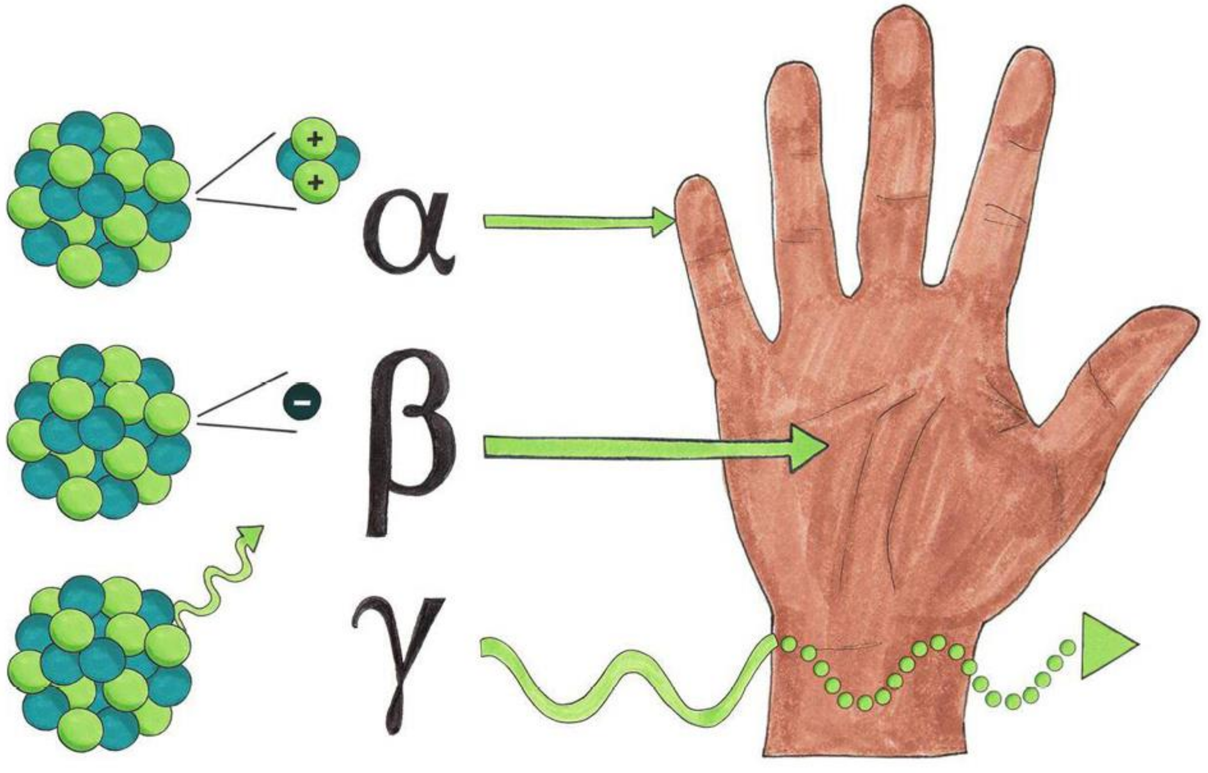
U.S. EPA Radiation Education Activities:

Radiation Exposure



United States Environmental Protection Agency

U.S. EPA Radiation Education Activities: **Radiation Exposure**

Radiation is energy that travels in the form of waves and makes up the electromagnetic spectrum. The electromagnetic spectrum is divided into two major categories: ionizing radiation and non-ionizing radiation.

Target Audience and Activity Topics

The Radiation Exposure activities are designed to help students understand the properties of ionizing and non-ionizing radiation. With this understanding, students will be able to identify sources of non-ionizing and ionizing radiation in our world. Students will also examine how they may be exposed to ionizing radiation, evaluate the benefits and risks associated with radiation exposure, and identify situations in which they may choose to control or limit their exposure to ionizing radiation. Students will learn about the penetrating powers of different types of radiation and with this knowledge they can correct the myths associated with radiation exposure.

NOTE: The term "radiation" used in the activities generally refers to ionizing radiation unless otherwise indicated.

Activity Times

All U.S. Environmental Protection Agency (EPA) Radiation Education Activities can be used individually or modified and combined to create multiple lessons. Activity options allow you to customize the activities to fit the time you have available (e.g., 1–2 class periods) and meet the needs and interests of your students.

The time needed to complete activities is between 45-60 minutes, not including optional activities or extensions.

Next Generation Science Standards

The concepts within these activity sets can be used to support the following science standards:

- PS4. Waves and Electromagnetic Radiation
- LS2. Matter and Energy in Organisms and Ecosystems

Common Core State Standards (CCSS)

The concepts in the Vocabulary Activities align with the following CCSS English Language Arts Standards for Literacy in History/Social Studies, Science, & Technical Subjects:

- Key Ideas and Details: CCSS.ELA-LITERACY.RST.6-12.2
- Craft and Structure: CCSS.ELA-LITERACY.RST.6-12.4
- Vocabulary Acquisition and Use: CCSS.ELA-LITERACY.L.6-12.6

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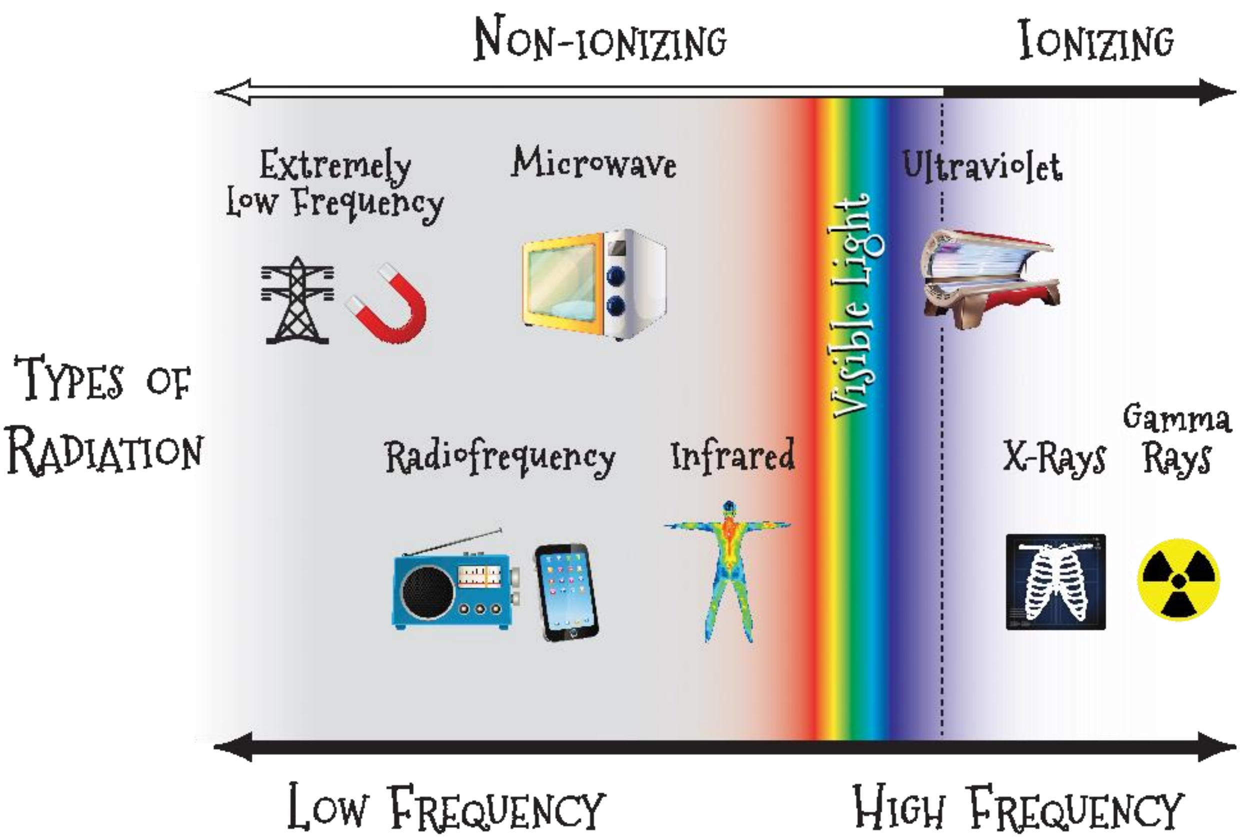
Radiation Exposure: Teacher Background Information

Radiation is part of our daily lives. It is all around us and has been present since the birth of this planet. Two main types of radiation — non-ionizing and ionizing — form the electromagnetic spectrum. We are routinely exposed to naturally occurring (background) radiation that comes from outer space, the sun, the ground, and even from within our own bodies, as well as man-made sources of ionizing and non-ionizing radiation.



Non-Ionizing Radiation

Non-ionizing radiation includes both low frequency radiation and moderately high frequency radiation, including radio waves, microwaves and infrared radiation, visible light, and lower frequency ultraviolet radiation. Non-ionizing radiation has enough energy to move around the atoms in a molecule or cause them to vibrate, but not enough to remove electrons.

Non-ionizing radiation is used in many common tasks. We use:

- Microwave radiation for telecommunications and heating food.
- Infrared radiation for infrared lamps to keep food warm in restaurants.
- Radio waves for radio broadcasting.

High frequency sources of non-ionizing and ionizing radiation (such as the sun and ultraviolet radiation) can cause burns and tissue damage with overexposure.

Ionizing Radiation

Ionizing radiation includes higher frequency ultraviolet radiation, x-rays and gamma rays. Ionizing radiation has enough energy to break chemical bonds in molecules or remove tightly bound electrons from atoms, creating charged molecules or atoms (ions).

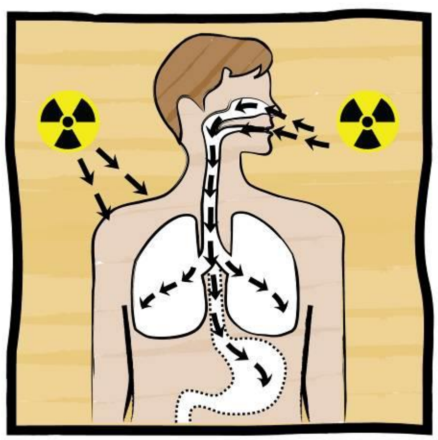
Ionizing radiation can pose a health risk by damaging tissue and DNA in genes. The amount of damage depends on the type of radiation, the exposure pathway, the radiation's energy, and the total amount of radiation absorbed. Because damage is at the cellular level, the effect from small or even moderate exposure may not be noticeable. Most cellular damage is repaired. However, some cells may not recover as well as others and could become damaged or cancerous. Radiation also can kill cells.

Sources of Radiation Exposure

The word "radiation" generally brings to mind man-made sources of ionizing radiation such as nuclear power plants, nuclear weapons or medical procedures, tests and treatments. However, we are routinely exposed to:

- Natural (background) radiation including naturally occurring ionizing and non-ionizing radiation sources from outer space, the sun, the ground, and even from within our own bodies.
- Man-made ionizing and non-ionizing sources such as smoke detectors, microwaves, cell phones and electrical power lines.

Exposure Pathways and Contamination



The three basic radiation exposure pathways are:

- Direct or external exposure (radioactive substances coming into contact with the skin).
- Inhalation (breathing radioactive gases, smoke, dust or particles into the lungs).
- Ingestion (eating or drinking substances that contain radioactive elements).

