THEME

4 Earth and Space Exploration

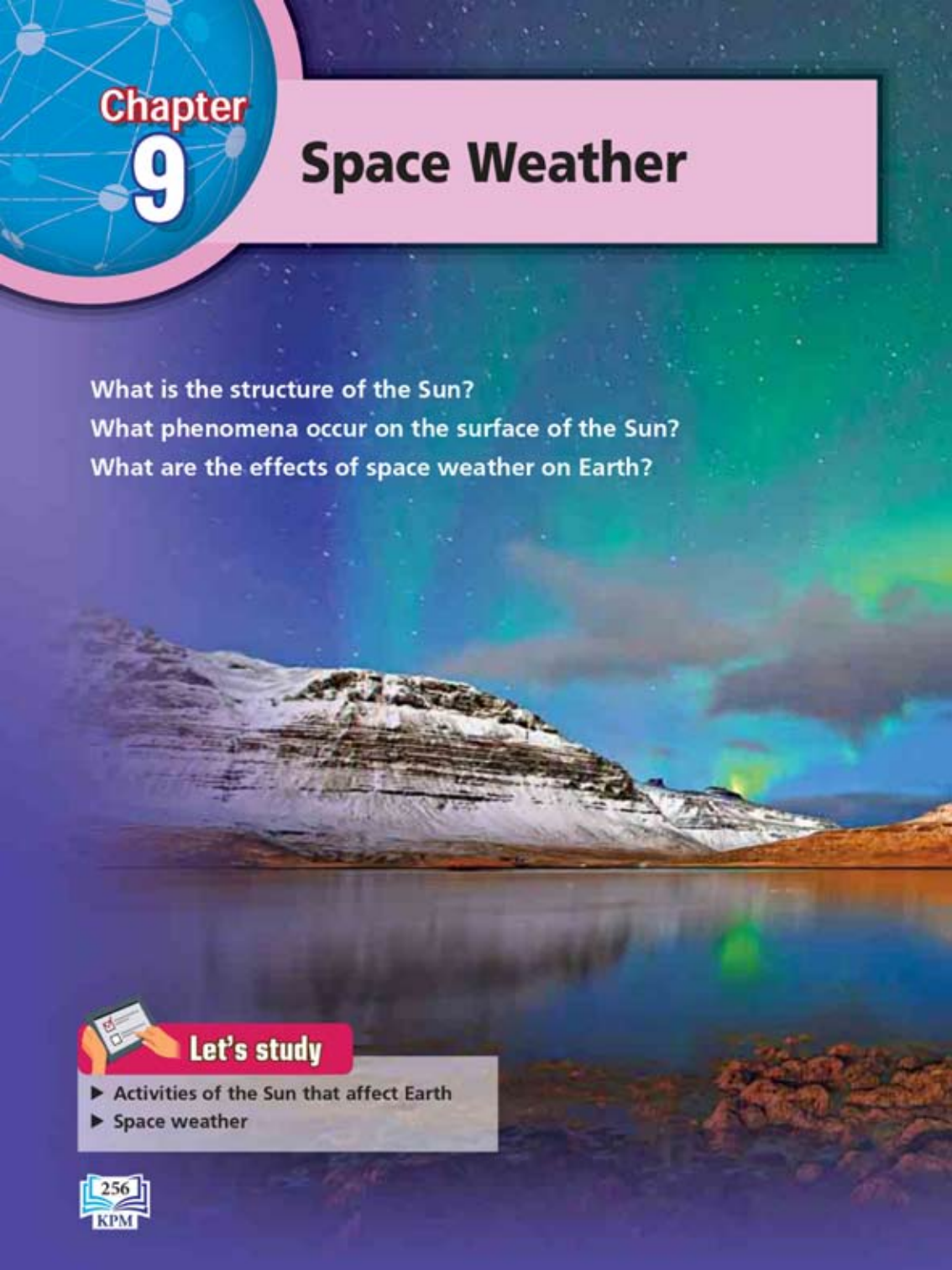
The RazakSAT-2 satellite is a satellite created entirely by local scientists. One of the uses of this satellite is in the field of defence.

Our life is affected by local weather conditions. For example, we will use an umbrella on a rainy day. What is the importance of space weather?

