chapter 6
Further Applications of Radiation

CASE STUDY CONTINUED: The Final Verdict for Francine

Francine kept going back to her doctor for physical examinations every year. Five years after her radiotherapy, the cancer had still not returned. The doctor congratulated her and told her she could look forward to a long and fulfilling life. Throughout the process of treatment, her doctor had encouraged her to continue practicing the healing ceremonies of her aboriginal cultural heritage. That encouragement, plus the support of her family and community members, helped her through the up-and-down emotions she had throughout the process of diagnosis, treatment and recovery. She could now say with some degree of confidence that she was "cancer-free."

Figure 6-1

Figure 6-2

Ionizing Radiation Applications: Sterilization

Gamma rays are commonly used to sterilize disposable medical equipment such as needles, IV sets, and syringes. Typically, cobalt-60 is the radioisotope of choice as it continuously emits gamma rays. Storage of this in a medical facility needs to take into account the hazards of gamma radiation on humans, as the gamma rays produced by this isotope are extremely high in energy.

Electron beams can also be used for medical equipment sterilization. The advantage of using electron beams rather than gamma radiation is that gamma rays continuously emit radiation, but electron beam processing can be turned on and off. As well, higher doses can be administered through electron beams so less exposure time is required to sterilize the equipment. This can prevent the degradation of plastics that may be sterilized (the longer plastic is subjected to radiation, the greater the risk of the polymers breaking down). One negative property of electron beam technology is that it does not penetrate as deeply as gamma rays.

Though it is not ionizing radiation, ultraviolet light has limited use for sterilization purposes, but is still popular in the form of **germicidal lamps**. Surfaces and some transparent objects can be sterilized in this way, including the interiors of biological safety cabinets. However, if the surfaces are dirty the UV radiation will not sterilize the surface underneath it. UV light can also damage many plastic surfaces, including polystyrene foam (used in home insulation).

Irradiation is used by the United States Postal Service to sterilize mail destined for the Washington, D.C. area. Food irradiation for some spices and ground meats is now widely used to prevent illness.

Did You Know

Litvinenko, Thallium, and Russian Radiation Intrigue

In November of 2006, the public's interest in espionage was piqued as The Russian Federation was thrust into the international spotlight with former KGB agent Alexander Litvinenko allegedly having been poisoned by another former KGB agent. The KGB was the "spy agency" of the former Soviet Union.

Litvinenko, a published author who had frequently spoken out against then Russian president Vladimir Putin, had a brief meeting with Andrei Lugovoy in a central London restaurant before meeting an Italian man for lunch. The following day, Litvinenko became violently ill and was taken to hospital by his wife. It would take more than two weeks for the effects of the poison – hair loss, shut-down of internal organs, breathing difficulty – to become clear. Toxicology tests finally confirmed that thallium was present in Litvinenko's bloodstream.

Scotland Yard detectives investigated both of the men with whom Litvinenko met previous to his illness for possible connections to the poisoning. They have not ruled out the possibility of the use of a "poison pen" that could have been used to inject the man with thallium unnoticed. This would be consistent with a previous assassination in London of Georgi Markov, a Bulgarian dissident stabbed with a poison-tipped umbrella in 1978.

Research Question:

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

Figure 6-3
A bone scan done with a tracer of radioactive strontium. In this image, bones can clearly be seen along with tendons.

Ionizing Radiation Applications: Tracer Methods in Nuclear Medicine (Gamma Scans)

We have already discussed how radiotracers are used in the various types of diagnostic technologies to enhance the results of the scan and indicate areas of interest or "hot spots." In nuclear medicine, gamma scans are done on bones to determine bone growth patterns, potential for arthritis, or identify cancerous areas. Almost all nuclear medicine studies are performed using an isotope of technetium – ^{99}Tc.

Gamma scans are done by a camera that picks up gamma rays emitted by a radiotracer. These gamma rays are converted into images that contain light and dark spots. Dark spots or "hot spots" do not necessarily indicate areas of cancer. Hot spots show where the radiotracer has collected. Since the radiotracer is typically attached to a substance that will gravitate towards areas of the body where cells are growing at faster or abnormal rates, the hot spots can either indicate cancer or arthritis or some other type of bone disease. Use of gamma cameras is much more common than PET scans.