Contamination occurs when a person makes direct contact with, ingests or inhales radioactive materials. Contamination may occur when radioactive materials are released into the environment as the result of an accident, an event in nature or an act of terrorism. After direct contact, people and personal property must be decontaminated.

Penetrating Power of Ionizing Radiation

When radioactive atoms decay, they give off energy in the form of ionizing radiation. The major types of ionizing radiation emitted during radioactive decay are alpha particles, beta particles and gamma rays. Other types, such as x-rays, can occur naturally or be machine-produced.

Alpha particles lack the energy to penetrate even the outer layer of skin, so exposure to the outside of the body is not a major concern. Inside the body, however, they can be very harmful. If alpha-emitters are inhaled, swallowed, or get into the body through a cut, the alpha particles can damage sensitive living tissue. The way these large, heavy particles cause damage makes them more dangerous than other types of radiation. The ionizations they cause are very close together — they can release all their energy in a few cells. This results in more severe damage to cells and DNA.

Beta particles are more penetrating than alpha particles but are less damaging to living tissue and DNA because the ionizations they produce are more widely spaced. They travel farther in air than alpha particles, but can be stopped by a layer of clothing or by a thin layer of a substance such as aluminum. Some beta particles are capable of penetrating the skin and causing damage such as skin burns. However, as with alpha-emitters, beta-emitters are most hazardous when they are inhaled or swallowed.

Gamma rays are a radiation hazard for the entire body. They can easily penetrate barriers, such as skin and clothing that can stop alpha and beta particles. Gamma rays have so much penetrating power that several inches of a dense material like lead or even a few feet of concrete may be required to stop them. Gamma rays can pass completely through the human body easily. As they pass through, they can cause ionizations that damage tissue and DNA.

Health Effects of Radiation Exposure

Low frequency sources of non-ionizing radiation are not known to present health risks. High frequency sources of non-ionizing radiation (such as the sun and ultraviolet radiation) can cause burns and tissue damage with overexposure.

Ionizing radiation can damage living tissue by changing cell structure and damaging DNA. The amount of damage depends on the type of radiation, the exposure pathway, the radiation's energy and the total amount of radiation absorbed.

Children are more sensitive to ionizing radiation than adults because children are still in the process of growing. There are more cells dividing and a greater opportunity for radiation to disrupt the growth process. Recent U.S. Environmental Protection Agency (EPA) radiation protection standards take into account the differences in sensitivity due to age and gender.

How Do We Know Ionizing Radiation Causes Cancer?

The greatest risk from exposure to ionizing radiation is cancer. Much of our knowledge about the risks is based on studies of more than 100,000 survivors of the atomic bombs in Hiroshima and Nagasaki, Japan, at the end of World War II. Studies of radiation industry workers and people receiving large doses of medical radiation are also important sources. Scientists learned many things from these studies, including:

- The higher the radiation dose, the greater the chance of developing cancer.
- The chance of developing cancer (not the seriousness or severity of the cancer) increases as the radiation dose increases.
- Cancers caused by radiation do not appear until years after the radiation exposure.
- Some people are more likely to develop cancer from radiation exposure than others.

Additional Resources:

- RadTown USA: www3.epa.gov/radtown
- Radiation Basics: http://www2.epa.gov/radiation/radiation-basics
- Radiation: Facts, Risks and Realities: http://www2.epa.gov/sites/production/files/2015-05/documents/402-k-10-008.pdf

Radiation Exposure Vocabulary Activities

The concepts surrounding radiation can be complex. By conducting a vocabulary activity before beginning an activity or series of activities, students will have a shared base knowledge.

Materials and Resources

- *Vocabulary Materials* document.
- Materials noted in activity suggestions.

Common Core State Standards (CCSS)

The concepts in this activity align with the following CCSS English Language Arts Standards for Literacy in History/Social Studies, Science, & Technical Subjects:

- Key Ideas and Details: CCSS.ELA-LITERACY.RST.6-12.2
- Craft and Structure: CCSS.ELA-LITERACY.RST.6-12.4
- Vocabulary Acquisition and Use: CCSS.ELA-LITERACY.L.6-12.6

Vocabulary by Activity

Activity 1: Types of Radiation	• Atom • Electromagnetic spectrum • DNA • Gamma rays	• Ionizing radiation • Non-ionizing radiation • Radiation • X-rays
Activity 2: Sources of Annual Radiation Exposure	• Cosmic radiation • Dose (optional) • Ionizing radiation • Man-made radiation • Natural (background) radiation	• Radiation • Radon • Rem (optional) • Terrestrial radiation
Activity 3: Penetrating Powers of Ionizing Radiation	• Alpha particles • Beta particles • Direct exposure • Exposure pathways • Gamma rays • Ingestion • Inhalation	• Ionizing radiation • Radiation • Radiation exposure • Radiation protection • Radioactive contamination • X-rays
Activity 4: Exposure Pathways	• Alpha particles • Beta particles • Direct exposure • Gamma rays • Ingestion • Inhalation • Ionizing radiation	• Man-made radiation • Natural (background) radiation • Radiation • Radiation exposure • Radiation protection • X-rays •

Activity 5: Radiation Health Effects	• Alpha particles • Beta particles • Direct exposure • Gamma rays • Ingestion • Inhalation	• Ionizing radiation • Man-made radiation • Natural (background) radiation • Radiation • Radiation exposure • X-rays
Activity 6: Acute versus Chronic Exposure	• Alpha particles • Beta particles • Direct exposure • Gamma rays • Ingestion • Inhalation	• Ionizing radiation • Man-made radiation • Natural (background) radiation • Radiation • Radiation exposure • X-rays
Activity 6: Acute versus Chronic Exposure	• Alpha particles • Beta particles • Direct exposure • Gamma rays • Ingestion • Inhalation	• Ionizing radiation • Man-made radiation • Natural (background) radiation • Radiation • Radiation exposure • X-rays
Activity 7: Radiation: Fact or Fiction?	• Ionizing radiation • Radiation • Radiation exposure	• Radioactive atom • Radioactive material • Radiation exposure

Activity Suggestions

- **Identifying images.**
  - Print the applicable images from the *Vocabulary Materials* document.
  - Display the images around the room or spread them out in an open area on the floor.
  - Pronounce the vocabulary words one at a time. NOTE: You can provide the definition of the given word at this time or after students have identified the words.
  - Have students take turns identifying the words in an active manner. Suggestions include having students move to and identify the correct image, use a flashlight to point to the correct image (review safety rule: never shine the light in another person's eyes), drive a remote control car to the correct image, or throw a bean bag to land on the correct image.
- **Matching words and images.**
  - Print the applicable words and images from the *Vocabulary Materials* document.
  - Give each student a vocabulary word or image. Options: Fold or ball up the copies and let each student select one. Have students trade their copy with another student once or twice. NOTE: You may need an even number of participants.
  - Direct students to find the person with the matching word or image.
  - Review the matches to confirm they are correct.
  - Pronounce each word and provide a definition.
- **Spelling the words.**
  - Print the applicable words and images from the *Vocabulary Materials* document.
  - Display the words and images.
  - Pronounce each word and provide a definition.
  - Conduct a spelling activity:
    - Have students create a word scramble or word find activity, trade papers and complete the activity.
    - Play spelling basketball. Divide the class into two teams. Pronounce a vocabulary word. Have a student (alternating between teams) spell or write the word on the board. Students that spell the word correctly are given an opportunity to shoot a basket (use a trash can) with a ball of paper (ball) from a designated distance (or varying distances for a different number of points). The team that scores the most points wins. You can have students provide a definition for extra points.
- **Creating definitions.**
  - Print the applicable words and images from the *Vocabulary Materials* document.
  - Display the vocabulary words and images.
  - Pronounce the vocabulary words.
  - Have students work in pairs or small groups to hypothesize and create a definition for each vocabulary word.
  - Options: Direct one student from each pair/group to rotate and join another pair/group or have two pairs/groups join together. Direct the newly formed groups to compare their definitions and modify them if desired.
  - Review each pair/group's definitions, have students discuss what they agree/disagree with and share the accurate definition.

Activity 1: Types of Radiation

Objectives

Students will:

- Differentiate between non-ionizing and ionizing radiation.
- Explore real-world sources of each.
- Gain an increased awareness of their everyday exposure to radiation.

Next Generation Science Standards

The concepts in this activity can be used to support the following science standard:

- PS4. Waves and Electromagnetic Radiation.

Materials and Resources

- *Radiation Exposure: Teacher Background Information*.
- *Vocabulary Materials.*
- *Radiation Types and Sources Workshee*t (one per student, pair or group or group).
- *Electromagnetic Spectrum* image (included in the *Radiation Exposure: Teacher Background Information* or the *Vocabulary Materials*)*;* display with computer and projector.
- *Radiation Worksheet* (one per student, pair or group or group) and *Radiation Worksheet Teacher Answer Key*.
- Marbles — approximately eight to ten marbles per group. Use unique sizes or colors with one marble representing the nucleus, five marbles representing electrons and the remaining two to four marbles representing radiation (e.g., one white, five blue and two to four red marbles).
- *Radiation Sources in Our Community Worksheet* (one per student, pair or group) and *Radiation Sources in Our Community Teacher Answer Key* (optional activity or extension).
- Student computers with Internet access (optional).

Time

45-60 minutes, not including optional activities or extensions.

Vocabulary

- Atom
- Electromagnetic spectrum
- DNA
- Gamma rays
- Ionizing radiation
- Non-ionizing radiation
- Radiation
- X-rays

Directions

1. Start with a vocabulary activity if students are not familiar with radiation and the terms used in this activity, or provide students with the terms and definitions.

2. Ask students to hypothesize whether all sources of radiation are the same or different. For example, have students explain whether there is a difference between the radiation from a cellphone, the radiation from the sun, and the radiation used in x-ray machines.

3. Distribute the *Radiation Types and Sources Worksheet*. Explain that radiation is energy that travels in the form of waves or high speed particles (photons) and makes up the electromagnetic spectrum in the form of non-ionizing and ionizing radiation. The energy of the radiation shown on the spectrum increases from left to right as the frequency rises.

4. Direct students to cut out the radiation source images and place them under the matching type of radiation on the electromagnetic spectrum. Alternatives:
   - Have students label each source image with the matching type of radiation.
   - Have eight students write a type of radiation on a sheet of paper (extremely low frequency radiation to gamma rays) and line up in the order of the electromagnetic spectrum. Provide nine other students with a radiation source image (use those provided or larger images of these items) and have them line up accordingly with the students representing the electromagnetic spectrum.

5. Display the *Electromagnetic Spectrum* image (included in the *Radiation Exposure: Teacher Background Information* or the *Vocabulary Materials*) so students can use it to check their work.

6. Distribute the *Radiation Worksheet* and direct students to complete the demonstrations and record their observations. Students should complete the critical thinking questions following the demonstrations. A *Radiation Worksheet Teacher Answer Key* has been provided.
   - Demonstration A shows that non-ionizing radiation can cause atoms to vibrate and move. A potential effect is heat generated from the vibration or movement. You can prompt students to think about how we use microwaves to heat our food or how cell phones get warm with use.
   - Demonstration B shows that ionizing radiation can change the structure of an atom by breaking chemical bonds in molecules or removing tightly bound electrons from atoms and creating charged molecules or atoms (ions). A potential effect is cell or DNA damage when this occurs.

