Teacher's Guide to

Health and Physics

A Grade 12 Manitoba Resource for Health and Radiation Physics

Canadian Cancer Society Société canadienne du cancer

Manitoba

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acknowledgements

The Manitoba Division of the Canadian Cancer Society and Manitoba Education, Citizenship and Youth gratefully acknowledges the contributions of the following individuals in the development of *Health and Physics: A Grade 12 Manitoba Physics Resource for Health and Radiation Physics.*

This resource, and its associated *Student Resource Guide,* were conceived and developed to assist students in achieving the learning outcomes for the "Medical Physics" topic in the Manitoba Grade 12 Physics curriculum. It provides a context for real-world applications of the fundamentals of radiation physics, with important connections to the health and well-being of the people of Manitoba.

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MINISTER OF EDUCATION, CITIZENSHIP AND YOUTH

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CANADA

To the Teachers of Manitoba:

It is with great pride that I announce the publication of *Health and Physics: A Grade 12 Manitoba Resource for Health and Radiation Physics* to support the teaching and learning experiences of your physics students. This is an important and timely resource to contextualize your approaches to this content area. It explores the safe and necessary applications of radiation to diagnostic imaging techniques, introduces the field of medical physics, and examines the treatment options used for various cancers. It constitutes the fruit of a long-standing and successful collaboration between the Manitoba Division of the Canadian Cancer Society and Manitoba Education, Citizenship and Youth (MECY).

Though great progress has been made in areas such as early detection and prevention strategies, there is an expectation that most Canadians will directly deal with cancer and/or its treatment among family members at some point. This is why having an education about the technologies involved in the fight against cancer will provide a firmer basis for healthcare decision-making down the road.

Manitoba students and their families are encouraged by the prospects of better detection and improved outcomes for cancer patients, and we believe that a sound science education in this area contributes to wider understanding of the complex field of cancer research, diagnosis and treatment. This partnership with the Canadian Cancer Society demonstrates a commitment to relevant, high-impact science education here in Manitoba. My hope is that this new resource will improve students' healthcare system awareness as it increases technical knowledge in applying science to vital human needs.

Sincerely,

Honourable Peter Bjornson

Canadian Cancer Society Société canadienne du cancer
MANITOBA DIVISION

July 23, 2009

Dear Students and Teachers of Manitoba,

The Manitoba Division of the Canadian Cancer Society has been pleased to fund this interesting and informative curriculum guide in health physics - *Health and Physics – A Grade 12 Manitoba Physics Resource for Radiation and Health Physics* and its associated Student Resource Guide. The project has been a partnership and fruitful collaboration among many individuals and organizations, including: students and teachers of physics who assisted in the pilot phases, the Department of Education, Citizenship and Youth's science consultants, medical physics expertise from CancerCare Manitoba and the St. Boniface Hospital Research Centre, and our staff here in the Manitoba Division of the Canadian Cancer Society.

The Canadian Cancer Society, Manitoba Division allocated donor dollars to this project as a demonstration of its commitments to public education in the sciences and to the well-being of all Manitobans. Our mandate is to serve all Manitobans who are at risk of developing cancer as well as those with cancer. We invested in this project as a meaningful connection to young adults, with the conviction that informed citizens are stronger advocates for their own health and the health of their families.

We believe that the information in the physics resource material will be of interest to students and their parents as the information is an excellent reference guide to imaging technology that is critical to much of health care. Imaging and radiation physics is also a core part of the cancer patient experience.

We are proud to have been associated with this project, and hope that students, teachers and families will find the material informative and useful for their future.

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table of contents

chapter 1
Radiation-Based Diagnostic Technology

Prior Knowledge: The Bohr Model of the atom was introduced in Grade 9 science. As well, the four fundamental forces were introduced in Grade 11 physics. Students should recall the formula relating velocity, frequency and wavelength from Grade 11 physics ($v=\lambda f$), as well as the measurement units for frequency (Hertz).

Terms You Should Know: The list below highlights important terms beyond what is listed at the end of the chapter in the Student Resource. Teachers could use either list as a knowledge activation activity—have students create a concept map or definitions frame—or as a review of concepts.

**Note that this list of terms is not intended to be a list for memorization. It is here to help the teacher incorporate new concepts into activities.*

alpha decay	hemorrhage
alpha particle	Hertz (Hz)
arthrography	hot spot
attenuation	isotope
benign	mammogram
beta decay	mammography
beta particle	N-ray
calcification	PET (Positron Emission Tomography)
cathode ray tube	photon
CT (Computed Tomography)	positron
CT scanner	radiation
cold spot	radiograph
density	radiopharmaceutical
electromagnetic radiation	radiotracer
electromagnetic spectrum	subdural trauma
electromagnetic wave	tomograph
electron	tomography
electron-volt (eV)	transmutation
frequency	tumour
gamma ray	wavelength
health physics	x-ray
	UV radiation

Chapter Summary: This chapter introduces the concept of X radiation and three types of diagnostic technology that use X radiation: Positron Emission Tomography (PET), Computed Tomography (CT), and the X Ray machine.
The chapter includes a brief review of the electromagnetic spectrum.

Blackline Masters/Enlarged Images: At the end of this set of answers and solutions to chapter 1's questions, there are enlarged images from the Student Resource guide, ready for either projection (display) or photocopying.

activity

Page 3 | Tissue Attenuation"

How much light goes through the single layer of tissue paper will depend on the thickness of the paper and on the brightness of the flashlight. Tissue paper thickness relates to human tissue density (for x-rays). Brightness of the flashlight relates to energy levels of the x-rays: the brighter (or more energetic) the rays are, the more they get through. (This does not necessarily mean that a clear image of tissue will be produced with more energetic x-rays!) Less light should travel through the double layer of tissue paper than the single layer. The more dense the material, the less light rays travel through. In a similar fashion, the more dense the tissue is, the less x-rays travel through and the darker the area on the radiograph.

Page 7 | "Questions: Electromagnetic Spectrum"

❶ Calculate the wavelength of sound waves that an FM radio station broadcasts using 88MHz broadcasts.

Students should recall the formula v=λf.
Solving for λ... $\lambda = v/f = (343\ m/s)/(88\ 000\ 000\ Hz) = 3.90\times10^{-6}\ m$

❷ What is the difference between "soft" and "hard" x-rays (mentioned in Figure 1-2)?

Soft x-rays have lower energy and longer wavelengths than the higher energy shorter wavelength hard x-rays. X-rays with energies between 10 keV and a few hundred keV are considered hard x-rays. Soft x-rays have less than 10 keV of energy.

❸ What is the wavelength used by cell phones compared to the wavelength of PET scans? Which carries more energy?

The wavelength of cell phones is approximately 0.3 metres, and their frequency ranges from 800 to 900 MHz. Different cell phone companies use different "bands" or ranges of frequencies. PET scanners use gamma (γ) radiation with a wavelength of below 10 picometres (1 picometre = 10^{-12} metres) and a frequency of between 1018 and 1021 Hz. Gamma radiation carries more energy than that used by cell phones.

❹ What is the difference between UV-A and UV-B light?

UV-A light has wavelengths between 315 and 400 nm and is sometimes referred to as "long wave" ultraviolet light. UV-B light has wavelengths between 280 and 315 nm and is "medium wave" UV light. UV-A light is considered the safest of the three types of UV light because it has lower energy and longer wavelengths than UV-B. The higher energy and shorter wavelengths in UV-B can cause sunburns and damage collagen. UV-A light can cause DNA damage, but only indirectly. UV-A light's longer wavelength means less of it is absorbed by the skin, but still has the potential to speed up skin aging and cause wrinkles.