Questions:

1. Can you identify what might be potential areas of concern in this bone scan?
2. Research what type of radiotracer might be used to enable doctors to see tendons on a scan.

In The Media

The Canadian Medical Isotope Controversy

Earlier, in Chapter 2, we were introduced to the importance Canada has in the production and distribution of what are called medical isotopes. In recent years, Canada has an interesting story to tell about how critical we are to the world supply of certain isotopes used in medical treatments - particularly cancer treatments. In November of 2007, the Canadian Nuclear Safety Commission (CNRC) and Atomic Energy of Canada Limited (AECL) brought Canada's role in providing much of the world's supply of medical isotopes to the forefront. In a controversial move, the CNRC shut down the nuclear reactor (run by AECL) at Chalk River, Ontario for twenty-seven days. It was a shutdown related to a safety concern on the part of the CNRC.

At that time, much of the world supply of certain medical isotopes produced by Canadian reactors became an urgent situation to address. On December 16, 2007 the Canadian government passed emergency legislation allowing the Chalk River reactors to reopen and to continue to provide medical isotopes to their clients around the world. This is an important example of how science connects to the well-being of people, and the reliance we have on technology to serve our health care needs. It also highlights the Canadian nuclear industry and our need to understand it better.

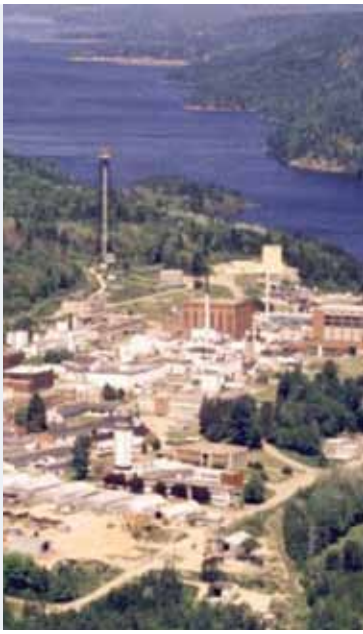

Figure 6-4

Research Question:

1. Check into this fascinating story, and explore in a balanced way the positions of the CNRC, the Canadian government, and the AECL (a good place to start is online at: http://www.cbc.ca/technology/ and use the search bar with the keywords "medical isotopes"). If you were the Natural Resources Minister for the federal government and you had to make the decision whether or not to shut down a Canadian reactor that produces one-third of the world supply of medical isotopes — even temporarily — what would you decide to do? You might want to have teams of students take positions on this controversy and debate the issue in class.
2. 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.

Non-Ionizing Radiation Applications: Tanning Beds

Non-ionizing radiation is electromagnetic radiation without enough energy to cause ionization. It does have enough energy to give to particles, with the end result usually being heating. Non-ionizing radiation includes frequencies from one hertz (1 Hz) up to 300 GHz (gigahertz), and wavelengths from 10^{-7}m to 10^{9} m. As wave frequency decreases and wavelength increases, the energy level decreases. Types of non-ionizing radiation include UV light, visible light, infrared light, microwaves, and radio waves.

Figure 6-5

Ultraviolet (UV) light is naturally obtained from sunlight. Artificial sources include germicidal lamps, mercury vapour lamps, halogen lights, fluorescent and incandescent lights, and tanning booths. Germicidal lamps are designed to emit UVC radiation to kill bacteria and sterilize surfaces. Humans can obtain severe sunburn to the face, sometimes called snow blindness, with overexposure to UVC light. Though very painful, it does clear up in a few days.

A component of sunlight is UVB light, and is the most destructive form of UV radiation. It has enough energy to cause damage at the cellular level (DNA is affected). Some tanning beds operate using UVB light. Effects of UVB on humans include erythema (sunburn), cataracts, and skin cancer.