7. Have students share their responses.

8. Conclude by explaining that people often view ionizing radiation as harmful. However, it is all around us and has been present since the birth of our planet. As a result, our bodies are adapted to some degree of radiation exposure and have developed mechanisms for repairing cell damage from radiation exposure. Health risks and the amount of cell damage depends on the type of radiation, the exposure pathway, the radiation's energy and the total amount of radiation absorbed.

9. Optional activities or extensions: Direct students to identify sources of radiation in their community and determine whether they are sources of non-ionizing and/or ionizing radiation.

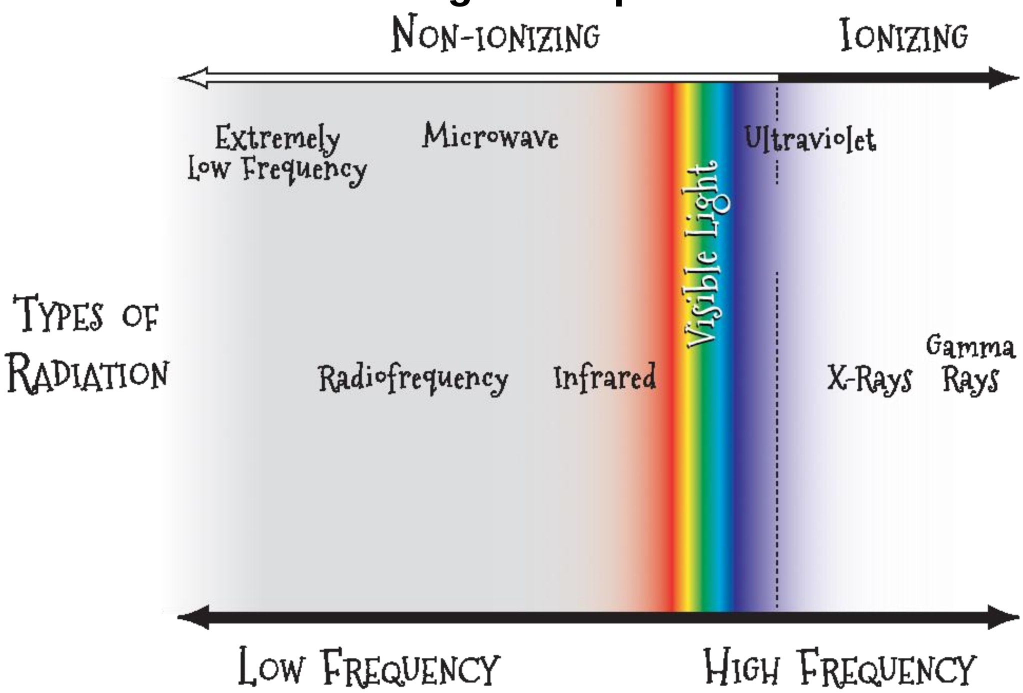
- Provide students with the *Radiation Sources in Our Community Worksheet*. Direct them to identify the location of the radiation sources and indicate whether they are a source of non-ionizing radiation, ionizing radiation or both. Students can refer to the RadTown USA website (www3.epa.gov/radtown). A *Radiation Sources in Our Community Teacher Answer Key* is provided.
- Direct students to tour their school, home and/or community and identify sources of radiation. Have them generate the list of identified sources by energy range (e.g., radio, microwave, ultraviolet or x-ray) in the electromagnetic spectrum and type (e.g., non-ionizing radiation, ionizing radiation or both).
- Have students research and debate the effects of non-ionizing radiation (e.g., use of microwaves and cellphones).

Radiation Types and Sources Worksheet

Name: ______________________________ Date: ________________

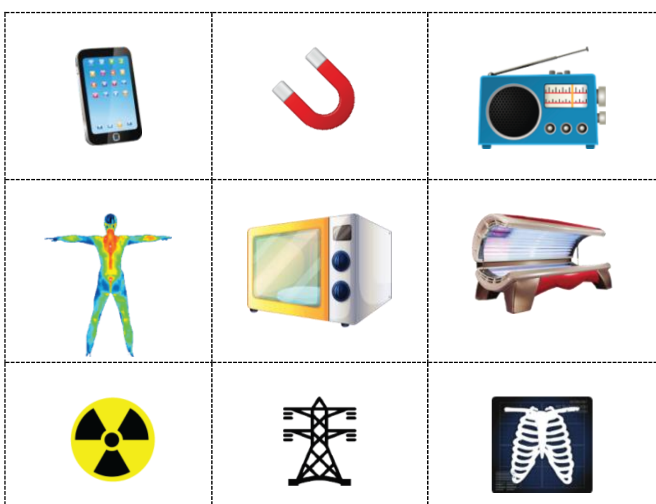
Radiation is energy that travels in the form of waves or high speed particles (photons) and makes up the electromagnetic spectrum. Radiation within the electromagnetic spectrum is divided into two major categories: ionizing radiation and non-ionizing radiation.

Electromagnetic Spectrum



Sources of Radiation

Cut out the sources of radiation images. Place them on the electromagnetic spectrum under the appropriate type of non-ionizing or ionizing radiation. Some types of radiation may have more than one source image.

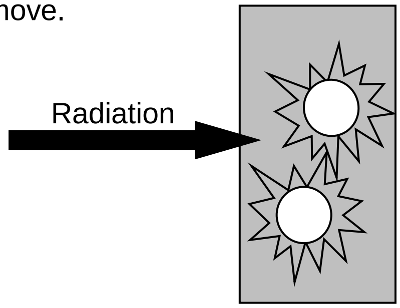


Radiation Worksheet

Name: ______________________________________ Date: _____________________

The images and demonstrations represent the effects of radiation when it is absorbed by atoms (represented by the white circles). Complete the demonstrations, record your observations and answer the questions.

Image A: This type of radiation can cause atoms to vibrate and move.



Demonstration A:

1. Place your hands together. Your hands represent atoms.
2. Rub them against each other for 10 to 20 seconds.
3. Observe and record what happens to the "atoms" and the potential effects.

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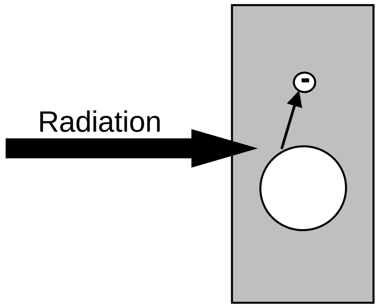
Image B: This type of radiation can change the structure of an atom by removing tightly bound electrons from atoms.



Demonstration B:

Equipment: 8 to 10 marbles. Select one marble to represent an atom nucleus. Select five marbles to represent electrons that surround the atom nucleus. Select two to four marbles to roll at the atom.

1. Place one marble (representing the nucleus of an atom) on a level surface.
2. Place five marbles tightly around the "nucleus" marble. The five marbles represent electrons. You now have a marble atom.
3. Roll one marble at a time at the "atom" and try to move, or knock away, an "electron."
4. Observe and record what happens to the atom nucleus and the potential effects.

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Questions:

1. Does image and demonstration A represent the effects of non-ionizing or ionizing radiation? Consider the effects you observed and what you know about these types of radiation in the electromagnetic spectrum. How might this type of radiation affect our bodies?

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2. Does image and demonstration B represent the effects of non-ionizing or ionizing radiation? Consider the effects you observed and what you know about these types of radiation in the electromagnetic spectrum. How might this type of radiation affect our bodies?

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3. Why do you need to be aware of and understand the difference between non-ionizing and ionizing radiation and their effects?

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Radiation Worksheet Teacher Answer Key

1. Does image and demonstration A represent the effects of non-ionizing or ionizing radiation? Consider the effects you observed and what you know about these types of radiation in the electromagnetic spectrum. How might this type of radiation affect our bodies? **Non-ionizing radiation. Low frequency sources of non-ionizing radiation are not known to present health risks. High frequency sources of ionizing radiation (such as the sun and ultraviolet radiation) can cause burns and tissue damage with overexposure.**

4. Does image and demonstration B represent the effects of non-ionizing or ionizing radiation? Consider the effects you observed and what you know about these types of radiation in the electromagnetic spectrum. How might this type of radiation affect our bodies? **Ionizing radiation. It can damage living tissue by changing cell structure and damaging DNA. Children are more sensitive to ionizing radiation than adults because children are still in the process of growing. There are more cells dividing and a greater opportunity for radiation to disrupt the growth process.**

2. Why do you need to be aware of and understand the difference between non-ionizing and ionizing radiation and their effects?
   Answers may vary, but students should be aware that ionizing radiation can affect atoms in living things and pose a health risk. Therefore, we may need to take measures to limit our exposure to ionizing radiation. Non-ionizing radiation does not typically pose a health risk. However, higher frequency forms of non-ionizing radiation such as the sun and ultraviolet lights can burn our skin or damage our eyes.

Radiation Sources in Our Community Worksheet

Name: ________________________________ Date: __________________

Review the following sources of radiation and indicate where you might encounter them, such as outdoors, in specific buildings or in certain work settings. Indicate whether the source is non-ionizing radiation, ionizing radiation or both.

Sources of Radiation	Locations	Non-Ionizing, Ionizing Radiation or Both
Ultraviolet (UV) light		
Security scanners		
Computed tomography (CT) scanners		
Cosmic radiation		
Electric and magnetic fields (EMF)		
Antique clocks and watches that glow in the dark		
Radon		
Tritium exit signs		
Ionizing smoke detectors		
Radioactive waste from abandoned uranium mines		
Wireless technology		
Nuclear moisture and density gauges		
Cigarettes/radiation in tobacco		

Radiation Sources in Our Community Teacher Answer Key

Sources of Radiation	Location(s)	Non-Ionizing and/or Ionizing Radiation
Ultraviolet (UV) light	**Outdoors, hospitals, tanning salons and certain jobs (e.g., welding or research)**	**Sun, medical uses and certain jobs: Both Tanning beds: Non-ionizing**
Security scanners	**Airports, courthouses and other buildings**	**Ionizing**
Computed tomography (CT) scanners	**Hospitals, clinics, medical/digital imaging diagnostic labs, and some veterinary offices**	**Ionizing**
Cosmic radiation	**Airplanes and outdoors**	**Ionizing**
Electric and magnetic fields (EMF) from power lines	**Near power lines and in all buildings with electrical devices and electrical outlets**	**Non-ionizing**
Antique clocks and watches that glow in the dark	**Homes, antique stores and flea markets**	**Ionizing**
Radon	**Outdoors and in some buildings; radon may also be encountered through drinking water and soil**	**Ionizing**
Tritium exit signs	**Many commercial and public buildings, as well as landfills**	**Ionizing**
Ionizing smoke detectors	**Many homes, schools and commercial and public buildings**	**Ionizing. Ionizing smoke detectors use a small amount of radioactive material to detect smoke. Photoelectric smoke detectors use a light source.**
Radioactive waste from abandoned uranium mines	**Water, buildings, soil and the air may be contaminated by radioactive waste**	**Ionizing**
Wireless technology	**Many homes, commercial and public buildings**	**Non-ionizing**
Nuclear moisture and density gauges	**Construction sites**	**Ionizing**
Cigarettes/radiation in tobacco	**Homes or designated smoking areas**	**Ionizing; naturally-occurring radioactive minerals accumulate on tobacco leaves**

Activity 2: Sources of Annual Radiation Exposure

Objectives

Students will:

- Predict and graph Americans' annual exposure to natural (background) and man-made radiation sources.
- Compare their predictions to data from the National Council on Radiation Protection and Measurements (NCRP).
- Define and classify sources of radiation exposure.