❺ What is the difference between sound waves we hear and ultrasound?

Ultrasound involves a repeated cycle of sound with a frequency of 20 kHz, higher than the upper limit of human hearing. This sound cycle can be used to reflect off of objects and is used in sonography to produce images. Humans can hear sound with frequencies between 20 Hz (a low bass note) and slightly less than 20 kHz. The range of frequencies that can be heard varies from person to person, with younger individuals usually having larger ranges and the ability to hear higher and lower frequencies.

Page 8 | "Research Questions"

Why use iodine in arthrography and not other elements? What does calcification mean?

Iodine is used in arthrography because it is a dye which is both air and water soluble. Arthrography involves x-rays of joints, which can either be fluid-filled or not. Thus, iodine is an appropriate choice due to its solubility: it is also economical. Calcification is another term for the hardening of tissue due to calcium deposits. Calcification can show up on an x-ray.

Page 9 | "Question"

Note that the wrist joint of Figure 1-3 is brighter than the finger joints. What does this tell you about comparative bone densities or thicknesses? *Brightness on x-rays indicates less dense material. Therefore, the wrist joint for this individual is either less dense than, or not as thick as, the finger joints on this radiograph.*

Page 10 | "Activity: X-Ray Analysis"

Below are nine different x-rays of various parts of the human body. Imagine you are the x-ray technician asked to analyze each radiograph. Do you see something that is unusual? What do the unusual sections potentially indicate? Why are some areas of the x-rays brighter? For each image, discuss with your class whether the differences in brightness are more likely due to density, thickness, or the nature of the material (attenuation coefficient).

In general, the more dense tissue will be shown by darker areas on each of the images. Brighter x-rays indicate images taken of less dense tissue or bone, or of a radiotracer enhancing the image.

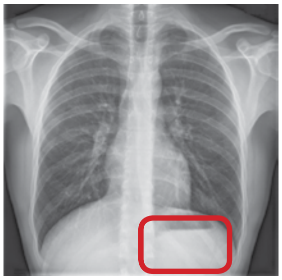
Figure 1-5

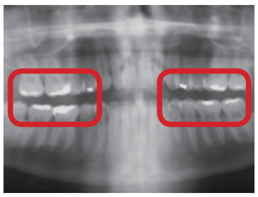
Figure 1-6/1-7


Figure 1-8

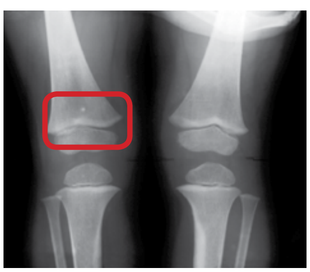
Figure 1-9

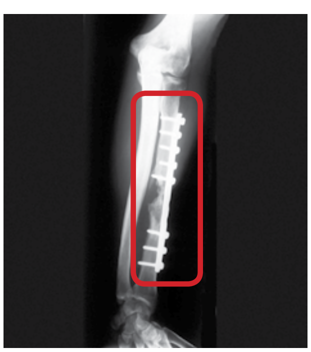
Figure 1-10

Figure 1-5: shows no broken bones. Shadow area at bottom right of x-ray may be cause for analysis—darker area means more density, and may indicate possible tumour growth.

Figure 1-6 (molars): show healthy roots and no bright areas indicating fillings.

Figure 1-7 (panoramic dental): teeth all seem to have healthy roots, however individual obviously has fillings on top and bottom teeth (bright spots).

Figure 1-8 (forearm): this x-ray confirms that there is a fracture to the forearm (broken bone!). Note—an interesting side note for students would be to compare figure 1-8 with figure 1-4. Both are images of wrists, however the bones are very clear in 1-4 and not clear in 1-8. The image in 1-8 is of a child's wrist, whereas the image in 1-4 is of an adult's wrist. You may want to point out that the bones in the child's wrist have not yet formed and are still mostly cartilage.

Figure 1-9 (knees): colouration all similar except for one bright spot on top left—calcification maybe? (Explain to students that calcification is a process where calcium builds up in soft tissue, causing it to harden.)

Figure 1-10 (forearm): this x-ray shows a broken forearm with a splint –attached by eight screws.

Figure 1-11 (colon): colon (on the right of the image) indicates no obvious change in colour. The left of the image shows the spine of the individual—no broken bones!

Figure 1-12 (skull): image shows no fractures in skull structure. Students may ask why there is a bright spot in the central brain area. This individual has ingested a contrast agent which travels through the blood stream and can help indicate bloodflow patterns in the brain if a functional MRI (fMRI) is performed.

Figure 1-13 (breast): the brighter circle on this image can indicate calcification (as in image 1-9) or a possible tumour. Further analysis, such as a biopsy (surgery to obtain sample of the area), would have to be done to be more definitive in the analysis. Ultrasound is also useful in determining if a structure such as this is fluid filled or a solid mass.


Figure 1-11

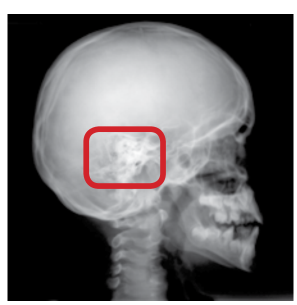
Figure 1-12


Figure 1-13

activity

a PET Radiotracer jigsaw

Your teacher will divide the class into four different groups. Each group will be assigned one of the questions below to research. Each group member should take notes and be prepared to explain the concepts.

1. How are each of the four radiotracers used for PET scans created? Which country (or countries) produces them?

2. If the process is called Positron Emission Tomography, why does the technology measure gamma rays and not positron emissions?

3. Technicians look for "hot spots" on the PET scans as well as for areas of inactivity or "cold spots" (blue/green areas). What types of body functions or diseases can hot spots (red/orange areas) potentially indicate other than cancerous tissue? What types of body functions or diseases can cold spots indicate to the technician?

4. Two photons per atomic decay are emitted, striking detectors mounted on linearly opposite sides of a ring that surrounds the patient in the PET scanner. How does conservation of linear momentum explain the motion of these two photons?

Once each group has completed their research and note-taking, your teacher will redistribute you into new groups of four people each. Each of the new groups will contain one person from each of the old groups. When you share your research results in your new group of four people, you should have a complete set of answers to the four questions.

Page 12 | "Research Questions: Mammography and Alternatives"

What exactly does a positive test result mean for a mammogram? (Cancer? A calcium deposit? A benign tumour? Something else? All of the above?)

A positive test result on a mammogram means that there is an abnormality on the x-ray. An abnormality must be analyzed further to determine whether it is calcification, a benign tumour, a malignant (cancerous) tumour, or simply an artifact.

What other types of diagnostic technologies could be used to confirm or deny the positive test results?

Other forms of technology used to confirm or deny positive test results include having a biopsy done, where a sample of the abnormality or growth is surgically removed and analyzed further. Doctors could order other diagnostic tests such as a CT scan or an MRI to obtain a better image of the abnormality for analysis.

Research and compare rates of breast cancer in males and females of similar ages. Are they the same or different? Why?