Cancer Connection

Non-Ionizing Radiation Applications: Tanning Beds

Non-ionizing radiation is electromagnetic radiation without enough energy to cause ionization. It does have enough energy to have an effect on particles, with the end result usually being heating. Non-ionizing radiation includes frequencies from one hertz (1 Hz) up to 300 GHz (gigahertz), and wavelengths from 10-7m to 109 m. As wave frequency decreases and wavelength increases, the energy level decreases. Types of non-ionizing radiation include UV light, visible light, infrared light, microwaves, and radio waves.

Ultraviolet (UV) light is naturally obtained from sunlight, and is probably the most familiar form of non-ionizing radiation for most people. Artificial sources include germicidal lamps, mercury vapour lamps, halogen lights, fluorescent and incandescent lights, and indoor tanning facilities. Germicidal lamps are designed to emit UVC radiation to kill bacteria and sterilize surfaces. Humans can obtain severe sunburn to the face, sometimes associated with "snow blindness," with overexposure to UVC light. Though very painful, it does clear up in a few days. A component of the spectrum of sunlight is UVB light, and this is the most destructive form of UV radiation where exposed skin is a concern. It has enough energy to cause damage at the cellular level (so DNA is affected). Some indoor tanning beds operate using some component of UVB light (less than 10% of the total exposure), with the remainder as UVA. Known effects of UVB on humans include erythema (sunburn), eye cataracts, and skin cancer. Most tanning beds are a concentrated source of UVA, and sometimes UVB, light and so these should be used with real caution. It is recommended these days that young people under the age of 18 not make use of indoor tanning at all, and those who are aged 35 or less face a dramatically increased risk of developing a form of skin cancer – called cutaneous malignant melanoma – later in life if they have significant exposure to UVA from tanning bed use.

Figure 6-6

Non-Ionizing Radiation Applications: Communications

Cell phones, AM and FM radio, microwave towers all radiate electromagnetic energy. These microwaves and radiofrequency waves surround humans daily.

Radiowaves are constantly being emitted by radio station towers. If you listen to a radio station labelled 99.9, that number indicates its frequency: it is operating at 99.9 megahertz. The wavelength of this station can be determined by taking the speed of light and dividing it by the frequency. (Recall: $v=\lambda f$). A station operating at 99.9 MHz would therefore have a wavelength of approximately 3.03 metres.

AM, FM, and cellular signals travel in a straight line, unimpeded through the earth's atmosphere. Since the earth's surface is curved, at some point these signals will be lost – unless they are reflected back to the earth's surface by the ionosphere or a transmission tower. The ionosphere (an atmospheric layer where sunlight ionizes atoms) reflects radiowaves with less than 30 MHz in frequency. Typically, FM signals carry higher frequencies and thus are not reflected by the ionosphere. AM radiowaves use shorter frequencies than cellular and FM waves, and so are typically reflected back to the earth's surface from the ionosphere.

Health Canada has a safety code which restricts exposure to the general public to no higher than 1/50th of the levels where harmful biological effects have been observed. The Safety Code restricts both the absorption rates and the corresponding exposure levels for these types of electromagnetic waves.

According to Health Canada, it is possible to exceed the maximum allowable exposure limit if an individual stands less than three metres away from a transmitting cellular antenna. However, there are safety fences around these sites and normally the general public does not have access. Workers in the vicinity of towers such as these can be exposed to no more than 1/10th the levels where harmful biological effects have been observed (according to Health Canada's regulations).

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

Reality Check

Question | Can Cell Phones Cause Cancer?

Origin: A few individuals attempted to take cell phone companies to court in the early 1980s, claiming brain tumours were caused by their cell phones. Online communities continue to perpetuate this and similar ideas, claiming that the electromagnetic energy radiating from cell phones is powerful enough to pop popping corn and to do damage to brain tissue.

Reality Check: The website *Discovery Health* states that the US Food and Drug Administration's Centre for Devices and Radiological Health believes that there is no consistent association between cell phone use and cancer. Rather, the Centre states that studies have shown that there is an identifiable link between cell phone usage and increased risk of having a car accident.