Chapter 9

Space Weather

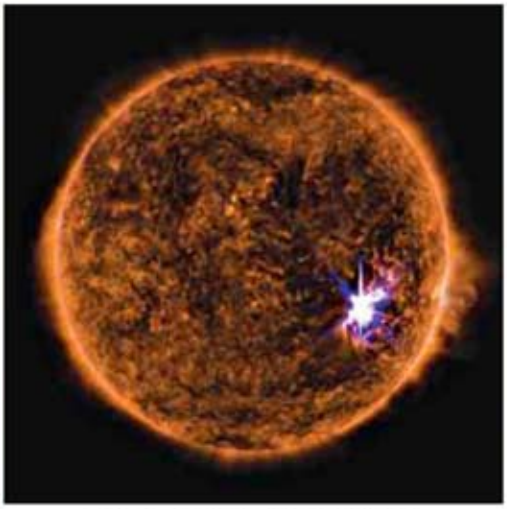
What is the structure of the Sun?
What phenomena occur on the surface of the Sun?
What are the effects of space weather on Earth?



Let's study

- Activities of the Sun that affect Earth
- Space weather

Science Gallery



The Sun's X9.3 class solar flare at 8.02 am on 6 September 2017

On 6 September 2017, coronal mass ejections caused disturbances to telecommunication, navigation system and electric power lines for about an hour. What are the effects of this phenomenon on daily life on Earth?

Keywords

- Sun
- Core
- Radiation zone
- Convection zone
- Photosphere
- Chromosphere
- Granule
- Corona
- Solar flare
- Sunspot
- Solar cycle
- Solar wind
- Magnetosphere
- Prominence

9.1 Activities of the Sun that Affect Earth

The **Sun** appears as a ball of glowing gases as shown in Photograph 9.1. The Sun consists almost entirely of two types of gases, **hydrogen** and **helium**.

Photograph 9.1 *The Sun*

Structure of the Sun

The structure of the Sun consists of the parts shown in Figure 9.1. Carry out Activity 9.1 to learn more about the structure of the Sun.

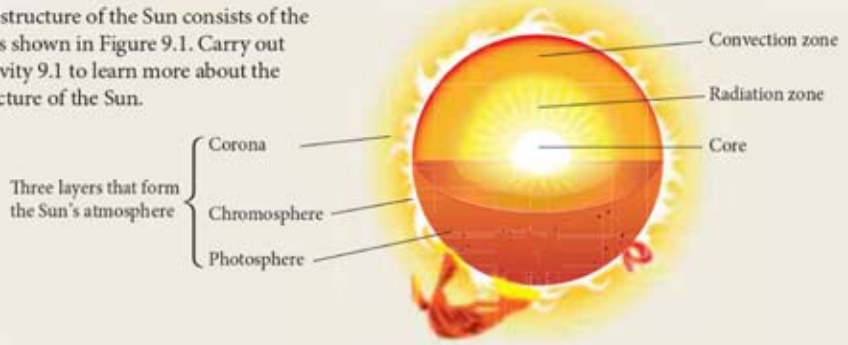


Figure 9.1 *Structure of the Sun*

Activity 9.1

21st Century Skills
- ICS, ISS
- Discussion activity

To gather and share information on the structure of the Sun consisting of the core, radiation zone, convection zone, photosphere, chromosphere and corona

Instructions

1. Work in groups.
2. Gather information from the Internet, printed media and other electronic media on the structure of the Sun consisting of the core, radiation zone, convection zone, photosphere, chromosphere and corona.
3. Discuss and share the information gathered.
4. Present the outcome of your group discussion using multimedia presentation.

Phenomena that Occur on the Surface of the Sun

Phenomena that occur on the surface of the Sun include:

- Granules
- Sunspots
- Solar cycles
- Prominences
- Solar flares
- Coronal mass ejections
- Solar winds

Science Careers

A career as a **solar scientist** is relatively new in the field of solar energy. Besides inventing solar energy equipment, a solar scientist also studies and forecasts space weather which greatly affects daily life on Earth.

Granules, Sunspots and Solar Cycle

The photosphere in the Sun's atmosphere is made up of **granules** which appear as grainy structures. The granules are the upper part of the convection zone of the plasma which is extremely hot with a temperature as high as 5 800°C. The average diameter of a granule is about 1 000 kilometres!

Sunspots are the dark regions seen on the surface of the Sun as shown in Figure 9.2. Sunspots appear dark because their temperatures are lower than their surrounding areas which are made up of granules. Sunspots are the locations of very large eruptions in the photosphere. This phenomenon may last more than a week. Sunspots are phenomena that always exist in pairs or groups.