According to the Canadian Cancer Society, an estimated 22,400 women were expected to be diagnosed with breast cancer in 2008 and some 5,300 would eventually die from it (Canadian Cancer Society, 2008). An estimated 170 men would be diagnosed with breast cancer and 50 will die of it. Students can go to www.cancer.ca to find provincial and national breast cancer statistics. Men have breast tissue just like women, and can develop breast cance though rarely. The rate of breast cancer in men is much lower, however. It is thought that the reason for this disparity is because men do not have the breast tissues per se that in women are the chief locations of tumour growth. For instance, cancer cells may thrive within the ducts (this is called ductal carcinoma) or in the lobules (lobular carcinoma). Ductal carcinoma is the most common type of breast cancer., The hormonal complexity of a woman's physiology may offer a hidden pre-cursor to cancer development as well, though not substantiated.

Page 15 | "Activity: X-Rays and CT Scans—The LINKs"

Many answers are possible.

"Activity: A PET Radiotracer Jigsaw"

1. How are each of the four radiotracers used for PET scans created? Which country (or countries) produces them?

   Oxygen-15 (15O), nitrogen-13 (13N), carbon-11 (11C) and fluorine-18 (18F) are all created by the same general process. A "mini" cyclotron (room-sized) is used to accelerate negative hydrogen ions and impart large amounts of energy to them. Once optimum energy levels are reached, the hydrogen ions are sent through carbon filters to strip them of their electrons. This converts them into a beam of protons which can be directed at a target. The target is usually a stable form of the isotope desired.

   Oxygen-15 has a half life of under two minutes; nitrogen-13 has a half life of under ten minutes; carbon-11 has a half life of under twenty minutes; fluorine-18 has a half life of under two hours.

   Water containing oxygen-15 (the radioactive isotope of oxygen) is used as a blood-flow tracer. Fluorine-18 is typically placed in a sugar-water mixture and used to analyze brain activity and cancerous growths. Ammonia containing nitrogen-13 is often used for heart research.

   The highest resolution PET scanner can be found at Berkeley Labs in California, where the first cyclotron was created. Canada has over a dozen facilities with PET scanners and cyclotrons used to produce the radiotracers used with this technology. The positron emitting isotopes used in PET have a very short half-life and are ideally produced onsite with a cyclotron. If there is no onsite cyclotron, a maximum travel time of only a few hours can be tolerated.

2. If the process is called Positron Emission Tomography, why does the technology measure gamma rays and not positron emissions?

A positron is the antimatter particle of the electron. It has the same mass as an electron but has a charge of +1. In positron emission tomography, a radiotracer is used that decays by emitting a beta-plus particle (positron) and gamma radiation. Though the process involves creation of positrons, the technology (PET scanner) registers the emissions of gamma rays by the radioactively decaying radiotracer.

3. Technicians look for "hot spots" on the PET scans as well as for areas of inactivity or "cold spots" (blue/green areas). What types of body functions or diseases can hot spots (red/orange areas) potentially indicate other than cancerous tissue? What types of body functions or diseases can cold spots indicate to the technician?

PET scans are used to analyze brain functioning or brain activity. The radiotracers used collect in areas of activity. Thus, hot spots can indicate areas of high activity, which could mean that a lot of energy is being used to create cancerous cells.

Hot spots can also indicate areas of high brain activity. Researchers can use this trait to determine the levels of activity or functionality of different areas of the brain when, say, a person is attempting to do mathematical calculations, or which areas of the brain become active when speech occurs. Cold spots, alternatively, can indicate lack of brain activity. Researchers studying Alzheimer's Disease have used PET scans to determine which areas of the brain are no longer functioning for patients with this disease.

4. Two photons per atomic decay are emitted, striking detectors mounted on linearly opposite sides of a ring that surrounds the patient in the PET scanner. How does conservation of linear momentum explain the motion of these two photons?

Total linear momentum of a system remains constant because of the law of conservation of momentum. The total momentum of the isotope before decay will equal the total momentum of the two released photons after decay. The two photons travel in opposite directions and strike oppositely located detectors: because they travel in opposite directions with equal momentum, there is a total linear momentum of zero. They must have a total momentum of zero after decay because before decay the isotope has a total overall momentum of zero.

"Activity: The Great Debate Should Patients Have the Right to Choose?"

Many answers are possible.

activity

THE GREAT DEBATE Should Patients Have the Right to Choose?

Based on the opposing viewpoints offered in this chapter, think about what you would do if faced with a decision whether to have certain of these diagnostic procedures in your own diagnosis. If it were possible, would you request the use of technology not involving ionizing radiation? Why (not)? Would you allow radiation-based technology to be used if that was the only way to obtain an effective image for proper diagnosis? Do the benefits of using radiation-based technology outweigh the risks? Should this type of health care service be free, or should patients pay extra for what can be expensive diagnostic procedures and treatments? Be prepared to justify your opinion.

Your teacher may set up the class into two opposing groups for a debate to either defend or refute the following statement:

"Patients should have the right to refuse the use of radiation-based diagnostic technologies during their own diagnoses. If they are given the right to choose the diagnosis technique, then they should have to pay for it too."

extra chapter follow-up questions

1. How does an atom become ionized?
2. Define non-ionizing radiation.
3. List examples of non-ionizing radiation.
4. List examples of ionizing radiation.
5. Does infrared light affect humans? Explain.
6. Do microwaves burn deep-tissue? Explain.
7. What are the three types of UV rays?
8. Which UV ray causes the most human sun damage?
9. Which UV ray causes the most aging of skin?
10. Does sunscreen protect from all 3 types of UV rays? Explain.
11. Define ionizing radiation.
12. Explain how these particles are related to ionizing radiation: alpha particles, beta particles, neutrinos.
13. Is ionizing radiation damaging to a human? How?
14. Define gamma radiation.
15. How can you mathematically determine the amount of gamma radiation a substance will absorb?