Next Generation Science Standards

The concepts in this activity can be used to support the following science standard:

- PS4. Waves and Electromagnetic Radiation.

Materials and Resources

- *Radiation Exposure: Teacher Background Information*.
- *Vocabulary Materials.*
- *Annual Radiation Exposure — 1987 and 2009* pie charts; display using computer and projector.
- *Annual Sources of Radiation Exposure Pie Chart* (one per student, pair or group).
- Colored pens, pencils or markers.
- *NCRP Sources of Radiation Exposure — 2009* pie chart (optional).
- *Relative Doses from Radiation Sources* diagram (optional).
- Student computers with Internet access (optional)

Time

45-60 minutes, not including optional activities or extensions.

Vocabulary

- Cosmic radiation
- Dose (optional)
- Ionizing radiation
- Man-made radiation
- Natural (background) radiation
- Radiation
- Radon
- Rem (optional)
- Terrestrial radiation

Directions

1. Start with a vocabulary activity if students are not familiar with radiation and the terms used in this activity, or provide students with the terms and definitions.

2. Ask students whether we can control our exposure to radiation? **The answer is both "no" and "yes." Radiation can come from natural and man-made sources. Natural (background) radiation is all around us and has been since the earth formed. We cannot control our exposure to natural cosmic (from space) radiation and terrestrial (from the ground) radiation. When made aware of the presence of radiation through testing or monitoring results, warning signs, labels and notices, we can make choices that limit our exposure. For example, people can fix high radon levels in homes, distance themselves from radioactive sources, and wear protective equipment and follow regulations when handling or being near a radiation source.**

3. Explain that the word "radiation" generally brings to mind nuclear power plants, nuclear weapons, or medical procedures, tests and treatments. However, radiation is part of our daily lives. Our bodies are well adapted to handle some exposure to radiation. We can also benefit from some sources of radiation in moderation, such as the sun. There are benefits from the use of x-ray machines that can tell us if something is wrong within our body and other medical radiation sources used to treat diseases like cancer.

4. Share the *Annual Radiation Exposure — 1987* pie chart. Explain to students that are unfamiliar with a pie chart that pie charts are circular graphs divided into sections that represent parts of the whole. Explain that the pie chart is based on data the NCRP collected in 1987. The chart shows that Americans' average annual exposure to radiation in 1987 came from 82 percent of natural (background) radiation and 18 percent of man-made radiation. The pie chart is further broken down to show exposure by more specific sources of natural and man-made radiation.

5. Provide students with the *Annual Sources of Radiation Exposure Pie Chart*. Review the example provided and the directions. Answer any questions. NOTE: Students can include the different types of natural and man-made radiation in the pie chart for more complexity if desired.

6. Display students' pie charts and the *Annual Radiation Exposure — 2009* pie chart. Have students compare their pie charts to the 2009 pie change and discuss:
   - How their pie chart compares to or differs from their classmates' pie charts and the NCRP's 2009 pie chart.
   - Reasons for any large differences.

7. Conclude by having students answer the following questions (verbally or in writing):
   - What differences do you see between the 1987 and 2009 pie charts? What do you think are the reasons for those differences?
   - What information was most surprising to you?
   - Did this activity confirm or change your perceptions and beliefs about radiation exposure? Explain your response.

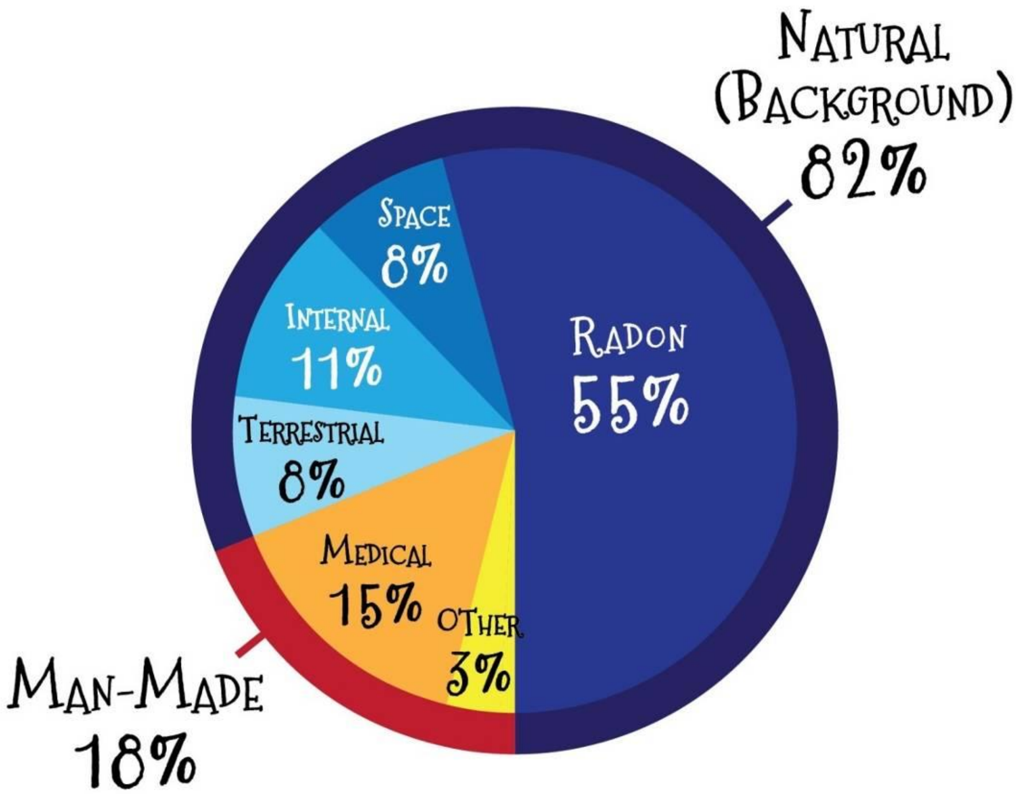
8. Optional activities or extensions:
   - Explain that, in the United States, radiation exposure is usually expressed in units called rems or millirems (mrem). (1000 mrem = 1 rem). In 1987, the NCRP found that

Americans were exposed to 320 mrem per year from all sources of radiation. In 2009 the exposure rate increased to 620 mrem per year. Have students:

  - Examine the *Relative Doses from Radiation Sources* diagram. Identify potential sources that can increase a person's exposure to radiation (e.g., certain medical procedures or living in areas with higher than average radon levels).
    - Have students examine the *Annual Radiation Exposure – 1987, Annual Radiation Exposure – 2009* and *NCRP Sources of Radiation Exposure—2009* pie charts and discuss the changes that have led to the average increase in radiation exposure from 320 to 620 mrem per year. Note the significant increase in medical radiation and the types of medical radiation used.
  - Consider the increased use of medical radiation to detect and treat diseases and discuss whether the benefits outweigh the potential risks of exposure.
- Have students complete a pie chart based on their prediction of Americans' exposure to natural (background) and man-made radiation in the next 10 or 20 years.

Annual Radiation Exposure — 1987

Based on data from NCRP Report No. 93, 1987, with permission of the National Council on Radiation Protection and Measurements, NCRPonline.org.



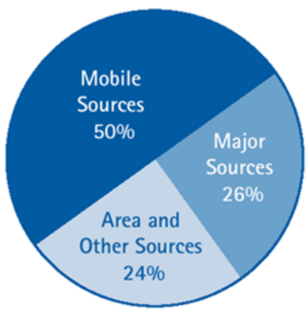
Annual Sources of Radiation Exposure Pie Chart

Name: ____________________________________ Date: ____________________

Pie charts show data in the form of sections, or parts, of a whole. The pie chart example shows three parts (50%, 26% and 24%) that add up to the whole (100%).

In 2009 the National Council on Radiation Protection and Measurements (NCRP) examined Americans' annual exposure to radiation. Hypothesize the amount of natural and man-made radiation Americans were exposed to by dividing the pie chart into two parts. Label each part according to its percentage of the whole. Make sure the two slices total 100%. Color each part (and the corresponding box in the legend) with a different color or pattern.

