengths.	Explains that colors can be identified by wavelengths.	Explains that each color has a unique wavelength.	Explains the position of colors within the spectrum (red, orange, yellow, green, blue, indigo, violet) in terms of their wavelengths.

Strand: Use Scientific Knowledge from the Physical Sciences in Real-World Contexts

Content Standard: 4. All students will describe sounds and sound waves; explain shadows, color, and other light phenomena; measure and describe vibrations and waves; and explain how waves and vibrations transfer energy. (Waves and Vibrations)

Benchmark
Describe waves in terms of their properties (SCI.IV.4.HS.3).

Benchmark Clarification
Mechanical waves (sound, ultrasound, water wave, shock wave) require a medium to travel through.
Electromagnetic waves are a form of energy that moves at the speed of light and does not require a medium to travel. Various types of electromagnetic waves (e.g., radio, microwave, and light) differ by their wavelength and frequency.

Waves have special properties:

- Frequency (*link to Glossary*)
- Wavelength (*link to Glossary*)
- Amplitude (*link to Glossary*)
- Wave velocity (*link to Glossary*)

Students will:

- Explain that waves transfer energy from one place to another
- Describe the properties of waves
- Recognize the units used to measure wave properties (See Key Concepts)

Frequency: the number of waves to pass a particular point in a certain amount of time

Wavelength: the distance measure of one complete cycle of a wave

Amplitude: the distance from the rest position to the crest or trough; indicates the relative amount of energy

Wave velocity: the rate at which the wave travels

Key Concepts (voc.)
Mechanical waves, electromagnetic waves
See (*link to SCI.IV.4.HS.4*).
Colors of light

Properties of waves:
- frequency
- amplitude
- wavelength
- wave velocity
- energy

Units of measurement:
- hertz or cycles per second
- micrometers
- meters
- meters per second

Tools for making spectra:
- prism
- diffraction grating

Real-World Context
Examples of mechanical and electromagnetic waves

Colors of light, frequencies of radio and TV transmission

Instructional Example SCI.IV.4.HS.3

Benchmark Question: How can we describe and measure vibrations and waves?
Focus Question: What are the properties of waves?

After a brief discussion about waves, students working in small groups will produce waves using a coiled phone cord or Slinky. Students will place the phone cord on the floor and anchor one end of the phone cord and then oscillate the other end back and forth across the floor. Students will observe the repeating patterns of the waves.

Students then will experiment to increase the height and the number of waves in the cord. Students will write down their observations and explanations and share them with the class. At the conclusion of the activity, the teacher will lead a discussion about frequency, amplitude, wavelength, and energy and relate them to the observations of the phone cord. In their journals, students will reflect on how these properties are related.

Constructing: (*link to SCI.I.1.HS.1*), (*link to SCI.I.l.HS.2*).

Reflecting: (*link to SCI.II.1.HS.3*).

Resources/References:

Webliography.
http://mtn.merit.edu/mcf/SCI.IV.4.HS.3.html/

Cea Light Tour.
http://www.cea.berkeley.edu/Education/light/light_tour.html/

Interactive Sound Lab.
http://library.advanced.org/19537/java/Beats.html/

Teacher's Guide.
http://imagers.gsfc.nasa.gov/teachersite/index.html/

Classroom Assessment Example SCI.IV.4.HS.3

Each student will describe the properties of waves by writing an essay or by creating a labeled diagram. Properties may include frequency, amplitude, wavelength, energy.

(Give students rubric before activity.)

Scoring of Classroom Assessment Example SCI.IV.4.HS.3

Criteria	Apprentice	Basic	Meets	Exceeds
Correctness of identification	Identifies correctly one to two properties of waves.	Identifies correctly three properties of waves.	Identifies correctly four properties of waves.	Identifies correctly five or more properties of waves by adding wave velocity or any other property.
Accuracy of description	Describes accurately one to two properties of waves.	Describes accurately three properties of waves.	Describes accurately four properties of waves.	Describes accurately five or more properties of waves.

Strand: IV. Use Scientific Knowledge from the Physical Sciences in Real-World Contexts

Content Standard: 4. All students will describe sounds and sound waves; explain shadows, color, and other light phenomena; measure and describe vibrations and waves; and explain how waves and vibrations transfer energy. (Waves and Vibrations)

Benchmark
Describe different types of waves and their technological applications (IV.4.HS.4).

Benchmark Clarification
There are many different types of waves. Mechanical waves (sound, ultrasound, water waves, shock waves) require a medium in order to travel.

Electromagnetic waves (radio waves, microwaves, radiant heat, infrared radiation, visible light, ultraviolet radiation, and x-rays) do not require a medium in order to travel.

Students will:
- Describe mechanical waves
- Describe electromagnetic waves
- Recognize that the amount of energy transferred determines the use of a wave
- Identify examples and applications of mechanical and electromagnetic waves (See Real-World Context)

Key Concepts (voc.)
- Types of waves:
  - mechanical:
  - sound
  - ultrasound
  - water wave
  - shock wave

- electromagnetic:
  - radio waves
  - microwaves
  - radiant heat
  - infrared radiation
  - visible light
  - ultraviolet radiation
  - x-rays

See Properties of waves (*link to SCI.IV.4.HS.3*).
See Energy transformations (*link to SCI.IV.2.MS.4*).

Real-World Context

Examples of mechanical waves:

- sound
- ultrasound
- ocean waves
- wave tanks
- earthquakes
- seismic waves

Examples of electromagnetic waves:

- light
- radio and television signals
- heat lamps
- microwaves
- transmitters
- radar
- ultraviolet radiation in sunlight
- x-ray machines
- CAT scans
- gamma rays from radioactive decay

Instructional Example SCI.IV.4.HS.4

Benchmark Question: How do we describe and measure vibrations and waves?
Focus Question: What are some technological applications of electromagnetic waves?

After a teacher-led class discussion of the electromagnetic spectrum of waves, small groups of students will conduct research using various media (internet, periodicals, etc.) to create a report about the applications of the following electromagnetic waves: radio waves, microwaves, radiant heat, infrared, visible light, ultraviolet light, radiation, and x-rays. In this report, students will describe the historical development of the technology. The class will discuss the students' findings.

Constructing: (*link to SCI.I.1.HS.4*), (*link to SCI.I.l.HS.5*).

Reflecting: (*link to SCI.II.1.HS.3*), (*link to SCI.II.1.HS.4*), (*link to SCI.II.1.HS.7*).

Resources/References:`

Webliography.
http://mtn.merit.edu/mcf/SCI.IV.4.HS.4.html/

Making waves.
http://www.smgaels.org/physics/home.htm/

Teacher's Guide.
http://imagers.gsfc.nasa.gov/teachersite/index.html)/

Classroom Assessment Example SCI.IV.4.HS.4

Each student will write an essay that explains the technological uses of each of the following electromagnetic waves: radio waves, microwaves, radiant heat, infrared radiation, visible light, ultraviolet, radiation, x-rays.

(Give students rubric before activity.)

Scoring of Classroom Assessment Example SCI.IV.4.HS.4

Criteria	Apprentice	Basic	Meets	Exceeds
Completeness of explanation	Explains one to three uses of electromagnetic waves.	Explains three to four uses of electromagnetic waves.	Explains five to six uses of electromagnetic waves.	Explains seven to eight uses of electromagnetic waves.