THE ELECTROMAGNETIC SPECTRUM

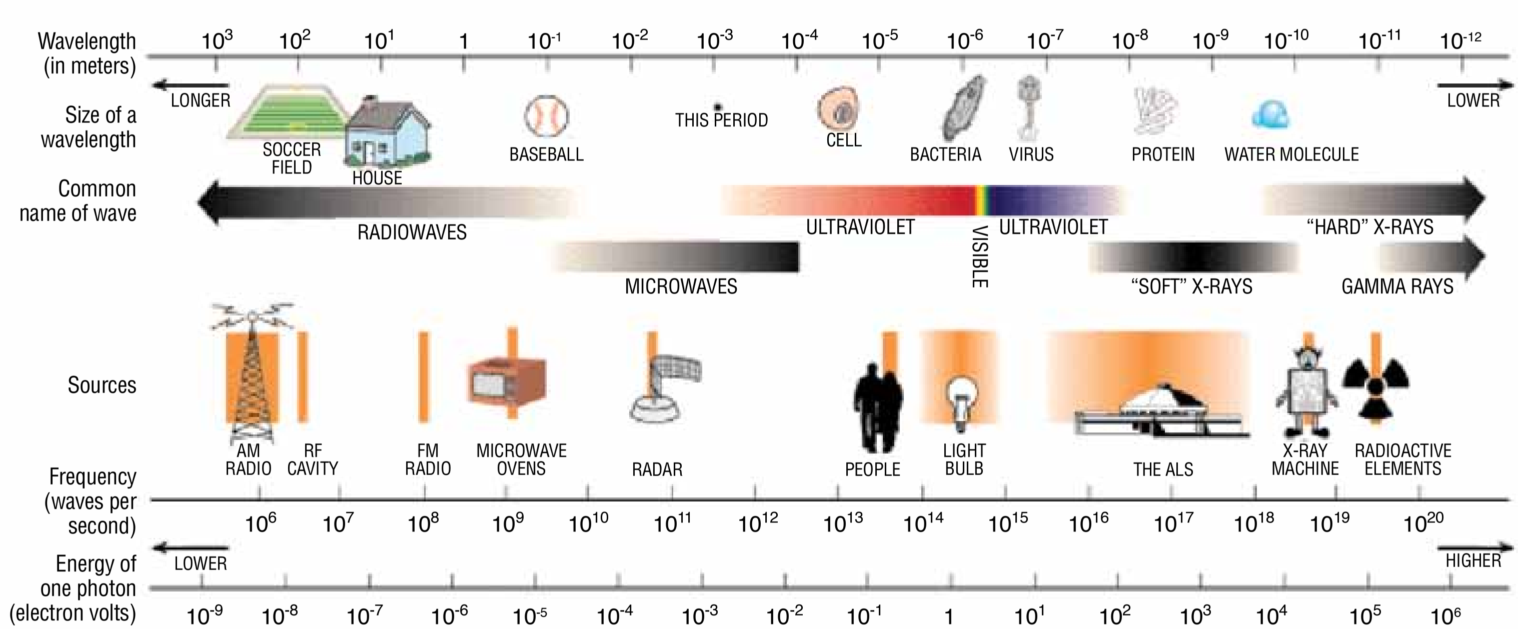

Figure 1-5 enlarged

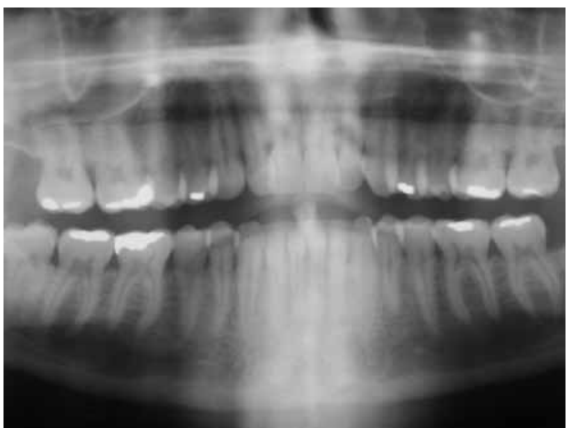

Figure 1-6 enlarged

Figure 1-8 enlarged

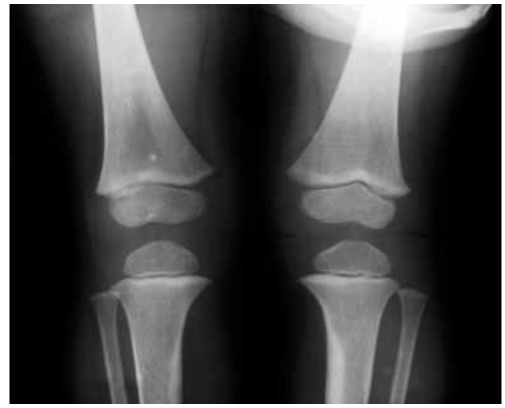

Figure 1-9 enlarged

Figure 1-10 enlarged

Figure 1-11 enlarged

Figure 1-12 enlarged

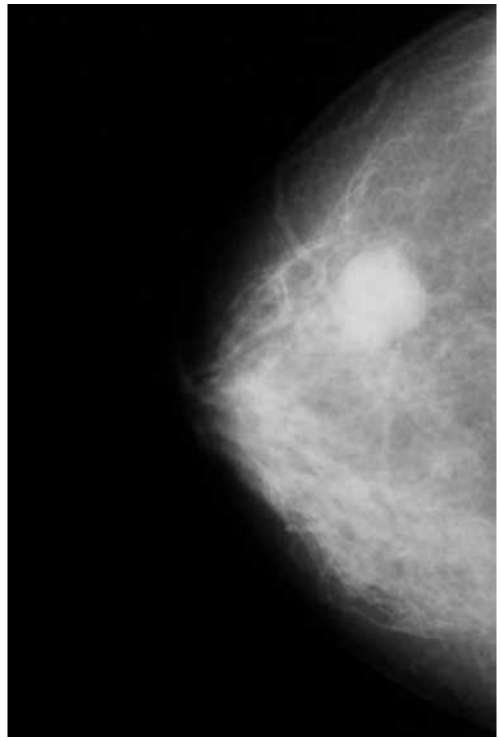

Figure 1-13 enlarged

The image here is of a "creation mural" inside one of the schools in Pripyat, Ukraine. The photograph was taken in 2003 by Winnipeg arts professor Dr. David McMillan, who has an interest in documenting the "return to nature" of the human-constructed world in and around the Chernobyl nuclear power facility . The so-called 30-kilometere Exclusion Zone surrounding the science city of Pripyat is still so radioactive, humans cannot live there for the foreseeable future. This is a good opportunity to assess the benefits and risks of operating a nuclear facility without the necessary safeguards against the release of radioactive isotopes. Many more images and commentary can be found online at:
http://home.cc.umanitoba.ca/~dmcmill/index.html

chapter 2

Other Forms of Diagnostic Technology

Prior Knowledge: The Bohr Model of the atom was introduced in Grade 9 science. As well, the four fundamental forces were introduced in Grade 11 physics. Students should recall the formula relating velocity, frequency and wavelength from Grade 11 physics ($v=\lambda f$), as well as the measurement units for frequency (Hertz). In this chapter, prior qualitative knowledge in magnetism is important.

Terms You Should Know: There is a list included here and at the end of the chapter highlighting important terms. Teachers could use this list as either a knowledge activation activity—have students create a concept map or definitions frame—or as a review of concepts.

Note that this list of terms is not intended to be a list for memorization or to provide lists of definitions. It is here to assist the teacher in the incorporation of new concepts and terminologies into the learning activities.

atomic number	barium
cobalt-60	colon
colonoscopy	Doppler Effect
electromagnetic field (EMF)	endoscope
enema	fibre-optic light
gadolinium	Hace 1 Gene
isotope	MRI (Magnetic Resonance Imaging)
magnetic field	mass number
radiofrequency coil	radium
transducer	ultrasound

Chapter Summary: This chapter introduces the concept of using non-radiation based technologies for diagnosis, including Magnetic Resonance Imaging (MRI) and Ultrasound. The chapter includes a brief description of Canada's role in isotope production, used in radiation-based technologies.

Blackline Masters/Enlarged Images: At the end of this set of answers and solutions to chapter 1's questions, there are enlarged images from the Student Resource guide, ready for either projection (display) or photocopying.

Page 19 | "Research & Extension Questions"

1. Why is gadolinium used as a contrast agent for MRI scans? Why wouldn't they use barium? Or cobalt?

   To find answers, students can use a search engine on the internet and type in phrases such as "gadolinium and contrast agent," "barium and contrast agent," etc.

   Gadolinium is a contrast agent injected intravenously. Gadolinium stays in blood vessels, which makes arteries, veins, and potential blood leakage highly visible in MRI scans. Gadolinium leaves the body through the kidneys, with a half life of 1-1.5 hours. While the MRI can be done without a contrast agent, gadolinium allows for greater detail and definition in the image produced. This makes diagnosis easier.

   The contrast agent barium is used in digestive tract analysis, but cannot be safely injected into the blood stream. Barium comes in the form of a dense liquid which coats the digestive tract to show any bumps or abnormalities on x-ray radiographs. Cobalt-60 is used in radiation treatment as it has a longer half life than gadolinium. Radioactive tracers such as cobalt-60 need to have short half-lives so that the radiation leaves the body quickly after the procedure is complete to allow the patient to return home safely.