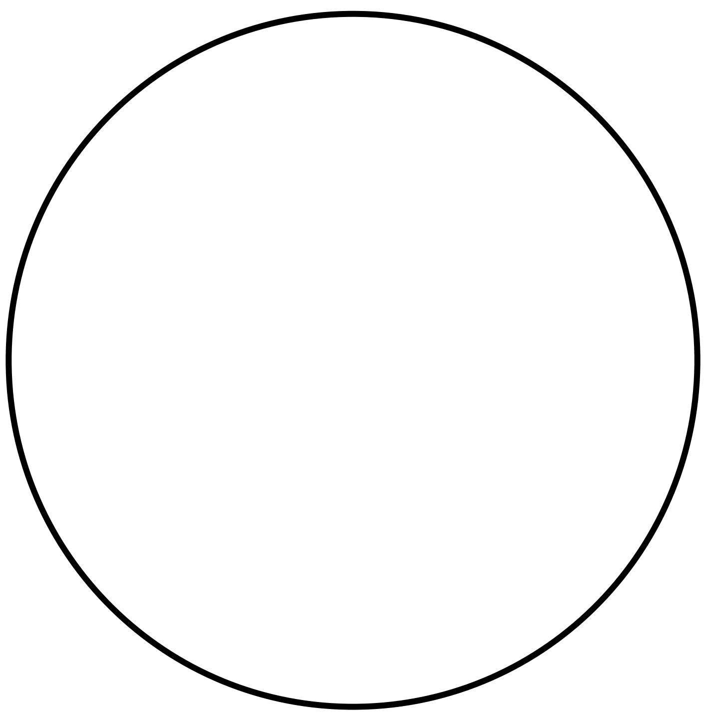
Pie Chart Example



Pie Chart Legend

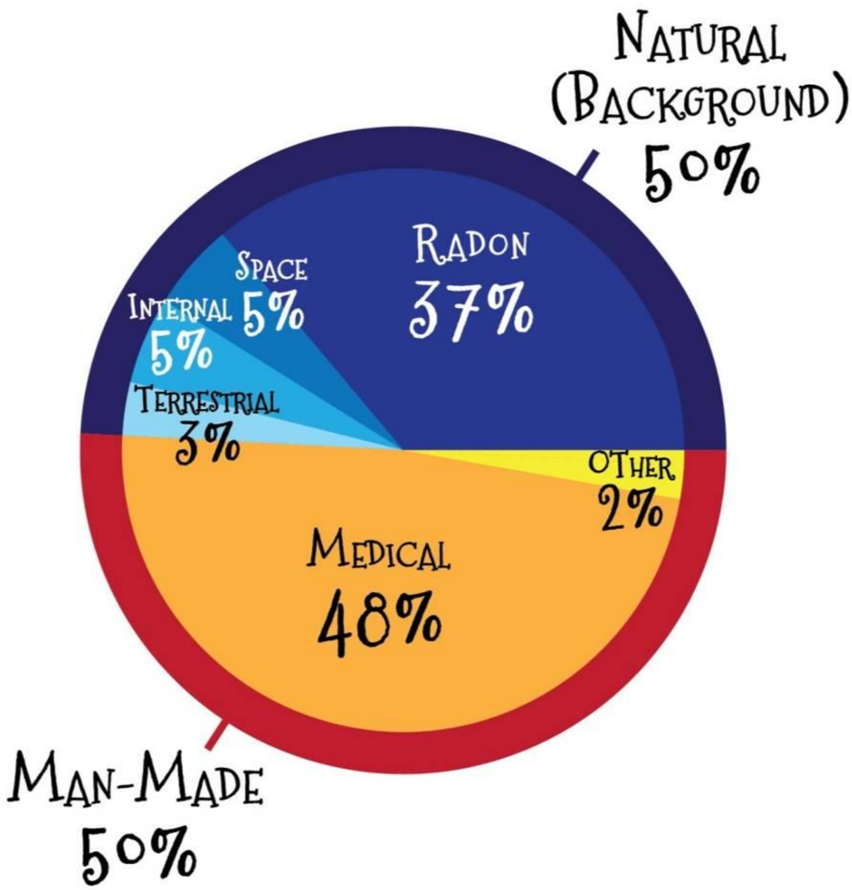
☐ Natural (Background) Radiation

☐ Man-Made Radiation



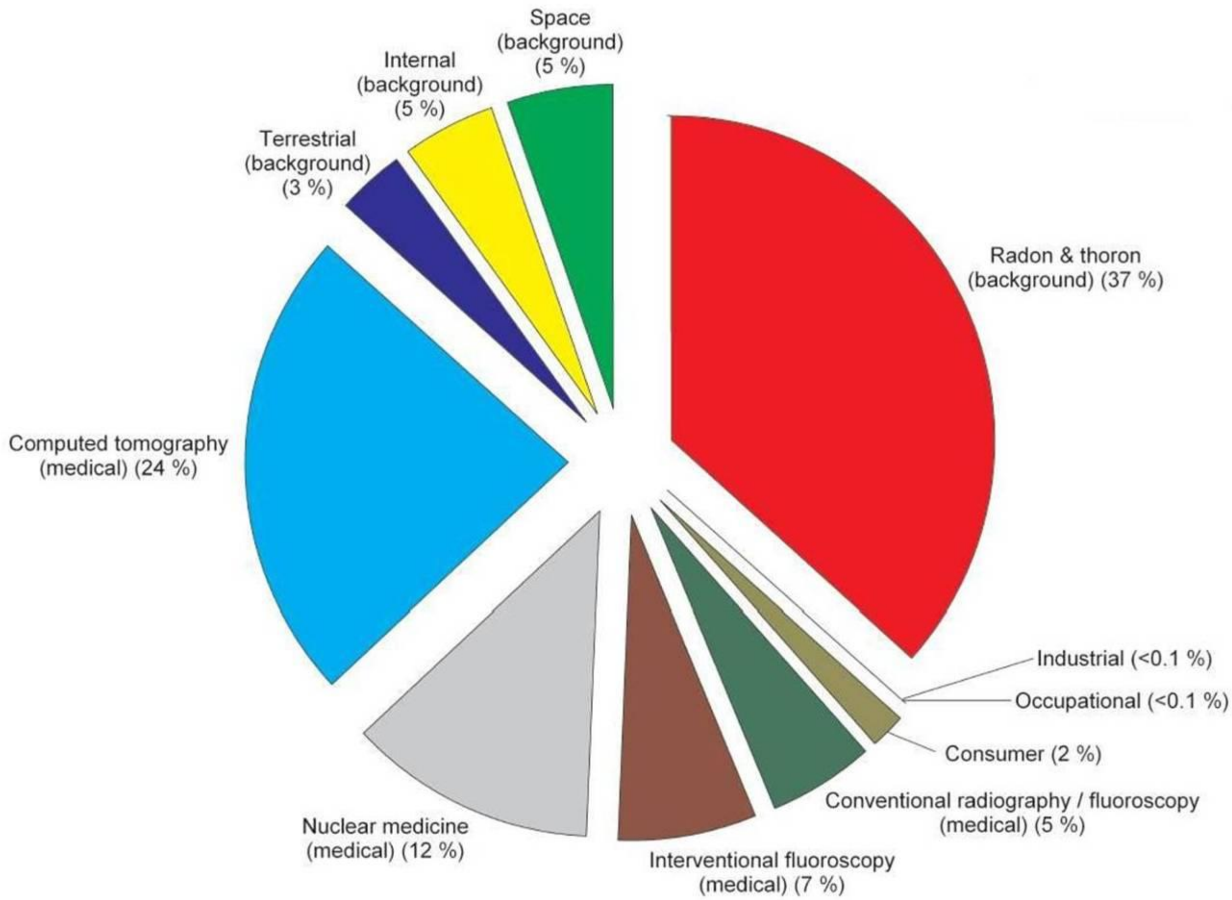
Annual Radiation Exposure — 2009

Based on data from NCRP Report No. 160, 2009, with permission of the National Council on Radiation Protection and Measurements, NCRPonline.org.



NCRP Sources of Radiation Exposure—2009

Reprinted from: NCRP Report No. 160, 2009, with permission of the National Council on Radiation Protection and Measurements, NCRPonline.org.

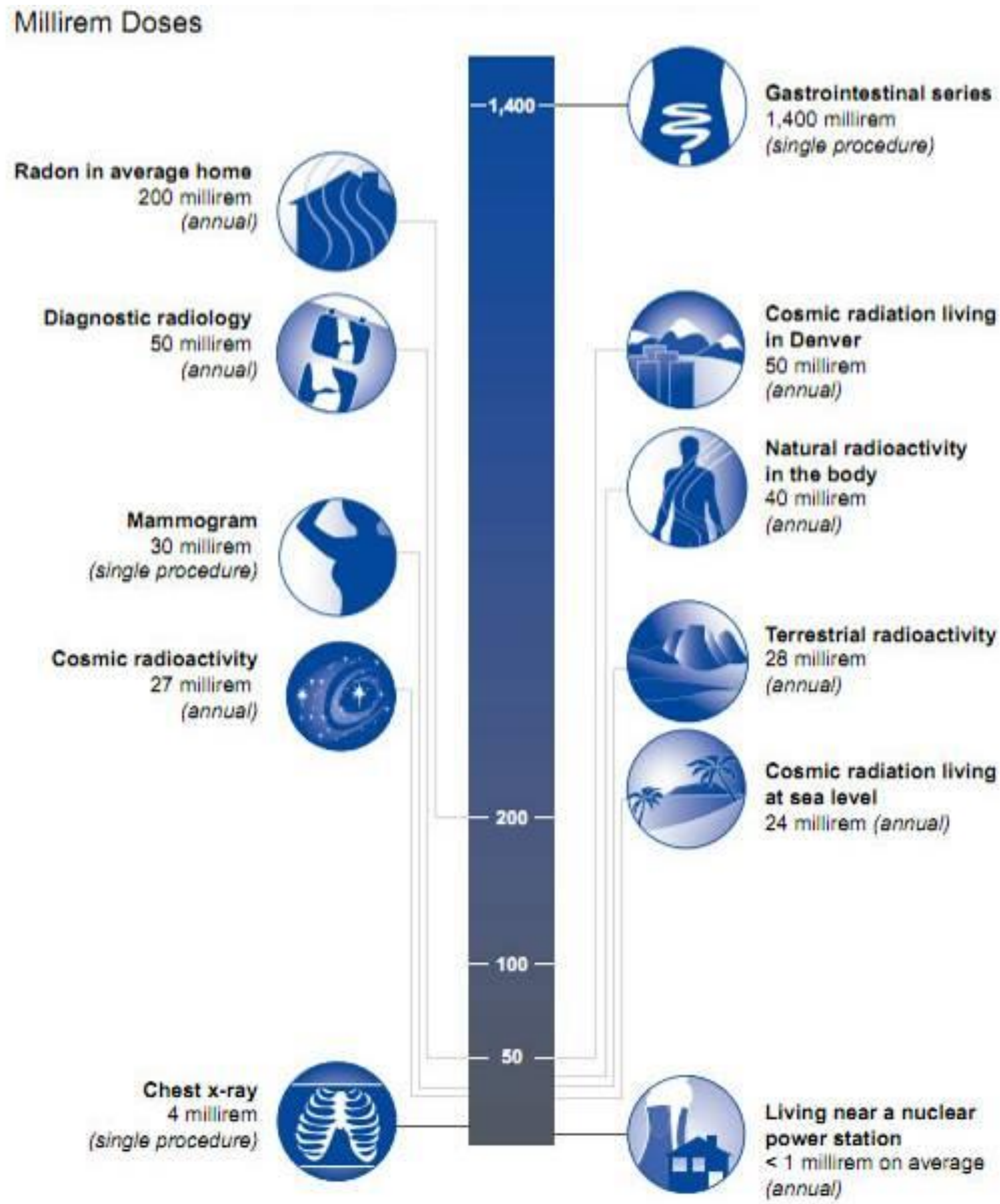


Description of Medical Terms:

- **Computed tomography (CT):** A medical imaging procedure that uses x-rays to show cross-sectional images of the body. Also called computerized axial tomography (CAT) scanning.
- **Interventional fluoroscopy:** The use of ionizing radiation to guide small instruments such as catheters through blood vessels or other pathways in the body.
- **Conventional radiography and fluoroscopy:** Radiography is the use of x-ray machines by doctors and dentists to view the human body. Fluoroscopy is a medical technique used by doctors to take real-time moving images of internal structures in the body by placing a patient between a fluorescent screen and an x-ray source.
- **Nuclear medicine:** Radioactive elements or tracers that are given intravenously or orally. A gamma camera detects gamma rays emitted by the tracer. These data are fed into a computer where they are used to produce images and other information about the body's organ system.

Relative Doses from Radiation Sources

From: http://www2.epa.gov/radiation/radiation-sources-and-doses#tab-2



Activity 3: Penetrating Powers of Ionizing Radiation

Objectives

Students will:

- Predict whether each type of ionizing radiation has the ability to penetrate, or pass through, our skin and body.
- Demonstrate the penetrating powers of ionizing radiation.
- Consider how we are exposed to radiation and how we can limit our exposure.
- Differentiate between radiation exposure and radiation contamination.

Next Generation Science Standards

The concepts in this activity can be used to support the following science standard:

- PS4. Waves and Electromagnetic Radiation.

Materials and Resources

- *Radiation Exposure: Teacher Background Information*.
- *Vocabulary Materials.*
- *Penetrating Powers of Ionizing Radiation Worksheet* demonstration materials:
  - Cardboard box (for a class demonstration or one box per group) with several holes in one side or a side covered with plastic mesh (from a hobby or hardware store); the holes/mesh size should be relative to the "beta particle" representations.
  - Light objects to represent beta particles (e.g., a ping pong ball or small beads if using mesh). Some, but not all, of the objects should be able to fit through the cardboard or mesh holes. Mark objects with a negative symbol (–) to represent the negative charge of a beta particle if possible.
  - Larger beads or objects (e.g., a baseball or larger beads) to represent alpha particles. The objects should be heavier than the "beta particles" and not fit through the cardboard or mesh holes. Mark objects with a positive symbol (+) to represent the positive charge of an alpha particle if possible.
  - Flashlight to represent x-rays and gamma rays.
- *Penetrating Powers of Ionizing Radiation Worksheet* (one per student, pair or group) and *Penetrating Powers of Ionizing Radiation Teacher Answer Key*.
- *Penetrating Powers of Ionizing Radiation Image*.

Time

45-60 minutes.