Source: Gansler, Dr. Ted. "Discovery Health:: Top 10 Cancer Myths: Myth 8." Discovery Health n.d.. 29 July 2008 health.discovery.com/centers/cancer/top10myths/myth8.html

Figure 6-7

Non-Ionizing Radiation Applications: Microwave Ovens

Figure 6-8

Microwave ovens for consumer use typically operate at 500 to 1000 watts at a frequency of approximately 2450 megahertz (MHz). The energy from these microwaves is used to boil water or cook food that is placed inside the oven.

Microwave ovens cook food by irradiating them with high-frequency, very low wavelength waves. Wavelengths typically are around 10-12 cm inside a microwave. Since most food has a high water content, and since water is a polar molecule, the energy carried by the electromagnetic waves inside the oven is imparted to the water molecules. This extra energy is converted into heat, which eventually cooks the food. Leave the food in long enough, and water will begin to evaporate, drying out the food.

Regulations require that microwave ovens be constructed so that radiation leakage to the outside of the oven is minimal – approximately 1000 times less than what is present inside the oven. Contrary to some emails and online bloggers, the radiation that does leak from your microwave is not harmful. Microwaves cannot penetrate metal, which is why the oven is constructed of metal (sometimes coated in plastic). Even the viewing window has a mesh made of metal on it. Unless your microwave is damaged or altered it will not leak sufficient amounts of microwave energy to cause damage.

activity—marshmallows, microwaves, and mathematics

Microwaves without turntables cook unevenly, due to wave patterns. We can use that principle to confirm that the electromagnetic radiation inside a microwave oven does, in fact, travel at the speed of light.

1. Remove the turntable from the microwave—if it has one. Place a flat piece of cardboard over the bottom of the microwave.
2. Line the entire bottom of the microwave with mini marshmallows.
   Set the microwave on high power and cook the marshmallows until you start to see a pattern of melting/toasting and uncooked marshmallows. At this point, carefully remove the cardboard and marshmallows.
3. Take a ruler and measure the distance between two consecutive melted spots. This will be equal to the wavelength of the electromagnetic waves. (Are the melted spots nodes or antinodes?)
4. Check on the back of the microwave for a sticker which will tell you the operating frequency of the microwave (typically 2450 MHz). Use this value and your wavelength converted into metres to calculate the speed at which the electromagnetic waves are traveling in your oven. Is it $3x10^8$ m/s?

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.

Figure 6-10

Career Moves

Accelerator Physicist

As an accelerator physicist, your job duties would include the operation of an accelerator complex: synchrotron, linear accelerator, and all the computer technology connected to those devices. Beam studies and high-level accelerator calculations aimed at understanding the performance of the accelerator and research into areas of personal interest are typically encouraged by employers. At this level of your career, you will have already completed doctorate-level studies, have several years of experience in theoretical and practical physics, and have developed the leadership skills to organize a team of researchers to meet specific goals. This is pure physics at an elite level!

Career Connection Website – Canadian Association of Physicists: *www.cap.ca*

Chapter 6 Review: Concepts and Terms

Concepts: Gamma rays can be used to sterilize disposable medical equipment. Typically, cobalt-60 is the radioisotope of choice for this, however electron beams can also be used for the same purpose. The advantage of using electron beams is that less exposure time is required to sterilize equipment, and electron beam processing can be turned on and off. Ultraviolet light has limited sterilization purposes in the form of germicidal lamps for surfaces and some transparent objects.

Gamma scans are done by a camera that converts gamma rays into images. Use of gamma cameras is much more common than PET scans.

Types of non-ionizing radiation include UV light, visible light, infrared light, microwaves and radiowaves. UV light is made up of UVA, UVB, and UVC light. UVC light can cause severe burns to human skin, which can clear up in a few days. UVB light can cause erythema (sunburn), cataracts, and skin cancer. Most tanning beds operate by using UVA and UVB light.

Applications of non-ionizing radiation include cell phones, AM and FM radio, and microwaves. Health Canada has a safety code which restricts exposure to the general public to no higher than 1/50 of levels where harmful biological effects have been observed. Contrary to some emails and online bloggers, the radiation that may leak from your microwave is not harmful.

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