A "Play on Words"

Form a group of three to four people. Create a drama that describes how one of the forms of diagnostic technology works. Your play must include the following:

1. Correct usage of the terminology in the previous chapters;
2. All group members must have an equal amount of time on stage;
3. Your play must have at least one portion which enacts what occurs at the atomic level when your chosen diagnostic technology is being used;
4. The following terms must be incorporated into the play: isotope, atomic mass, electromagnetic spectrum, gamma ray, and positron.

Your drama will be marked for scientific accuracy, clarity, creativity, and whether the four elements above have been incorporated and to what extent.

2. Discuss with a classmate what the list of general characteristics may be that would qualify an isotope as a "good" choice for use in diagnosis.

   Many answers are possible. Some possibilities: short half life; slim to no adverse side effects; provides clear images.

3. Could gadolinium be used in PET scans? Why (not)?

   Gadolinium is ferro-magnetic and useful as a contrast agent rather than a radioactive tracer which PET scans require. Isotopes of oxygen, nitrogen, carbon, and fluorine are used instead. These isotopes are used for their very short half lives and their ability to travel to and collect in areas where greater amounts of energy (glucose) are being used. Gadolinium cannot indicate brain activity as it remains in blood vessels. Gadolinium could be used in PET scans if the technician is attempting to analyze blood flow (or blood clotting) in the brain.

Page 25 | "Internet Activity: The Visible Human Project®"

Teachers may want to explore this website prior to students using it. Alternatively, a discovery approach with teacher and students exploring together can also be used. The three specific links provided at the end of this activity are good starting points for guided explorations.

Page 27 | "Activity: Concept Map"

Using the same vocabulary list as Activity III, create a concept map for RADIATION (like a spider-web that shows how the concepts are interconnected) to link the vocabulary together.

Many answers are possible.

"Activity I: A Play on Words"

Many answers are possible.

"Activity II: Compare and Contrast: CT and PET Scans"

How are CT and PET scans alike? How do CT and PET scans differ?

Many answers are possible. Some suggestions for similarities: both can use radiotracers; both are used to analyze internal organs/tissues. Some suggestions for differences: PET scans monitor brain activity (energy use), while CT scans can monitor other areas of the body too.

"Activity III: Sort and Predict"

Read the list of words below and sort them into four different categories, choosing the names of your categories carefully. When selecting categories, try to make the fourth category different than any other category of which your classmates would think. Be original!

Many answers are possible.

"Activity IV: CT and MRI Online Exploration"

Go to The Visible Human Project® online to perform a detailed exploration of an area of the body, or specific body part of interest to you. You can work with either a female or male "virtual subject." Your objective is to find out what the current state of research is with respect to your chosen area of focus: what function does this region have, how large are the structures involved, how do their tissue densities differ if you were to image the area. Come up with an interesting way to communicate your results to others

URL: http://www.nlm.nih.gov/research/visible/visible_human.html

There are many different areas that have been studied by the Visible Human Project. Teachers may want to divide the class into groups and have each group research one area. Students could present their findings using a "jigsaw" approach, or do presentations in front of the class. Note that page 25 of the Student Resource Booklet has examples of specific areas in the site students may explore.

activity 2

Compare and Contrast: CT and Pet Scans

Sometimes the essential vocabulary words of this module are very similar to each other. This encourages you to go beyond a simple definition of two words, and to describe how the two words are similar (compare) and how they are different (contrast). Create a larger version of the chart below and fill it in.

Compare: How are CT scans and PET scans different?

CT Scans	PET Scans

Contrast: How are CT sans and PET scans different?

CT Scans	PET Scans

Compare your chart to your classmates' charts: what's similar? What's different?

activity 3

Sort and Predict

Read the list of words below and sort them into four different categories, choosing the names of your categories carefully. When selecting categories, try to make the fourth category different than any other category of which your classmates would think. Be original!

Barium
Radiograph
Distance
Contrast
Tissue
Electron
Hemorrhage
Gamma ray
Gadolinium
Density
Endoscope
Isotope
Tumour
Attenuation
Electromagnetic
Frequency
Wavelength
Colonoscopy
Alpha
Beta
Transmutation
Tomography
Radiotracer
Doppler Effect
Atomic number
Carbon-14

activity 4

CT and MRI Online Exploration

Go to The Visible Human Project® online to perform a detailed exploration of an area of the body, or specific body part of interest to you. You can work with either a female or male "virtual subject." Your objective is to find out what the current state of research is with respect to your chosen area of focus: what function does this region have, how large are the structures involved, how do their tissue densities differ if you were to image the area. Come up with an interesting way to communicate your results to others

URL: http://www.nlm.nih.gov/research/visible/visible_human.html

activity 5

Radiation Exposure

Supplies: broom, dustpan, red confetti, white confetti, and an area to do this activity where cleanup will be easy.

Background: Researchers estimate that if finely divided uranium oxide (or its equivalent) is ingested or inhaled, 95-99% of it leaves the body, with only 1-4% remaining to cause potential long-term radiation exposure effects. Researchers estimate that individuals working in nuclear research facilities will have up to four times the amount (16%) remain in their bodies for the long term, due to chronic exposure despite safety precautions and equipment.

PART A Setup: Mix 4 pieces of red and 96 pieces of white confetti in a bag. Have one classmate stand (carefully) on a chair slowly sprinkling confetti from the bag as the class walks underneath. Some confetti will fall on classmates; some will fall to the side.

Analysis: Locate where the four pieces of red confetti landed. How many landed on people? How many landed on the floor? CLEAN UP ALL THE CONFETTI!

PART B Setup: Mix 16 pieces of red and 84 pieces of white confetti in a bag. Follow the same procedure and analysis as before. By how much did the number of people exposed to radiation (red confetti) increase? Again, CLEAN UP ALL CONFETTI!

Final Analysis: How do your confetti statistics match with the background statistics? What kinds of precautions do workers in nuclear research facilities take to minimize their radiation exposure?

"Activity V: Radiation Exposure"

Final Analysis: How do your confetti statistics match with the background statistics? What kinds of precautions do workers in nuclear research facilities take to minimize their radiation exposure?

When students compare their confetti statistics with background statistics, they should be able to explain why they are similar (or different). Variables that were (not) controlled should be discussed. When answering the final question, students should refer to protective clothing as well as monitoring devices (such as pins that emit a warning sound when radiation levels are too high).

chapter 3
Effects of Radiation on Humans

Prior Knowledge: Pre-calculus Mathematics or Applied Mathematics students will have seen exponential functions. Students will need to review the concept of "e" (2.71828183…) as well as scientific notation to complete calculations in this chapter.

Terms You Should Know: The list below highlights important terms beyond what is listed at the end of the chapter in the Student Resource. Teachers could use either list as a knowledge activation activity—have students create a concept map or definitions frame—or as a review of concepts.

Note that this list of terms is not intended to be a list for memorization or to provide lists of definitions. It is here to assist the teacher in the incorporation of new concepts and terminologies into the learning activities.

absorbed dose	malignant tumour
absorption coefficient (µ)	metastasis
alpha decay	microcephaly
alpha particle	microwaves
anaemia	neutrino
beta particle	non-ionizing radiation
biologically equivalent dose	positron
DNA	quality factor (QF)
dose rate	radiation absorbed dose (rad)
electron	relative biological effectiveness (RBE)
gamma radiation	roentgen (R)
genetic damage	roentgen equivalent, man (rem)
gray (Gy)	sievert (Sv)
incident intensity (I0)	somatic damage
infrared light	Systeme Internationale (SI)
ionize	ultraviolet A, B, or C (UVA, UVB, UVC)

Chapter Summary: This chapter includes an analysis of the four types of ionizing radiation: alpha, beta, gamma, and X. It also includes an analysis of non-ionizing radiation, getting into the somatic and genetic effects as well as measurement units for radiation. The relationship between types of radiation and the electromagnetic spectrum is highlighted in Figure 3-4.