Vocabulary

- Alpha particles
- Beta particles
- Direct exposure
- Exposure pathways
- Gamma rays
- Ingestion
- Inhalation
- Ionizing radiation
- Radiation
- Radiation exposure
- Radiation protection
- Radioactive contamination
- X-rays

Directions

1. Start with a vocabulary activity if students are not familiar with radiation and the terms used in this activity, or provide students with the terms and definitions. NOTE: When defining alpha particles, beta particles, gamma rays and x-rays, do not include the penetrating powers and how they can be stopped.

2. Distribute the *Penetrating Powers of Ionizing Radiation Worksheet* to students. Direct students to read and complete the first question.

3. Discuss students' predictions and reasons for their predictions.

4. Explain that the students are going to help you demonstrate the penetrating powers of radiation, or the ability of radiation to pass through our skin and body.

5. Show students the alpha particle, beta particle, x-ray and gamma ray representations (see Materials and Resources for appropriate objects).

6. Ask for several student volunteers if conducting a class demonstration, or provide direction to students if having them conduct the demonstration in groups.
   - Explain that the cardboard box or mesh represents our skin.
   - Have at least two students try to toss the alpha particles (larger object like baseball or large beads) through the cardboard holes or pour them over the mesh. If tossing the alpha particles, direct at least one student to toss the alpha particle lightly so that it falls short of the cardboard box.
   - Ask students to think about what they saw and hypothesize why this occurred and how this relates to exposure to alpha particles. **Alpha particles are heavy and may lack the energy to reach you and penetrate the outer dead layer of skin.**
   - Have several students try to toss beta particles (smaller object like ping pong ball or small beads) through the cardboard holes or pour beta particles through the mesh. Some should make it through and some not. Ask students to hypothesize what occurred and how this relates to exposure to beta particles. **The speed of individual beta particles depends on how much energy they have, and varies over a wide range. Some beta particles may have enough energy to penetrate our skin while others may not.**
     NOTE: Alpha and beta particles may not have enough energy to penetrate skin or clothing, but if inhaled or ingested, alpha and beta particles can transfer large amounts of energy to surrounding tissue and damage cells. Radiation exposure can serve as a benefit; for example, in controlled situations when it is used to diagnose and treat diseases. In uncontrolled situations, like high radon levels in a home, radiation can pose health risks and concerns.
   - Ask a student to (or you) shine the x-ray and gamma ray representation through the cardboard or mesh. Be sure to turn the box so it's facing the students and they can see the light shining through the holes/mesh or open the back side of the box so they can see the light shining through. Make sure the light is not directed toward another person. Ask students to hypothesize what occurred and how this relates to exposure to x-rays and gamma rays. X-rays and gamma rays are the most energetic. They can penetrate and pass through many kinds of materials, including our bodies.

7. Direct students to answer the remaining questions on the *Penetrating Powers of Ionizing Radiation Worksheet*.

8. Discuss students' responses using the *Penetrating Powers of Ionizing Radiation* *__Teacher Answer Key__*. You can also share the *Penetrating Powers of Ionizing Radiation Image* while reviewing students' answers and the correct responses.

9. Conclude by having students share (verbally or in writing) at least one thing they have learned and how the activity changed their perceptions about radiation.

10. Optional activity or extension: Direct students to research radioactive elements and determine their penetrating power and how the penetrating power might serve as a risk or a benefit. A potential resource - Radionuclides: http://www2.epa.gov/radiation/radionuclides

Penetrating Powers of Ionizing Radiation Worksheet

Name: ___________________________________ Date: ____________________

Radiation is energy that can come from unstable (radioactive) atoms or be produced by machines. Radiation travels from its source in the form of energy waves or energized particles. The major types of ionizing radiation include:

- Alpha particles: Relatively heavy, high-energy particles.
- Beta particles: Small, fast-moving particles that vary in energy and penetrating power.
- Gamma rays: High-energy electromagnetic radiation that can travel at the speed of light and can cover hundreds to thousands of meters in air before spending their energy.
- X-rays: High-energy electromagnetic radiation that is generally lower in energy and, therefore, less penetrating than gamma rays.

1. Hypothesize whether each has the ability to penetrate (pass through) your skin and body.
   Alpha particles: ____
   Beta particles: ____
   Gamma rays: ____
   X-rays: ____

2. Did the demonstration confirm your predications above? Explain.
   ____
   ____
   ____

3. How might people be exposed to ionizing radiation?
   ____
   ____
   ____

4. How can people prevent or reduce their exposure to ionizing radiation?
   ____
   ____
   ____

5. What is the difference between radiation exposure and radiation contamination?
   ____
   ____
   ____

Penetrating Powers of Ionizing Radiation Teacher Answer Key

1. Hypothesize whether each has the ability to penetrate (pass through) your skin and body.

   Alpha particles: **Alpha particles cannot penetrate most matter. A piece of paper or the dead outer layers of skin is sufficient to stop alpha particles.**

   Beta particles: **Beta particles are capable of penetrating the skin and causing radiation damage, such as skin burns. They can be stopped by a layer or two of clothing or by a few millimeters of a substance such as aluminum.**

   Gamma rays: **Gamma rays are very penetrating. Several feet of concrete or a few inches of lead may be required to stop gamma rays.**

   X-rays: **X-rays are generally lower in energy (less penetrating) than gamma rays. Most diagnostic medical x-rays are stopped by a few millimeters of lead.**

2. Did the demonstration confirm your predications above? Explain.
   Answers will vary.

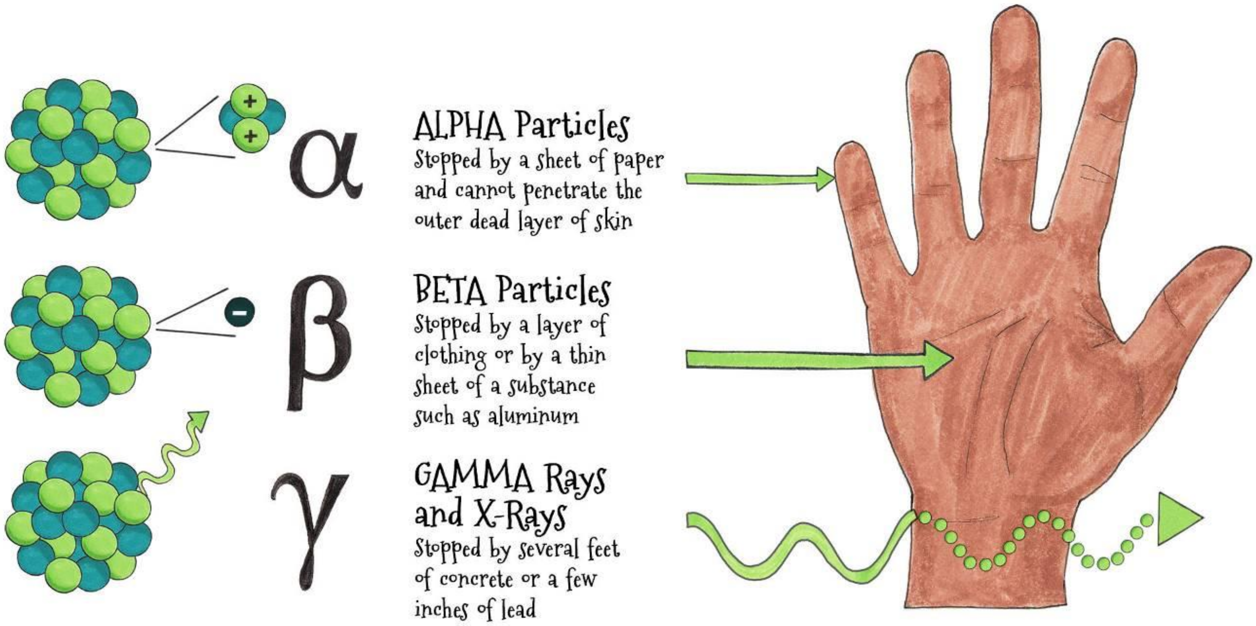
3. How might people be exposed to ionizing radiation?
   Exposure may occur from man-made sources like abandoned mines, mills, nuclear test sites or radioactive waste sites; contaminated water sources and building materials from these sites; and radioactive materials that are not disposed of properly. Exposure may also occur from natural (background) radiation sources like the sun, the atmosphere and the soil.

4. How can people prevent or reduce their exposure to ionizing radiation?
   The main radiation protection concepts are time (reducing time near a source), distance (increasing our distance from a source) and shielding (placing a barrier between us and the radiation source). It's also important to have homes and water supplies tested for radiation contamination and fixed if any problems are identified.

5. What is the difference between radiation exposure and radioactive contamination?
   Radiation exposure occurs when a person is near a radiation source. Though the radiation penetrates the body, it does not remain on the skin or in the body. Receiving an x-ray is an example of radiation exposure.

   Radioactive contamination occurs when radioactive materials are deposited on or get in objects (building materials or surfaces), people, or the environment (air, water, soil, animals and plants). For example, if radioactive dust, powder, or liquid lands on us or our clothing, or if it gets in and remains inside our body, we are contaminated.

Penetrating Powers of Ionizing Radiation Image



Activity 4: Exposure Pathways

Objectives

Students will:

- Identify sources of radiation exposure.
- Diagram exposure pathways.
- Assess the benefits and risks of radiation exposure.

Next Generation Science Standards

The concepts in this activity can be used to support the following science standards:

- PS4. Waves and Electromagnetic Radiation.
- LS2. Matter and Energy in Organisms and Ecosystems.

Materials and Resources

- *Radiation Exposure: Teacher Background Information*.
- *Vocabulary Materials.*
- Chalkboard, whiteboard, interactive whiteboard, computer and/or projector if needed for student presentations.
- Student computers with access to the Internet and a printer (optional).
  - RadTown USA: www.epa.gov/radtown
- Art supplies for students (e.g., paper or poster board, magazines, colored pencils and markers).

Time

45-60 minutes.

Vocabulary

- Alpha particles
- Beta particles
- Direct exposure
- Gamma rays
- Ingestion
- Inhalation
- Ionizing radiation
- Man-made radiation
- Natural (background) radiation
- Radiation
- Radiation exposure
- Radiation protection
- X-rays

Directions

1. Start with a vocabulary activity if students are not familiar with radiation and the terms used in this activity, or provide students with the terms and definitions.

2. Ask students how they might be exposed to radiation and the pathways through which radiation can enter their body. You can provide several examples such as radon, x-rays, and radiation sources contained in ionizing smoke detectors or tritium exit signs. The routes of exposure include direct or external exposure, inhalation and ingestion. X-rays are an example of direct exposure. Radon may be inhaled as a gas or ingested if it is in drinking water. Industrial radiation sources, like nuclear power plants, may be a source of all three exposure routes if released into the environment by accident.

3. Direct students to:
   - Work in small groups to identify a natural and a man-made ionizing radiation source.
   - Determine the possible routes or pathways of exposure (i.e., direct or external exposure, inhalation and ingestion) for each radiation source, including exposure pathways for accidentally released sources.
   - Diagram the exposure routes or pathways in the form of radiation webs or chains (similar to food webs or chains) using paper and art supplies, computers or an interactive whiteboard to display their diagrams. An example for airborne radioactive pollutants is provided by the U.S. Department of Energy (DOE). NOTE: If sharing the DOE example with students, it may include terms with which students are not familiar. Helpful resources may include their textbooks or Radionuclides: http://www2.epa.gov/radiation/radionuclides
   - Discuss as a group or class whether the radiation sources or exposure pathways present a benefit (e.g., nuclear medical treatments), a risk (e.g., accidentally released, ingested or inhaled radiation sources) and/or if it is a natural occurrence (e.g., cosmic rays). If a source presents a risk and exposure can be limited, have students hypothesize and list possible methods that can limit one's exposure and risk.