The activity of the sunspots seems to appear and disappear according to a cycle that lasts 11 years known as the **solar cycle**. Figure 9.3 shows the position of sunspots in the photosphere since 1875.

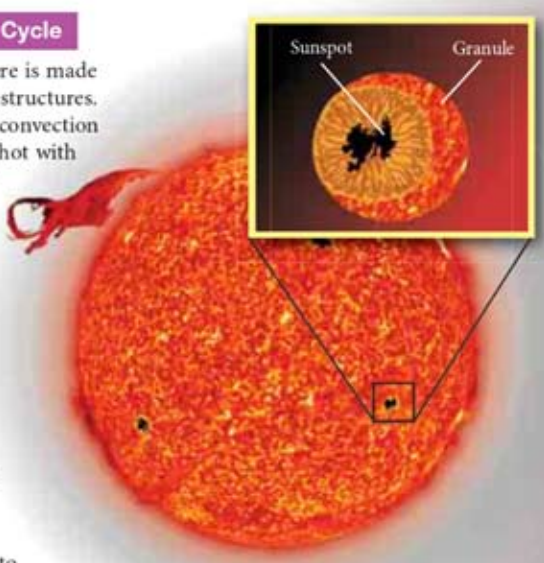


Figure 9.2 Granules and sunspots

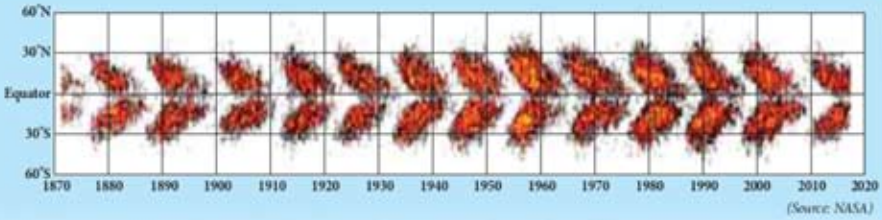


Figure 9.3 Position of sunspots on the surface of the Sun

Prominence

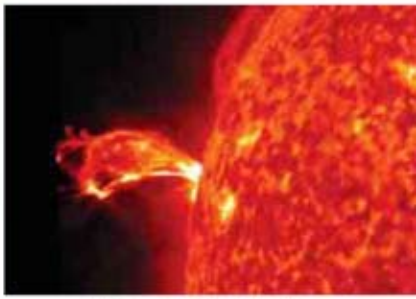
A **prominence** shown in Photograph 9.2 is a huge loop or arched column of glowing gases over the sunspot. Prominences can reach heights of hundreds of thousands of kilometres and may last for several days or months. Prominences that are very strong can throw out matter from the Sun into space at speeds ranging from 600 km s^{-1} to more than 1 000 km s^{-1}.

Photograph 9.2 *Prominence*

Solar Flares

A **solar flare** shown in Photograph 9.3 is a column of large amounts of charged gases erupting from the Sun and often occurs near sunspots. Solar flares are strong and spectacular explosions of gases. Solar flares attain their maximum brightness level within a few seconds or minutes and then become dim after a few minutes or hours. Solar flares spout charged gas particles at high speeds into outer space. The light from solar flares which is at the speed of light takes eight minutes to reach Earth while the charged gas particles take tens of minutes.

These charged gas particles often collide with atoms and molecules in Earth's atmosphere to produce a stunning light display in the sky known as **aurora** which uniquely occurs only in the air space around Earth's poles.

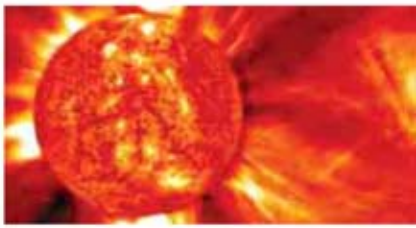


Photograph 9.3 *Solar flare*

Coronal Mass Ejections

A **coronal mass ejection** shown in Photograph 9.4 is a huge cloud of plasma that erupts from the Sun and often occurs together with solar flares which are huge and strong. A coronal mass ejection is an ejection of magnetic gas particles. The coronal mass ejection spouts magnetic particles at high speeds into outer space and appears like an expanding cloud. These magnetic particles from the coronal mass ejection take three days to reach Earth.

Like the charged gas particles in solar flares, the magnetic gas particles also react with atoms and molecules in Earth's atmosphere to produce aurora.