Page 32 | "Activity: SunSense"

Check out the package of information and activities you can get called SunSense from the Canadian Cancer Society. It even includes some experiments that show how different sunblock lotions work! To obtain a free package for yourself (or for your whole class), go to http://www.cancer.ca Locate the regional office nearest you!

Page 34 | "Practice Questions"

1. Compare the number of non-absorbed gamma rays for a substance with a thickness of 30 cm and absorption coefficients of 0.000025 for an energy level of 1000 keV and 0.00027 for an energy level of 120 keV.

   First scenario: $I(d) = I_0 e^{-\mu d}$

   $I(d) = I_0 e^{-(0.000025x30)} = I_0 (0.99925)$

   Second scenario: $I(d) = I_0 e^{-\mu d}$

   $I(d) = I_0 e^{-(0.00027x30)} = I_0 (0.99193)$

   The second scenario has almost as many gamma rays absorbed as the first scenario.

2. If a substance that is 10 cm thick has 35 times as much gamma radiation passing through it when the rays carry 90 keV compared to 30 keV, determine the absorption coefficient for the higher energy gamma ray scenario. Assume $\mu = 0.018$ for 30 keV.

   We can use our knowledge of exponent rules to help us solve for µ.

   $35 = I_0 e^{-(10\mu)} / I_0 e^{-(0.018x10)}$

   or… $35 = e^{-(10\mu)} / e^{-(0.18)}$

   therefore… $35 = e^{-10}e^{\mu}/0.83527$

   so… $29.2345 = e^{-10} e^{\mu}$

   or… $29.2345/e^{-10} = e^{\mu}$

   $e^{\mu} = 643931.78$ *therefore* $\mu = \ln(643931.78) = 13.375$

Page 36 | "Cancer Warrior"

NOVA has provided this documentary online as well as activities and questions available for free use. Check out http://www.pbs.org/wgbh/nova/cancer/program.html for more details.

Page 36 | "In the Media: Questions"

How accurately does the movie portray the criticality incident? How accurately does the movie portray Louis Slotin?

The movie portrays the criticality incident with reasonable accuracy, with the exception of the blue "flash" (which, if researched, is still a phenomenon that is debated). Louis Slotin is portrayed as an individual from Chicago (with a different name), and his character is mostly fictitious in comparison to the real-life Winnipegger of that name. Teachers may want to read the biography of Louis Slotin found in the Winnipeg Free Press publication Greatest Manitobans.

Page 37 | "Questions"

1. What is standard temperature and pressure? How might the amount of ionization in air due to radiation change as temperature increases? How might the amount of ionization in air due to radiation change as pressure increases?

   Standard temperature and pressure is defined by IUPAC (International Union of Pure and Applied Chemists) as air at zero degrees Celsius and one atmosphere of pressure (101.325 kPa).

2. In human tissue, one Roentgen of gamma radiation exposure results in about one rad of absorbed dose. Why is this number (1 rad) an approximation?

   One Roentgen is approximately equal to one rad of absorbed dose because absorbed dosage depends on the type of tissue that is absorbing the radiation. Therefore this number is an average or an approximation.

Page 38 | "Research Questions"

1. Fiestaware was a popular style of dishes in the 1960s. However, we now know that Fiestaware releases low levels of radiation. Research why, and how much radiation (in rems) is released.

   Fiestaware contains Uranium-235, a radioactive isotope in a form of mineral pigment known as uraninite (uranium oxide, U3O8). The dye used in the glaze for these products contains the uranium isotope, chosen to be part of the glaze because it made the orange and red colours brighter and more vivid. Red Fiestaware, in particular, had higher amounts of uranium added to make the pottery a brighter red. Depending on the colour of the Fiestaware, pottery items can release anywhere from 50 to 5000 rems of radiation. Compare this to typical naturally occurring background radiation amounts which tend to be less than 2500 rems.

2. How many rems of radiation was Switzerland exposed to when the toxic cloud of radiation blew over their country from the Chernobyl disaster?

   Researchers have determined that the average individual effective dose Switzerland was exposed to ranged anywhere from 1 to 10 milliSieverts (or up to 1 rem) of radiation from 1986 onward.

Page 39 | "Calculation Questions"

1. An individual is exposed to the following forms of radiation: 20 mrad of gamma rays, 35 mrad of electrons, 10 mrad of protons, and 5 mrad of slow neutrons (RBE=2). Rank the types of radiation from highest to lowest, according to their biologically equivalent dose.

2. *Biologically equivalent dose=absorbed dose (in rads) x RBE*
   RBEs for gamma rays, electrons and protons are given in chapter 3 on page 9.

   Protons: Biologically equivalent dose = (0.005) x (10) = 0.05 rem
   Slow neutrons: Biologically equivalent dose = (0.005) x (2) = 0.01 rem
   Gamma Rays: Biologically equivalent dose = (0.005) x (1) = 0.005 rem
   Electrons: Biologically equivalent dose = (0.005) x (1) = 0.005 rem

3. If an individual is exposed to two different types of radiation where the absorbed doses are the same but RBEs are different, which type of radiation—the one with the larger RBE or the smaller RBE—will cause the greater damage?

   The one with the larger RBE will cause the greater damage.

4. The typical biologically equivalent dose for a chest x-ray is 2.5x10-2 rem. If the mass of exposed tissue is 19 kg and the energy absorbed is 5.9x10-3 J, what is the RBE for this type of radiation on chest tissue? How does this compare to the RBE for gamma rays?

   absorbed dose = energy absorbed/mass of absorbing material
   Biologically equivalent dose = absorbed dose x RBE
   therefore… *RBE = (biologically equivalent dose) / absorbed dose*
   $RBE = (2.5x10^{-2})/[(5.9x10^{-3})/(19)] = 80.5$

   This is eighty times larger than the RBE for gamma rays.

5. If you stand in an area where the dose rate for an unknown source of radiation is 40 mrem/hr for half an hour, what would your total dose of radiation be? If this radiation was aimed at your chest (as in question #3), with the same mass of exposed tissue and the same amount of energy absorbed, what is the RBE for this unknown source of radiation?

   total radiation dose = 0.040 x 0.5 = 0.020 or 20 mrem
   RBE = biologically equivalent dose/absorbed dose
   $RBE = (0.020)/[5.9x10^{-3})/(19)] = 64.4$

chapter 4
Radiation and Treatment

Prior Knowledge: The Bohr Model of the atom was introduced in Grade 9 science. As well, the four fundamental forces were introduced in Grade 11 physics.

Terms You Should Know: There is a list here and at the end of the chapter highlighting important terms. Teachers could use this list as either a knowledge activation activity—have students create a concept map or definitions frame—or as a review of concepts.

Note that this list of terms is not intended to be a list for memorization or to provide lists of definitions. It is here to assist the teacher in the incorporation of new concepts and terminologies into the learning activities.

anaesthesia	barium enema
biopsy	brachytherapy
Chernobyl	cobalt
collimator	colonoscopy
esophagus	fractionated treatment
gamma knife	intensity modulated radiation therapy (IMRT)
intracranial	linear accelerator (linac)
neurosurgeon	photodynamic therapy
radiation oncologist	radioisotope
radium	systemic radiation
teletherapy	

Chapter Summary: Chapter 4 discusses types of treatment involving radiation, including radioisotope therapy, brachytherapy, systemic radiation, teletherapy, and the gamma knife. At the end of the chapter is a featured biography of Dr. David McMillan, photojournalist and professor of arts at the University of Manitoba who has contributed two images of the setting around the science city, Pripyat, in Ukraine in the wake of 20 years of isolation from human activity. You can access a number of Dr. McMillan's images online at: http://home.cc.umanitoba.ca/~dmcmill/ . He has made at least six visits to the area since 1994, and his images provide a haunting time series of nature reclaiming a "dead zone."