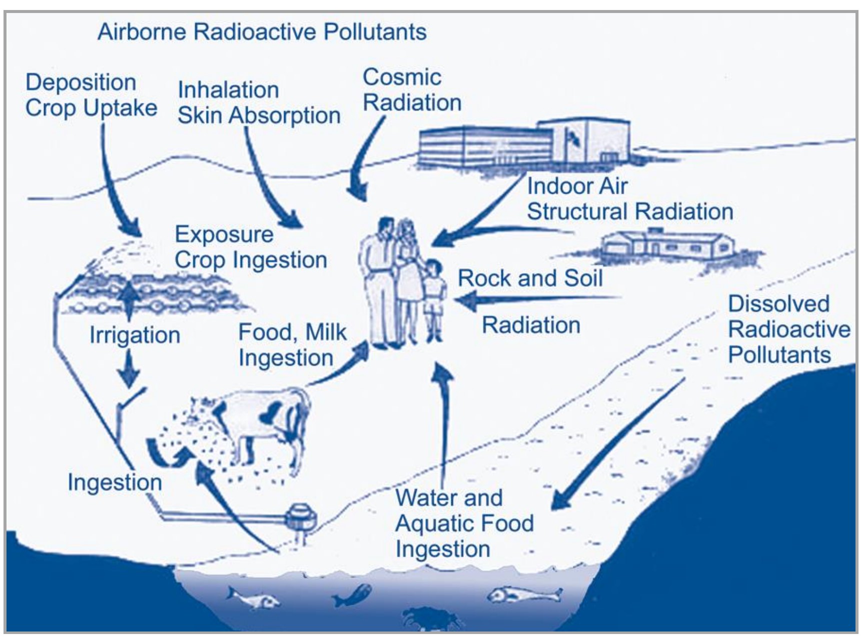


Image Source: U.S. DOE

4. Ask students or groups to share and describe their web or chain, listing the benefits, risks (limitations if applicable) and natural occurrences of the radiation sources.

5. Conclude by asking students to:
   - Describe interesting facts or findings they learned from the activity.
   - Explain whether the activity changed their perceptions or fears about radiation exposure.

Activity 5: Radiation Health Effects

Objectives

Students will:

- Identify sources of radiation exposure.
- Research the uses and health effects.
- Assess the benefits and risks of radiation exposure.

Next Generation Science Standards

The concepts in this activity can be used to support the following science standards:

- PS4. Waves and Electromagnetic Radiation.

Materials and Resources

- *Radiation Exposure: Teacher Background Information*.
- *Vocabulary Materials.*
- Student computers with Internet access (or provide print versions for students).
    - Radionuclides: http://www2.epa.gov/radiation/radionuclides
    - Radiation in Tobacco: www3.epa.gov/radtown/tobacco.html
- Paper or poster board and colored pencils, pens, markers or other art supplies or student computers.

Time

45-60 minutes, not including optional activities or extensions.

Vocabulary

- Alpha particles
- Beta particles
- Direct exposure
- Gamma rays
- Ingestion
- Inhalation
- Ionizing radiation
- Man-made radiation
- Natural (background) radiation
- Radiation
- Radiation exposure
- X-rays

Directions

1. Start with a vocabulary activity if students are not familiar with radiation and the terms used in this activity, or provide students with the terms and definitions.

2. Ask students why people often fear radiation. **They fear radiation because it can damage cells and our DNA. Ironically, radiation can cause cancer as well as be used to diagnose and treat diseases, including cancer.**

3. Explain that radiation is a part of our natural world and it's all around us. Our bodies are adapted to handle some radiation exposure. Each of our bodies, and the cells within our bodies, reacts differently to radiation exposure. The health effects may also depend on the type of radiation, the exposure pathway, the radiation's energy and the total amount of radiation absorbed.

4. Ask students to name several sources of natural (background) and man-made ionizing radiation (e.g., radon, the sun, x-rays and nuclear power plants).

5. Explain that each radiation source gives off different types of ionizing radiation. The major types of ionizing radiation include alpha particles, beta particles, gamma rays and x-rays. We also may be exposed to radiation through different exposure pathways. The three main exposure pathways are direct exposure, inhalation (through breathing) and ingestion (through eating). For example, we are exposed to the sun through direct exposure and radon is a gas that we might inhale.

6. Ask students to hypothesize whether the different types of ionizing radiation produce the same health effects and how the health effects may differ by exposure pathway. **For example, radiation in tobacco may be inhaled and increase a person's risk of developing lung cancer, exposure to the sun can lead to sunburns and skin cancer, and ingested radioactive materials could impact the thyroid gland, the stomach or kidneys. Exposure to radiation can also serve as a health benefit. For example, nuclear medicine may be ingested to help diagnose and treat a sick individual. In moderation, the sun serves as a source of vitamin D.**

7. Direct students to select and review common radioactive elements (http://www2.epa.gov/radiation/radionuclides) or the radiation found in tobacco (www3.epa.gov/radtown/tobacco.html). NOTE: If student computers are not accessible, the information can be printed and shared with students.

8. Direct students to research a radiation source. Have students identify potential health risks and benefits for each exposure pathway (direct exposure, inhalation or ingestion) and the targeted organs or systems. Students can collect information to present in the form of a (visual or electronic) presentation including a representation of the human body and the targeted organs or systems.

9. Have students share their findings.

10. Conclude by having students discuss:
    - Any identified relationships between radiation types, radiation health effects (whether perceived as a risk or benefit) and exposure pathways.
    - When the benefits of particular radioactive elements may outweigh the risks.
    - Situations in which they may have control over their exposure or be able to limit their exposure, such as avoiding cigarettes and secondhand smoke or reducing any elevated radon levels in their home.
    - How the activity has changed or supported their perceptions or concerns about radiation exposure.

Activity 6: Acute versus Chronic Exposure

Objectives

Students will:

- Develop a basic understanding of acute and chronic radiation exposure.
- Differentiate between the two terms.

Next Generation Science Standards

The concepts in this activity can be used to support the following science standard:

- PS4. Waves and Electromagnetic Radiation.

Materials and Resources

- *Radiation Exposure: Teacher Background Information*.
- *Vocabulary Materials.*
- Student access to Internet and research sources (optional whether students conduct research in class or outside of class).
- *Acute versus Chronic Exposure Worksheet* (one per student, pair or group).

Time

You may choose to have students complete the entire activity within one or two class periods (45-60 minutes, not including optional activities or extensions). If time or computer access is limited, the activity can be introduced, completed outside of the class and concluded in another class period.

Vocabulary

- Alpha particles
- Beta particles
- Direct exposure
- Gamma rays
- Ingestion
- Inhalation
- Ionizing radiation
- Man-made radiation
- Natural (background) radiation
- Radiation
- Radiation exposure
- X-rays

Directions

1. Start with a vocabulary activity if students are not familiar with radiation and the terms used in this activity, or provide students with the terms and definitions.

2. Explain that we encounter a variety of radiation sources in our everyday life, and generally, this does not cause any health concerns. However, there may be situations in which we encounter acute or chronic exposures to radiation.

3. Describe the following situations and ask students to determine whether they are an example of acute or chronic exposure.
   - A radiation source breaks and you are exposed to the radiation for a brief period. **Acute**
   - You have been living in a home with high indoor radon levels for years. **Chronic**

4. Ask students to describe how they came to their conclusion. **Acute conditions are usually severe, sudden and only last a short time. Chronic conditions persist continuously or intermittently over a long period of time.**

5. Ask students to answer the following questions (orally or in writing):
   - When might people experience acute radiation exposure? **Acute doses can result from accidental exposures during an emergency or from specific medical procedures such as radiation therapy.**
   - When might people experience chronic radiation exposure? **People may experience chronic exposure in a work setting if safety practices are not being followed or if radon levels in their home are high.**
   - Which presents a greater concern, acute or chronic radiation exposure? Why? **Acute exposure, because the exposure dose is large and the exposure can lead to severe health effects. However, people may have to weigh the benefits and risks of some exposures. For example, radiation therapy may help fight cancer.**

6. Distribute the *Acute versus Chronic Exposure Worksheet*.

7. Have students research and investigate incidents that resulted in acute or chronic exposure and answer the questions. Potential scenarios and those affected include Japanese atomic bomb survivors, natives of the Marshall Islands impacted by nuclear testing fallout, uranium miners, radiation industry workers or radium dial workers.

7. Have students share their findings. Ensure that students have a correct understanding of the terms acute and chronic and the time span in which effects may occur. **In most cases, an acute exposure to radiation causes both immediate and delayed effects. For chronic exposure, there is generally a delay of months or years between the exposure and the observed health effect. Health effects will vary greatly depending on the event students choose to research, but could include DNA or cellular damage, nausea, vomiting, cancer, or organ-specific effects (kidney failure, thyroid issues, etc.). Remind students that each person reacts differently to radiation exposure. The extent of the damage depends on the total amount of energy absorbed, the time period of the exposure, the dose rate of the exposure, and the particular organs exposed.**

8. Conclude by asking students what they learned from the activity and how the activity has changed their perceptions or concerns about radiation exposure.

Acute versus Chronic Exposure Worksheet

Name: ___________________________________ Date: ___________________

Research a past event in which people were exposed to radiation. Respond to the following statement and questions.

1. Briefly describe the incident and how victims were exposed to radiation. Did the victims experience acute and/or chronic exposure to radiation?

   ____
   ____
   ____
   ____
   ____
   ____
   ____

2. From your description in question 1, how soon did people begin to experience noticeable health effects (immediately or after a period of time)? Explain.

   ____
   ____
   ____
   ____
   ____

3. What were some of the health effects?

   ____
   ____
   ____
   ____
   ____

4. Did everyone experience the same effects? What may affect how a person reacts to radiation exposure?

   ____
   ____
   ____
   ____
   ____

Activity 7: Radiation: Fact or Fiction?

Objectives

Students will examine their understanding of radiation as well as any misconceptions they have about exposure.

Next Generation Science Standards

The concepts in this activity can be used to support the following science standard:

- PS4. Waves and Electromagnetic Radiation.

Materials and Resources

- *Radiation Exposure: Teacher Background Information*.
- *Vocabulary Materials.*
- *Superheroes Worksheet* (one per student, pair or group or group) and *Superheroes Teacher Answer Key* (optional).
- *Radiation: Fact or Fiction? Quiz* (one per student, pair or group) and *Radiation: Fact or Fiction? Teacher Answer Key* (optional).
- Student access to computers or research sources (optional).

Time

45-60 minutes.

Vocabulary

- Ionizing radiation
- Radiation
- Radiation exposure
- Radioactive atom
- Radioactive material
- Radiation exposure

Directions

1. Start with a vocabulary activity if students are not familiar with radiation and the terms used in this activity, or provide students with the terms and definitions.

2. Ask students to name superheroes that received or lost their powers when exposed to radiation or distribute the *Superheroes Worksheet* for students to complete in small groups.

3. Explain that cartoons, comics or movies may help fuel myths about radiation.

4. Ask students to provide examples of myths that people may have about radiation exposure (e.g., radiation exposure will make you glow) and potential sources of this misinformation such as movies, comics, video games, other media sources and people).

