The Sun

8.2

Stars and other celestial objects in the Universe emit energy consisting of electromagnetic waves that travel at the speed of light, known as **electromagnetic (EM) radiation**. Together, these forms of radiation are contained in the **electromagnetic (EM) spectrum**. The EM spectrum consists of radio waves, microwaves, infrared rays, visible light, ultraviolet rays, X-rays, and gamma rays. These waves have energies that become greater as their wavelengths become smaller.

The Sun emits radiation across most of the EM spectrum. Although some of the Sun's energy is absorbed by Earth's atmosphere and some is reflected into space, almost all of the energy that reaches Earth's surface comes from the Sun. EM radiation from the Sun is the driving force behind Earth's weather and climate, and also provides the energy needed for life to exist on Earth (Figure 1).

electromagnetic (EM) radiation energy emitted from matter, consisting of electromagnetic waves that travel at the speed of light

electromagnetic (EM) spectrum the range of wavelengths of electromagnetic radiation, extending from radio waves to gamma rays, and including visible light

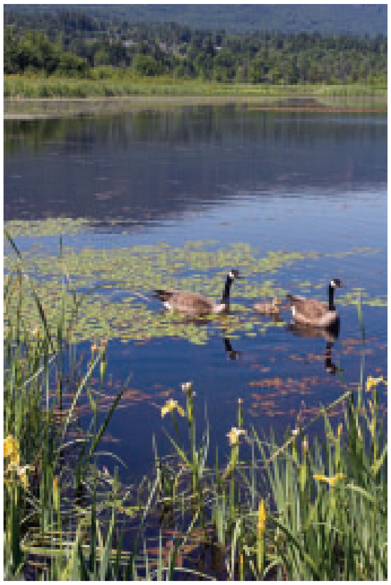

Figure 1 Plants and animals could not exist without sunlight.

The Structure of the Sun

The Sun is composed of many layers of gas. Deep inside the Sun's centre is the core, where high temperatures and pressures cause particles to collide with each other at extremely high speeds. This causes the particles to fuse, or join together, in a process called nuclear fusion, which gives off enormous amounts of energy. These high-energy reactions make the core the hottest part of the Sun, reaching a temperature of 15 000 000 °C.

The energy released by nuclear fusion makes its way to the radiative zone, the first layer that surrounds the core. This energy can take up to a million years to reach the next region of the Sun, the convective zone. In the convective zone, hotter substances rise as colder substances fall. Energy continues to move outward until it reaches the photosphere, where light and other types of radiation escape. The photosphere has a temperature of 5500 °C. Above the photosphere lies the Sun's atmosphere. It is divided into two layers: the chromosphere and the corona. The chromosphere makes up the inner atmosphere, and is 60 000 °C hotter than the photosphere. The thin outer layer of the solar atmosphere—the gleaming white, halo-like corona—extends millions of kilometres into space (Figure 2).