Page 42 | "Question"

Is your water source chlorinated?

Students can contact the local municipal water treatment facility or their town council office to find out whether their local town water supply is chlorinated. What if their water source is a well? How might this alter the ability to have a water supply that is sufficiently free of, say, colliform bacteria? Also, consider the protocols for testing that are often put in place for wells after overland flooding events have occurred in agricultural regions.

Page 42 | "Activity: A Personal Cancer Journey"

Be sure to respect those students who do not wish to share details of close family and friends who may have experienced cancer.

Page 46 | "Question:"

Would there be complications if this technology (photodynamic therapy) were used to treat children?

This type of technology could be used on children, however the dosage amounts would have to be adjusted accordingly. If not, complications such as radiation poisoning could occur.

activity

In the Movies

"Erin Brockovich" (Jersey Films, 2000) tells the story of a concerned citizen who acted on behalf of Hinkley CA residents when their enviroment became toxic. Most viewers are of the opinion that this is a "radioactivity story." Through your research, find out if this is the casse, or, whether the effects seen in the local residents were related to "chemical" influences of a non-radioactive nature.

Page 49 | "Activity: Flashlight 'Beamlets':"

What problems occur? What variables do you need to control or change to obtain a better result? How do these results help in understanding IMRT?

Some problems are that the flashlight beams are not concentrated enough to light up only the image; the beams spread as they travel further away from the source; one flashlight beam may be brighter than another. To obtain a better result, we need to be able to concentrate the light and control the beam so it does not spread with distance away from the source. IMRT is similar in that these types of variables are controlled to ensure that only cancerous tissue is irradiated and healthy tissue is not damaged.

Page 51 | "Questions for Further Research:"

1. Which type of radiation therapy discussed in this chapter is the least invasive? Which one has the least impact on quality of life immediately after treatment?

   Photodynamic therapy, systemic therapy, or IMRT are the least invasive. All therapies which do not involve surgery have the potential to have the least impact on quality of life immediately after treatment as the patient can go home almost immediately after. If an isotope is taken internally, such as with systemic therapy, the patient may have to remain in hospital for a few hours until the radiation has left his/her body.

2. What types of treatment is your water plant using to make sure drinking water is safe? How have methods changed with time? Acknowledge your sources of information.

   Many answers are possible.

3. Why do you think it took more than 30 years to obtain gamma knife technology in Canada from the time of its invention? Justify your answer.

   Many answers are possible.

4. Research the Three Mile Island disaster that took place in Pennsylvania in 1979. Discuss the similarities and differences between this disaster and the Chernobyl disaster of 1986, both in terms of damage to the environment and in how the government handled the public health situation after that. Acknowledge your sources of information.

   On March 28, 1979, some of the coolant pumps failed on the second reactor at Three Mile Island (TMI) facility in Pennsylvania. This is unlike the Chernobyl disaster, which was ironically caused after safety tests went horribly wrong. The TMI disaster built up pressure in the reactor core: radiation was released to alleviate the pressure on March 30th. At the time, it was described as uncontrolled radiation release, however it was later determined that it was planned by the officials involved. This is similar to the Chernobyl disaster in that officials tried to hide at least some of the details from the public. All official reports of radiation exposure in the TMI area indicate that no person received a radiation dosage greater than what natural background radiation would provide in the environment over a calendar year.

   (Many more answers are possible.)

EXTRA ACTIVITY FOR CHAPTER FOUR:

"In the Movies:"

Research what the effects of this element were on the people of Hinkley, CA. Did the movie accurately portray the somatic and genetic effects?

Hexavalent chromium is toxic and carcinogenic. Hinkley drinking water had 0.58 parts per million of hexavalent chromium, well above the accepted level of 0.1 ppm. As a result, more than 25% of children ages five and up showed some form of disability or illness or even cancer. Liver cancer, kidney failure, respiratory and circulatory problems, gastrointestinal problems, reproductive problems (including miscarriages), and cancers of the brain and other body organs were some of the effects this isotope had on the population of Hinkley. Note: Be sure to distinguish for students that hexavalent chromium is NOT an isotope of chromium…it is a specific oxidation state of chromium. (Oxidation states may be worth exploring briefly if students have or are currently taking Chemistry courses.)

chapter 5
Radioactivity

Prior Knowledge: Pre-Calculus Mathematics and Applied Mathematics students will be familiar with exponential functions, including the radioactive decay function discussed in the chapter. A review of chapter three's units of measurements would be useful before the new units are introduced at the end of this chapter.

Terms You Should Know: There is a list here and at the end of the chapter highlighting important terms. Teachers could use this list as either a knowledge activation activity—have students create a concept map or definitions frame—or as a review of concepts.

Note that this list of terms is not intended to be a list for memorization or to provide lists of definitions. It is here to assist the teacher in the incorporation of new concepts and terminologies into the learning activities.

activity	Becquerel (Bq)
beta-minus particle	beta-plus particle
Curie (Ci)	daughter nucleus
decay constant	electromagnetic force
fission	fluorescence
fundamental force	Geiger counter
Geiger-Muller counter	gluon
half-life	Henri Becquerel
mass number	neutron
neutron ray	nucleon
quark	spontaneous fission
strong nuclear force	weak nuclear force

Chapter Summary: Chapter 5 explores the history of radioactivity and discoveries made over the past two hundred years. The nuclear model of the atom, radioactive decay, and half life are covered, and more units of measurement are introduced at the end of the chapter.

Page 55 | "Research Question:"

Research the June 2008 YouTube phenomenon of videos on "microwaves, cell phones, and popcorn" attempting to show how cell phones can take raw kernels of corn and convert them into popcorn. What is the hoax behind the videos? (How did they really pop the corn?) Was there any motive for promoting these videos on YouTube?

The videos claim that if you put three or four cell phones in a circle around some kernels of corn, and they all start ringing or vibrating at once, the kernels will pop because of the radiation being released by the phones. This is a hoax because cell phones do not release enough energy to pop even one kernel of corn. Most likely, there is a heat source underneath the table (they never show you what is under the table) which pops the corn. As for motives, students may offer many answers.

Page 57 | "Questions:"

1. If ^{14}C were to release an alpha particle, what would the daughter nucleus be? Write the chemical equation.

   Carbon-14's nucleus contains 6 protons and 8 neutrons. If it were to release an alpha particle consisting of two protons and two neutrons, the daughter nucleus would have four protons and six neutrons in it. The chemical equation for this process would be:

$$^{14}C \longrightarrow He^{2+} + {}^{10}Be$$

2. If ^{14}C were to release a positron, what would be the chemical equation for this process?

   Releasing a positron usually also involves releasing γ radiation. Carbon-14 would undergo the following chemical process if it were to release a positron:

   $$^{14}C \longrightarrow {^{14}C^{+}} + \gamma$$

3. If ^{14}C were to release a beta-minus particle, what would be the chemical equation for this process? Why might ^{14}C release a beta particle instead of alpha or gamma rays?

   $$^{14}C \longrightarrow {^{14}N} + e^{-}$$

   Releasing alpha particles or positrons (and gamma rays) cannot occur in isolation: it requires energy. Beta decay can occur spontaneously without an external energy source.