Photograph 9.4 *Coronal mass ejection*

VIDEO

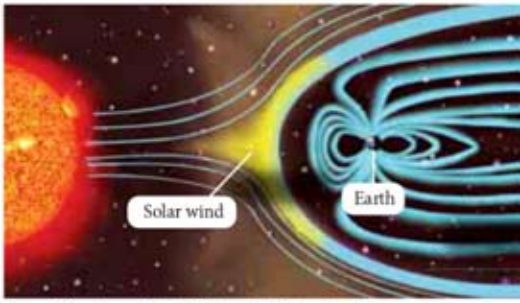
Watch a video on prominences, solar flares and coronal mass ejections.

SCAN PAGE

Solar Wind

Particles in plasma such as electrons, protons and alpha particles that erupt from the Sun to outer space travel together at high speeds known as **solar wind** as shown in Photograph 9.5.

Solar wind also carries the interplanetary magnetic field along with it. The speed of solar wind is supersonic with values ranging from 250 km s^{-1} to 750 km s^{-1}. However, the speed, temperature and density of the solar wind changes along the course of its movement.



Photograph 9.5 *Solar wind (in yellow)*

Earth's Magnetosphere and its Importance

Shape of Earth's Magnetosphere

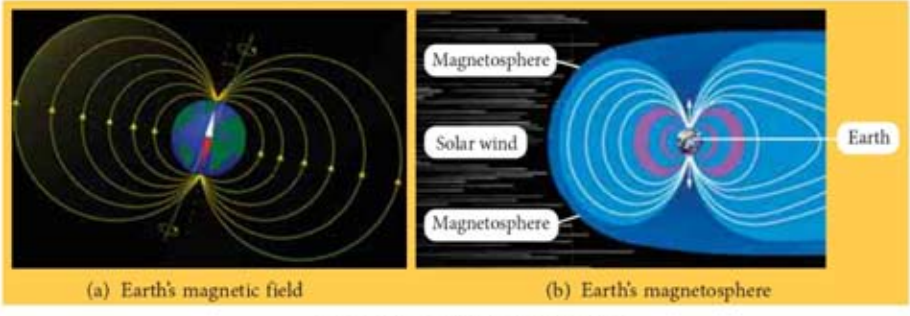


Figure 9.4 *Shape of Earth's magnetosphere*

Compare and contrast the pattern of magnetic field lines between Earth's magnetic field and Earth's magnetosphere. Even though both of these patterns of magnetic field lines are not fixed, the pattern of Earth's magnetic field lines changes slightly while the pattern of the magnetic field lines in the magnetosphere changes a lot based on the interaction between solar wind and Earth's magnetic field.

MARVELS OF SCIENCE

Animation that shows the relationship between magnetosphere and solar wind.

http://bt.sasbadi.com/sc3261

Definition of Earth's Magnetosphere

Earth's magnetosphere is defined as a region in outer space surrounding Earth where the magnetic field in Earth's magnetosphere is a combination of Earth's magnetic field (as the prime magnetic field) and the magnetic field in the region in outer space as shown in Figure 9.4(b).

Formation of Earth's Magnetosphere

Magnetosphere is formed by the interaction between the magnetic field brought by the solar wind and Earth's magnetic field. As the number and energy of particles brought by the solar wind change, the shape of the magnetosphere also changes.

Importance of Earth's Magnetosphere

The **importance of magnetosphere** is to protect Earth from the adverse effects caused by dangerous particles from the Sun or other bodies in the Universe.

Figure 9.5 Protection from Earth's magnetosphere

The magnetosphere:

- functions as a biological shield to protect life on Earth from the adverse effects of solar wind
- blocks charged particles such as electrons, protons and alpha particles in the solar wind from reaching Earth. Excessive numbers of charged particles in Earth's atmosphere will disrupt telecommunication, navigation system and electric power lines
- reduces the pressure exerted by solar wind on Earth's atmosphere

Activity 9.2

21st Century Skills
- ICS, CPS, ISS
- Discussion activity

To gather and share information on the definition, formation, shape and importance of the magnetosphere

Instructions

1. Work in groups.
2. Gather information from the Internet, printed media and other electronic media on the definition, formation, shape and importance of the magnetosphere.
3. Discuss and share the information gathered.
4. Brainstorm on the condition of Earth without the magnetosphere.
5. Present the outcome of your group discussion using multimedia presentation.

Formative Practice 9.1

1. State **three** structures of the Sun that form the Sun's atmosphere.
2. State **three** phenomena that occur on the surface of the Sun where charged gases erupt.
3. Define Earth's magnetosphere.
4. What influences the shape of the magnetosphere?
5. Name **one** object in the Solar System that has the same shape as solar wind.