5. Explain that we may receive misinformation from various sources and perceive it to be true. That is why it is important to verify information with reliable resources. Have students complete one or more of the following activities:

Option A: *Radiation Fact or Fiction? Quiz.* Have students complete the quiz and work in groups to rewrite fictitious statements as factually accurate statements providing as much detail as possible. Review the correct responses and students' factually accurate statements.

Option B: Research Project. Have students:

- Brainstorm and list what they know or have heard about radiation in general, or particular radiation sources and any questions or concerns they have about radiation.
- Predict whether the information they have received is fact or fiction.
- Conduct research, listing the sources, to confirm whether the statements are fact or fiction, answer any questions raised, and address any concerns. Rewrite any fictitious statements as factually accurate statements.
- Submit a written report, develop a presentation or use technology (e.g., post to an educational wiki or create a video or online game) to share findings and educate classmates.

Option C: Superhero Research Project. Have students:

- Brainstorm what they know about a particular superhero (e.g., Superman; Spider-Man; the Incredible Hulk; Daredevil; the Fantastic Four; Doctor Solar, Man of the Atom; or Radioactive Man)
- Predict what perceptions or misperceptions about radiation existed or what radiation-related events occurred around the time of the superhero's creation.
- Conduct research, listing the sources, to identify the radiation perceptions or misconceptions that existed or the radiation events that occurred before or at the time of the superhero's development. For example, Superman was developed as an action comic character in the 1930s when people were beginning to understand the effects of ionizing radiation and the need for protection. Spider-Man, the Incredible Hulk, Daredevil, and the Fantastic Four were created in the 1960s after the development of the atomic bomb or during the nuclear arms race and widespread nuclear weapons testing.
- Submit a written report, develop a presentation or use technology (e.g., post to an educational wiki or create a video or online game) to share findings and educate classmates.

6. Conclude the activity with the following questions; you can have students respond orally or in writing:
   - How can you tell the difference between fact and fiction? **This can sometimes be a challenge when made up, misleading, or misinterpreted information (fiction) is believed to be fact. However, a fact can be proven true with evidence and fiction cannot.**
   - Why do you think knowing the difference between fact and fiction is important when you are learning about radiation? **Knowing the facts about radiation and radiation protection can help people effectively protect themselves from harmful and unnecessary exposure to radiation.**
   - We are presented with lots of information and misinformation about radiation. How can you ensure you have accurate information? **Use reliable resources to verify the information you receive—textbooks, professional journals, books and papers and websites of professional organizations related to radiation and health physics, federal agencies like the U.S. Environmental Protection Agency (EPA), and state and local agencies like departments of health.**

- What misperceptions did you have about radiation and what did you learn when correcting those misperceptions? **Answers will vary.**

Superheroes Worksheet

Name: ___________________________________ Date: ____________________

Name the superhero described:

1. A high school student is bitten by a radioactive spider while visiting a science exhibit. Afterward he gains spider-like powers including super-strength, the ability to climb walls and throw webs, and phenomenal jumping skills.

2. A physicist develops a gamma ray bomb. While testing the bomb, he is exposed to the blast as he saves a teenage boy driving into the test area. Afterward, he develops a split personality and turns into a large, strong, green monster when angry.

3. After being exposed to radioactive sludge, four turtles — Michelangelo, Raphael, Leonardo and Donatello — mutate into human-sized ninjas and fight criminals, aliens and other evil characters.

4. A group of four individuals gain superpowers after being exposed to cosmic rays during a scientific space mission. Afterward, each individual develops a different power, including the ability to stretch to incredible lengths and shapes, the ability to become invisible and project powerful force fields, the ability to generate flames, and the gift of superhuman strength and endurance.

5. This superhero is more powerful than a locomotive, can fly and has x-ray vision. His weakness is kryptonite. Lead is the only substance that will block and save him from kryptonite. It is also the one material he cannot penetrate with his x-ray vision.

Answer the following questions.

1. What do these superheroes have in common?

   ____

2. What thoughts or events do you think led to the development of these characters?

   ____

   ____

   ____

   ____

Superheroes Teacher Answer Key

Name the superhero described:

1. A high school student is bitten by a radioactive spider while visiting a science exhibit. Afterward he gains spider-like powers including super-strength, the ability to climb walls and throw webs, and phenomenal jumping skills. **Spider-Man.**

2. A physicist develops a gamma ray bomb. While testing the bomb, he is exposed to the blast as he saves a teenage boy driving into the test area. Afterward, he develops a split personality and turns into a large, strong, green monster when angry. **The Incredible Hulk.**

3. After being exposed to radioactive sludge, four turtles — Michelangelo, Raphael, Leonardo and Donatello — mutate into human-sized ninjas and fight criminals, aliens and other evil characters. **The Teenage Mutant Ninja Turtles.**

4. A group of four individuals gain superpowers after being exposed to cosmic rays during a scientific space mission. Afterward, each individual develops a different power, including the ability to stretch to incredible lengths and shapes, the ability to become invisible and project powerful force fields, the ability to generate flames, and the gift of superhuman strength and endurance. **The Fantastic Four.**

5. This superhero is more powerful than a locomotive, can fly and has x-ray vision. His weakness is kryptonite. Lead is the only substance that will block and save him from kryptonite. It is also the one material he cannot penetrate with his x-ray vision. **Superman.**

Answer the following questions.

1. What do these superheroes have in common?
   Their stories are based on fictional effects of radiation exposure.

2. What thoughts or events do you think led to the development of these characters?
   Answers will vary. Perhaps the characters are a reflection of the perceptions or misperceptions of radiation and events that were occurring around the time of their creation.

Radiation: Fact or Fiction? Quiz

Name: ______________________________ Date: __________________

Read each statement. Mark “Fact” or “Fiction” for each statement depending on what you think or believe to be correct.

☐ **Fact**	☐ **Fiction**	1. Radioactive waste remains radioactive forever.
☐ **Fact**	☐ **Fiction**	2. People who live in Denver, Colorado, receive more exposure to cosmic radiation than people living in Florida.
☐ **Fact**	☐ **Fiction**	3. Radiation from a tanning bed is more harmful than radiation from the sun.
☐ **Fact**	☐ **Fiction**	4. If you are exposed to radiation you will develop cancer.
☐ **Fact**	☐ **Fiction**	5. Suntans are the result of skin damage from the sun.
☐ **Fact**	☐ **Fiction**	6. Most radiation that we are exposed to is man-made.
☐ **Fact**	☐ **Fiction**	7. Living near a nuclear power plant poses less risk of radiation exposure than living in a home or area with high radon levels.
☐ **Fact**	☐ **Fiction**	8. You should keep track of the number of medical x-rays and scans you have received.
☐ **Fact**	☐ **Fiction**	9. Exposing food to radiation makes it radioactive.
☐ **Fact**	☐ **Fiction**	10. All glow-in-the-dark items contain radioactive sources.
☐ **Fact**	☐ **Fiction**	11. Radiation was discovered during World War II when the atomic bomb was developed.
☐ **Fact**	☐ **Fiction**	12. Radiation exposure will cause you to glow.
☐ **Fact**	☐ **Fiction**	13. Cigarettes are a source of radiation exposure.
☐ **Fact**	☐ **Fiction**	14. Children are more sensitive to radiation than adults.

Radiation: Fact or Fiction? Teacher Answer Key

☐ **Fact** ☑ **Fiction**	1.	Radioactive waste remains radioactive forever. **Some radioactive materials and radioactive waste may remain radioactive for hundreds or thousands of years, while others only remain radioactive for seconds or days.**
☑ **Fact** ☐ **Fiction**	2.	People who live in Denver, Colorado, receive more exposure to cosmic radiation than people living in Florida. **Even though Florida is known as the "Sunshine State," people at higher altitudes receive more exposure from cosmic radiation than people who live at a lower altitude.**
☐ **Fact** ☑ **Fiction**	3.	Radiation from a tanning bed is more harmful than radiation from the sun. **Our bodies do not differentiate between types of radiation; they absorb radiation as energy regardless of the source, dose or type**.
☐ **Fact** ☑ **Fiction**	4.	If you are exposed to radiation you will develop cancer. **We are regularly exposed to some amounts of radiation. Our bodies have "repair genes" that help cells repair themselves from radiation exposure, much like the way our bodies heal from a sunburn or injury. However, large doses or long-term exposure to radiation may damage our body's DNA to the extent that it cannot repair itself. The extent of the damage depends on the total amount of energy absorbed, the time period (duration) and dose rate of the exposure, and the particular organs exposed. Also, everyone reacts differently to radiation exposure.**
☑ **Fact** ☐ **Fiction**	5.	Suntans are the result of skin damage from the sun. **Suntans and sunburns are both types of sun damage. The fading of a suntan is a sign of the skin repairing itself.**
☐ **Fact** ☑ **Fiction**	6.	Most radiation that we are exposed to is man-made. **Approximately half of our annual radiation exposure comes from natural sources like cosmic rays from outer space or radon gas in the soil. This is called "background radiation." The other half of our annual exposure comes from man-made sources of radiation.**
☑ **Fact** ☐ **Fiction**	7.	Living near a nuclear power plant poses less risk of radiation exposure than living in a home or area with high radon levels. **Radon exposure accounts for 37 percent of our annual exposure to radiation, and living in a home or area with high radon levels can be very harmful to your health. Nuclear power plants implement many radiation protection measures to limit your exposure to radiation. Therefore, living near a power plant barely increases your radiation exposure.**

☑ **Fact** ☐ **Fiction**	8.	You should keep track of the number of medical x-rays and scans you have received. **By tracking the number of medical x-rays and scans, you can better assess and control your exposure to radiation.**
☐ **Fact** ☑ **Fiction**	9.	Exposing food to radiation makes it radioactive. **Food irradiation is a technology for controlling spoilage and eliminating foodborne pathogens (e.g., salmonella). Like pasteurization, irradiation kills bacteria and other pathogens that could otherwise result in spoilage or food poisoning. Irradiation is safe and does not cause food to become radioactive.**
☐ **Fact** ☑ **Fiction**	10.	All glow-in-the-dark items contain radioactive sources. **When radium was discovered in the early 1900s, people were fascinated with its mysterious glow. The hands and faces of some clocks, watches, and ship and airplane instruments were painted with radium to make them glow in the dark. Over time, however, experts discovered that radium is highly radioactive and emits alpha, beta, and gamma radiation. Some glow-in-the-dark items like road signs, exit signs, clock dials and watches may contain tritium or promethium. However, non-radioactive sources are also becoming more widely used. If unsure of the glow-in-the-dark source, you should take precautions to handle and/or dispose of the item safely.**
☐ **Fact** ☑ **Fiction**	11.	Radiation was discovered during World War II when the atomic bomb was developed. **Radiation is all around us and has been present since the birth of this planet.**
☐ **Fact** ☑ **Fiction**	12.	Radiation exposure will cause you to glow. **While many fictional movies and the media have portrayed this, radiation does not cause you to glow.**
☑ **Fact** ☐ **Fiction**	13.	Cigarettes are a source of radiation exposure. **Naturally-occurring radioactive minerals accumulate on the sticky surfaces of tobacco leaves as the plant grows, and these minerals remain on the leaves throughout the manufacturing process.**
☑ **Fact** ☐ **Fiction**	14.	Children are more sensitive to radiation than adults. **Children are growing more rapidly than adults. There are more cells dividing and a greater opportunity for radiation to disrupt the growth process. Recent U.S. Environmental Protection Agency (EPA) radiation protection standards take into account the differences in sensitivity due to age and gender.**