Page 58 | "Activity: The Half-Life of Pennies"

Many answers are possible.

Page 59 | "Calculation Questions:"

1. In 16 days the number of radioactive nuclei decreases to one-eighth the number present initially. What is the half-life (in days) of the mystery substance?

   ½ x ½ x ½ = 1/23 = 1/8 thus 16/3 = 5.33 days is the half life

2. Francine's thyroid disorder was treated with an isotope of iodine, 131I. If this isotope has a half-life of 8.05 days, what percentage of a pill remains after one month (30 days)?

   30/8.05 = 3.72 thus 1/23.723 x 100 = 7.55% is left after one month

3. To make the dials of 1950s watches glow in the dark, radium-226 is painted on. Assuming that the mass of paint ending up on one watch is one-billionth of a kilogram, how much radium, in kilograms, disappears while the watch is in use for 50 years? (Assume the half-life of radium is 1600 years.)

   ½ x 50/1600 x $(1x10^{-9}) = 1.5625x10^{-11}$ *kg left after 50 years*
   thus what disappears = $(1x10^{-9}) - 1.5625x10^{-11} = 9.84x10^{-10}$ *kg*

4. Two radioactive substances Q and X are being observed by researchers, with equal amounts at the start of the experiment. Three days later, there are three times as many Q atoms as there are X atoms. If the half-life of the Q atoms is 2.0 days, find the half-life of the X atoms.

   3/2 = 1.5 thus $1/2^{1.5}$ *x 100 = 35.4% left of Q after 3 days*
   35.4/3 = 11.8% left of X after 3 days
   11.8/100 = 3/? thus ? = 25.5 days, the ½ life of X

5. The number of radioactive atoms present at the beginning of an experiment is 5.0x1012. The number of radioactive atoms present thirty days later is 8.2x1011. What is the half-life (in days) of this substance?

   ½ x 30/h x $(5.0x10^{12}) = (8.2x10^{11})$ *where h = ½ life*
   Solving for h … h = 91.4 days

Page 61 | "Activity: Radioactivity of Household Objects"

Note that for this particular activity, you will likely need to disassemble the metal shield that surrounds the source to obtain readings from the Geiger Counter. Use this activity as an opportunity to compare class results in a laboratory setting.

extra chapter questions

1. How did Henri Becquerel accidentally discover natural radiation?
2. What other elements were discovered to be radioactive by the Curies?
3. Why did the use of radium get replaced? Which elements replaced it?
4. What are some disadvantages of using radium?
5. Define each of the following: isotope; strong nuclear force; electromagnetic force.
6. What does it mean for an isotope to be “stable”?
7. Describe the processes of spontaneous fission, alpha decay, and beta decay.
8. What are the differences among the three types of beta decay? What is the commonality amongst them?

chapter 6
Other Applications of Radiation

Prior Knowledge: The Bohr Model of the atom was introduced in Grade 9 science. As well, the four fundamental forces were introduced in Grade 11 physics. A review of subatomic particles

Terms You Should Know: There is a list here and at the end of the chapter highlighting important terms. Teachers could use this list as either a knowledge activation activity—have students create a concept map or definitions frame—or as a review of concepts.

Note that this list of terms is not intended to be a list for memorization. It is there to help the teacher incorporate new concepts into activities.

accelerator physicist	Atomic Energy of Canada Limited (AECL)
blogger	Canadian Nuclear Safety Commission (CNRC)
Chalk River Laboratories	electron beam
erythema	gamma ray
gamma scan	germicidal lamp
gigahertz	ionization
radiofrequency	radiowave
smoke detector	sterilization
synchrotron	World Health Organization (WHO)

Chapter Summary: Beyond diagnosis and treatment, this chapter looks at other uses of radiation. These uses include sterilization, tanning beds, communications, and microwave ovens.

Page 65 | "Did You Know: Research Question"

What are the effects of thallium poisoning on the human body? In what everyday products can thallium be found?

Thallium can be found in rat poison. Because thallium is so easily ingested into the system, consequences of thallium poisoning can be quick and severe. Stomach aches and damage to the nervous system can occur. With acute exposure to thallium, the damage is so irreversible that death occurs. If the individual survives poisoning, often irreversible damage to the nervous system occurs with shaking, paralysis, and joint pain being common.

Page 66 | "Questions:"

1. Can you identify what might be potential areas of concern in this bone scan?

   It looks like there is a fracture in the small toe bone.

2. Research what type of radiotracer might be used to enable doctors to see tendons on a scan.

   Typically, the fluorine-18 isotope is used.

Page 66 | "In the Media: Research Question"

Read the public written and verbal statements made by both the CNRC and the AECL (which can be found online). If you were the Health Minister for the federal government and you had to make the decision whether or not to shut down the reactor—albeit temporarily—what would you decide? Justify your decision.

Many answers are possible.

http://www.nuclearfaq.ca/cnf_sectionD.htm#nru-safety As of November 2008, this website has, under #17, a summary of the November 2007 incident. AECL's comments on the CNRC position can be found at http://www.nuclearfaq.ca/AECL_NRU_Jan2008.htm. You can find the CNRC and CNSC (Research and Safety Commissions) opinions on the CNSC website at http://www.nuclearsafety.gc.ca: using their search engine, type "November 2007 shutdown" and there will be many article choices to find quotes.

Page 68 | "Research Questions:"

1. Which new frequencies did the Canadian government recently open up to allow for more competition amongst cellular service providers? How does a cellular service provider or radio station obtain an operating frequency?

   Over 100 MHz of new spectrum was released in 2008 for companies to purchase bandwidths for cellular service. To obtain an operating frequency, an individual (such as a "ham radio" operator) must pass a licensing examination covering basic concepts. They then have access to larger segments of the radiofrequency spectrum. Cellular service providers and radio stations purchase a bandwidth or section of the radiofrequency spectrum for their company's use.

2. Why are radio station signals sometimes more clear at night than during the day?

   AM radio signals have relatively long wavelengths which interact with layers of the atmosphere above the earth's surface. Because of shifts in the layers of the atmosphere from daytime to night-time, AM radiowaves propagate differently at night. During daytime hours, reflection of AM waves from the ionosphere does not occur to any great degree. The radiowaves travel by conduction over the surface of the earth during the day. At night, however, the same radiowaves are reflected off the ionosphere and can travel hundreds of kilometres further than they can during the day, a phenomenon called "skywave" propagation. Because of this, AM stations are required to drastically decrease their operating power at night to decrease interference.

Page 70 | "Activity: Marshmallows, Microwaves, and Mathematics:

If measurements are made carefully and the marshmallows are not left in the microwave too long, answers should be very close to 3.0×10^8 m/s. Mini chocolate chips, if lined up tightly together, may be used instead of marshmallows.

Page 70 | "For Further Research:"

How do smoke detectors use alpha-particle emitters? Is it ionizing or non-ionizing radiation that is used? Create a presentation of your results.

Ionizing smoke detectors have an ionizing chamber and a source of ionizing radiation. Typically, the source of radiation is an isotope of americium. The ionizing chamber has two plates separated by a small distance. The battery provides electricity to the plates. Because the americium constantly releases alpha particles in the chamber, these alpha particles ionize the air enough to allow current to flow from one plate to the other.

When smoke enters the ionization chamber, the ions are neutralized and the current no longer flows from one plate to another. This causes an alarm to sound.