9.2 Space Weather

Space Weather and its Effect on Earth

Space weather is defined as the phenomena that occur:
- on the **surface of the Sun** such as solar flares, prominences, sunspots and coronal mass ejections
- in **space** such as solar wind, solar radiation storm and geomagnetic storm

Websites

Space weather

http://bt.sasbadi.com/sc3263

Study Figure 9.6. Then, carry out Activity 9.3.

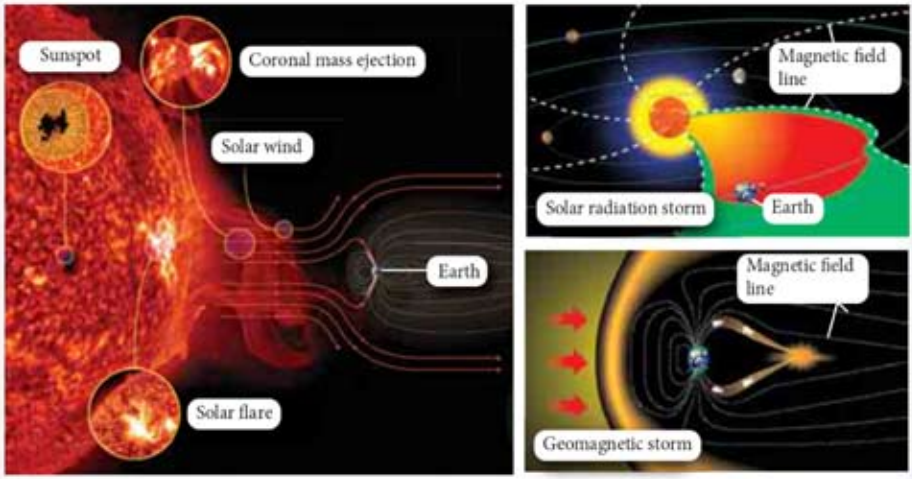


Figure 9.6 Space weather

Activity 9.3

21st Century Skills
- ICS, CPS, ISS
- Discussion activity

To gather and share information on the definition of space weather and its effects on Earth

Instructions

1. Work in groups.
2. Gather information from the Internet, printed media and other electronic media on the definition of space weather and effects on Earth such as the formation of the aurora, disturbances to telecommunication, navigation system as well as electrical power lines.

Space storms
http://bt.sasbadi.com/sc3264-1

Effects of geomagnetic storm, solar radiation storm and disturbances of radio transmission
http://bt.sasbadi.com/sc3264-2

3. Discuss and share the information gathered.
4. Present the outcome of your group discussion using multimedia presentation.

Interpretation of Data on Space Weather

Data on space weather is used or analysed to:
- forecast when coronal mass ejections occur in the Sun
- determine the reasons for the occurrence of solar flares and coronal mass ejections on the surface of the Sun

Activity 9.4

21st Century Skills
- ICS, CPS, ISS
- Discussion activity

To interpret data on space weather

Instructions

1. Work in groups.
2. Gather information or data on space weather from the Internet, printed media and other electronic media.

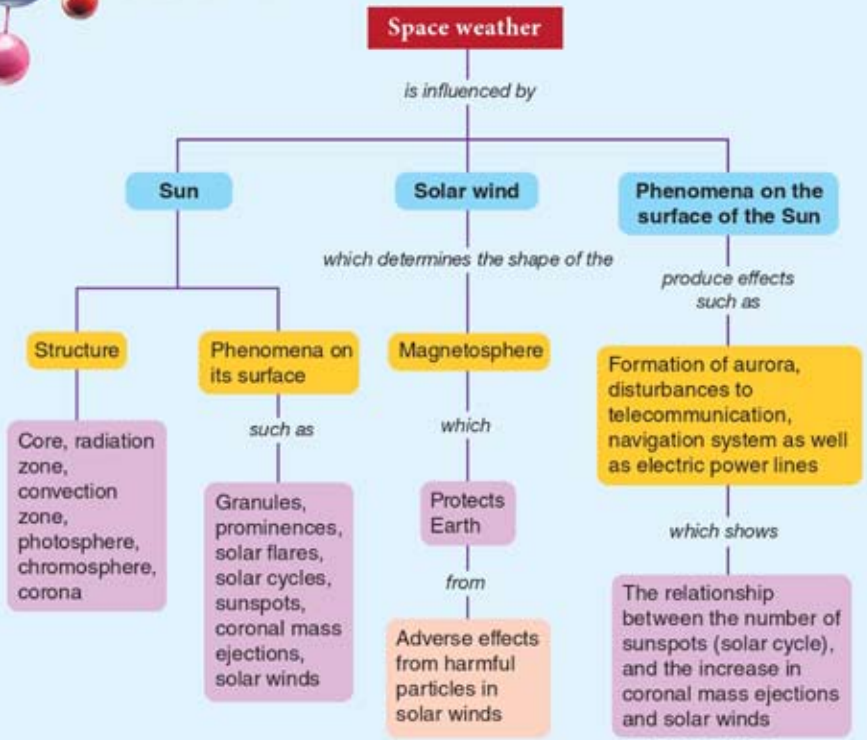
Sources of solar wind in relation to solar cycle
http://bt.sasbadi.com/sc3264-3