To learn more about the Sun's structure and how it works,
GO TO NELSON SCIENCE

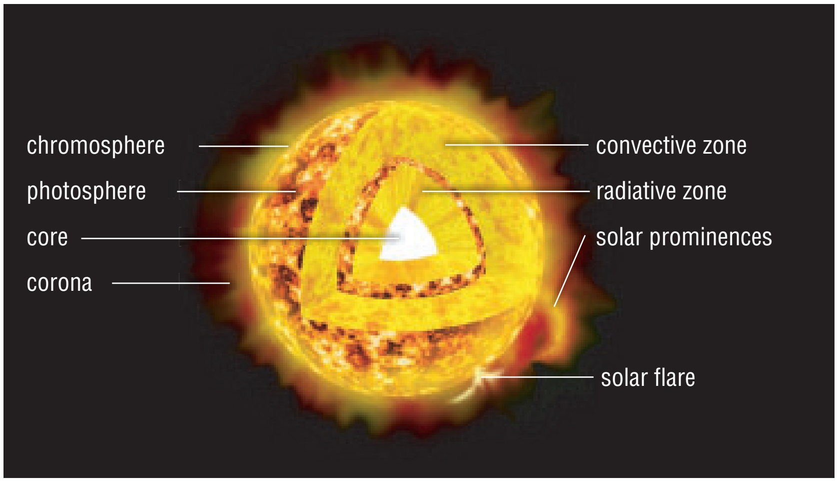

Figure 2 The structure of the Sun

The Sun's Surface

The Sun rotates on its axis, taking approximately 25 days to make one complete rotation. Near its equator, the Sun spins more quickly than at its poles. Early astronomers believed that the Sun's surface was smooth and featureless. Today, with the aid of telescopes, we know that the photosphere has a texture that appears similar to that of a boiling liquid. As heated material rises, it reaches the surface, cools, and sinks back inside. As this happens, convection cells called granules form. This gives the photosphere a grainy appearance. At the centre of each granule, hot solar gases radiate into space. The gases move outward and sink back into the Sun at the darker, cooler boundaries of the granule.

sunspots dark spots appearing on the Sun's surface that are cooler than the area surrounding them

Sunspots, which are darker, cooler areas visible on the Sun's photosphere, appear to move as the Sun rotates. They are caused by disturbances in the Sun's magnetic field. Sunspots vary in size and regularity (Figure 3). Galileo Galilei, an astronomer who lived approximately 400 years ago, was one of the first people to observe and study sunspots in detail. His observations led him to conclude that sunspots must be occurrences taking place on the Sun's surface. To date, the largest sunspot ever recorded covered an area of 1.8×10^{10} km^2—this is 36 times the surface area of the entire Earth!

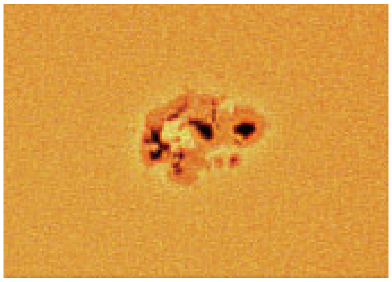

Figure 3 Sunspots consist of a dark central zone, which may be larger than several Earths, and a lighter border.

Solar flares are found in active regions near sunspots and release large quantities of gas and charged particles. They are produced by the rapidly changing magnetic fields around sunspots and last only a short time. **Solar prominences** are slow, low-energy ejections of gas that travel through the corona. Refer back to Figure 2, which shows a solar flare and a solar prominence on the Sun.

solar flare gases and charged particles expelled above an active sunspot

solar prominence low-energy gas eruptions from the Sun's surface that extend thousands of kilometres into space

The Sun's Effects on Earth

The Sun experiences powerful activity in its outer atmosphere. Constantly in motion and rotating at different speeds, the gases of the Sun swirl around, causing solar storms. These storms are the cause of solar winds. Solar winds are strongest when there are solar flares and prominences.

TRY THIS TRACK SUNSPOTS

SKILLS: Observing, Analyzing

SKILLS HANDBOOK 3.B.

In this activity, you will observe and track the movement of sunspots using modern satellite images.

Equipment and Materials: photos of sunspots taken by the SOHO satellite over four consecutive days; overlay of mapping grid; graph paper; pencil

1. Identify the different sunspot groups A, B, and C on each of the photos.
2. Copy Table 1 into your notebook and complete the information for each sunspot group. Use the nearest whole number.

Table 1

Date	Longitude of Sunspot Group A	Longitude of Sunspot Group B	Longitude of Sunspot Group C

3. Determine how many degrees in longitude each sunspot group moved each day. Then calculate the average daily movement of each group.

A. What was the average daily movement of each group? Provide your answer in degrees of longitude. T/I

B. Using the number of degrees that you observed the sunspots to move each day, calculate how long it takes the Sun to make one full rotation on its axis. T/I

C. How many of the sunspots changed in size and shape over the four day period? T/I

D. How might the tracking of sunspots be important? A

THE AURORAS

Earth is surrounded by an atmosphere containing atoms of different gases, such as oxygen, nitrogen, argon, and carbon dioxide. Earth is also surrounded by a magnetic field that is strongest near the North and South Poles (Figure 4). Solar winds travelling toward the Earth become influenced by, and follow, the lines of magnetic force created by Earth's magnetic field. Near the poles, they come in contact with particles in Earth's atmosphere, producing a display of light in the night sky. In the northern hemisphere, we call these colourful displays of light the **aurora borealis** or northern lights (Figure 5). Whenever there is a display of northern lights, there is a simultaneous display near the South Pole called the aurora australis or southern lights.

aurora borealis a display of shifting colours in the northern sky caused by solar particles colliding with matter in Earth's upper atmosphere

To learn more about auroras,
GO TO NELSON SCIENCE

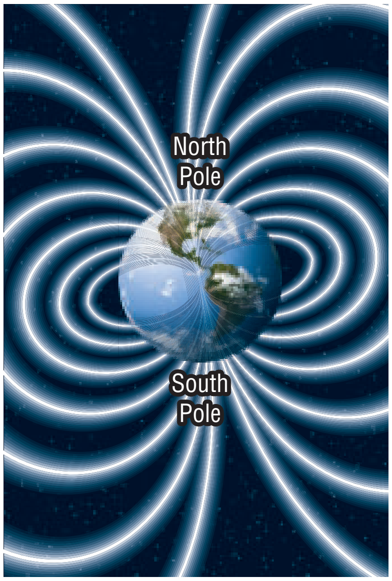

Figure 4 Earth's magnetic field is strongest near the North and South Poles.

Figure 5 The northern lights are featured in many Aboriginal legends. For example, the Cree people call this phenomenon the "dance of the spirits."

COMMUNICATION DISRUPTIONS

Solar activity at the Sun's surface can affect artificial satellites, human-made objects that orbit celestial objects in the Solar System. For example, particles ejected by the Sun can damage the information stored on computer microchips on satellites. This can disrupt cellphone and satellite TV communications (Figure 6).

Figure 6 When directed toward Earth, solar particles can affect communications, navigation systems, and power grids.

DID YOU KNOW?

Observatories in Space
Astronomers use telescopes both on the ground and in space to study the Sun. NASA's recently launched STEREO (Solar TErrestrial RElations Observatory) twin spacecrafts are creating the first ever three-dimensional images of the Sun. The new views will help scientists understand structures in the Sun's atmosphere and improve space weather forecasting.

To learn more about becoming a solar scientist,
GO TO NELSON SCIENCE

The temperature and density of Earth's upper atmosphere, where satellites orbit, is sometimes increased by solar radiation and storms. The friction caused by the denser atmosphere slows down the satellites and can alter their orbital path. Scientists constantly monitor satellites and boost them back into their orbits to prevent them from falling and burning up in the atmosphere.

RADIATION HAZARDS

On July 14, 2000, a powerful solar storm occurred. It is referred to as The Bastille Day Event. Charged solar particles entered Earth's atmosphere and disrupted signals from communications satellites orbiting the planet. Solar scientists warned that people travelling in airplanes could receive a higher than usual dose of radiation because of their high altitude. The radiation in solar storms can also be harmful to astronauts during a space walk or through the walls of their spacecraft while they orbit Earth because they are not protected by Earth's atmosphere.

UNIT TASK Bookmark

How can you apply what you learned about radiation hazards in this section to the Unit Task described on page 446?

IN SUMMARY

- The Sun emits radiation across most of the EM spectrum. Some of the Sun's energy is absorbed by Earth's atmosphere and some is reflected into space. Almost all of the energy that reaches Earth's surface comes from the Sun.
- The Sun is necessary for life on Earth.
- The Sun has various layers with different temperatures and properties.
- The Sun constantly undergoes changes due to storms and a turbulent atmosphere that also affects Earth.
- The aurora borealis (northern lights) and aurora australis (southern lights) are caused by the interaction between solar particles and the Earth's atmosphere near the North and South Poles.
- Solar radiation causes communication disruptions and can be hazardous to human health.

CHECK YOUR LEARNING

1. In a short paragraph, explain the types of radiation given off by the Sun. K/U
2. Why is the Sun so important for life on Earth? A
3. Draw and label a diagram of the different layers of the Sun. Briefly describe each layer. K/U C
4. What range of temperatures are found on, and within, the Sun? K/U
5. How long does it take for the Sun to rotate on its axis? How do astronomers know this? K/U T/I
6. Who was the first astronomer to observe sunspots in detail? What did he conclude from his observations? K/U
7. Compare and contrast solar prominences, solar flares, and solar winds. K/U
8. What are the auroras and where on Earth are they visible? K/U
9. How are communication satellites affected by activity on the surface of the Sun? A