3. Interpret data on space weather by relating the number of sunspots or solar cycles with the increase in coronal mass ejections and solar winds.
4. Present your group's interpretation of space weather data using multimedia presentation.

Formative Practice 9.2

1. What is the definition of space weather?
2. State **four** examples of the effects of space weather on Earth.
3. What is the relationship between the number of sunspots and the increase in coronal mass ejections?

Summary



Self-reflection

After studying this chapter, you are able to:

9.1 Activities of the Sun that Affect Earth

- ☐ Explain the structure of the Sun and phenomena that occur on the Sun's surface by drawing.
- ☐ Justify the importance of Earth's magnetosphere.

9.2 Space Weather

- ☐ Communicate space weather and its effects on Earth.

Summative Practice 9

Answer the following questions:

1. Figure 1 shows the structure of the Sun.

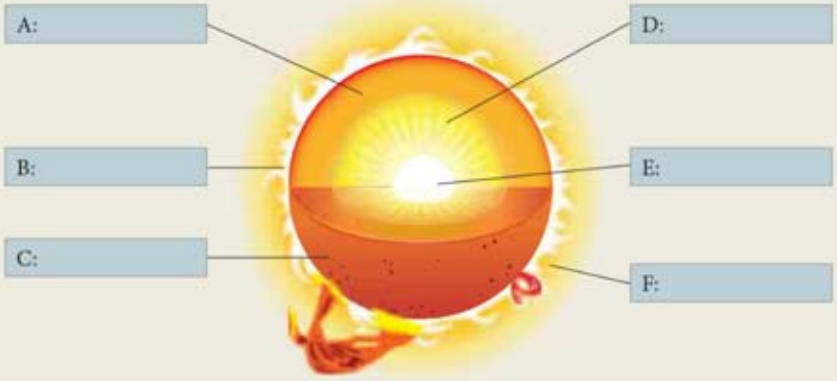


Figure 1

Name the structures labelled A to F using the following words:

Photosphere	Corona	Chromosphere
Core	Convection zone	Radiation zone

2. What is the duration of one solar cycle?

3. State the phenomenon related to solar cycle.

4. State **three** examples of equipment or service used daily which is disrupted by solar winds.

5. What would happen to the condition of Earth if there is no magnetosphere? Explain your answer.

Focus on HOTS

6. Earth's magnetosphere shown in Figure 2, is a region in space which protects Earth.

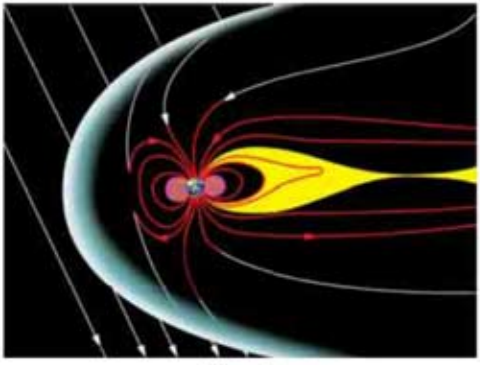


Figure 2

The shape of Earth's magnetosphere is produced by the interaction between Earth's magnetic field and solar wind. Magnetic field lines from other planets in the Solar System are represented by white lines while Earth's magnetic field lines are represented by red lines as shown in Figure 2.

You are required to create a model of the magnetosphere using the following materials:

- Green-coloured plastic bag
- White thread
- Red thread
- Polystyrene cup with a convex cover
- Plasticine

Sketch the model of the magnetosphere. Explain how the model functions.