Our Future in Space

If space stations are successful, the next stages of space travel may be exploration of Earth's Moon, and the planet Mars and its small moons, Phobos and Deimos. These objects could be mined and the materials used to build structures in space. Eventually, human colonies may be established on the Moon and on Mars.

Many problems must be overcome before we can travel to, and live on, Mars. One of the biggest problems is the reaction of the human body to constant free fall. To reduce the effects on long space trips, a feature of any piloted trip to Mars will probably be artificial gravity, created by rotating the spacecraft (**Figure 1**). Once on Mars, the astronauts will find a gravitational force only 38% of that on Earth. This may also cause problems for the human body over long periods of time.

Visitors to Mars will require water, food, oxygen, and warm shelter. Oxygen and small amounts of water could be extracted from the low-density atmosphere, which consists mostly of carbon dioxide. Water could also be extracted from the permafrost on Mars and from the recycling of plant and human wastes. Large greenhouses could be used to grow fruits and vegetables. Even though Mars is farther from the Sun than Earth is, the Sun's radiation is far more harmful there because the atmosphere on Mars has no ozone to offer protection. As a result, living quarters would have to be buried beneath the Martian soil to protect humans from harmful solar radiation.

Some scientists predict that by the time humans have settled on Mars, we will have propulsion systems powerful enough to allow spacecraft to reach extremely high speeds. Perhaps such a craft, if unpiloted, would be sent to explore neighbouring stars in our galaxy.

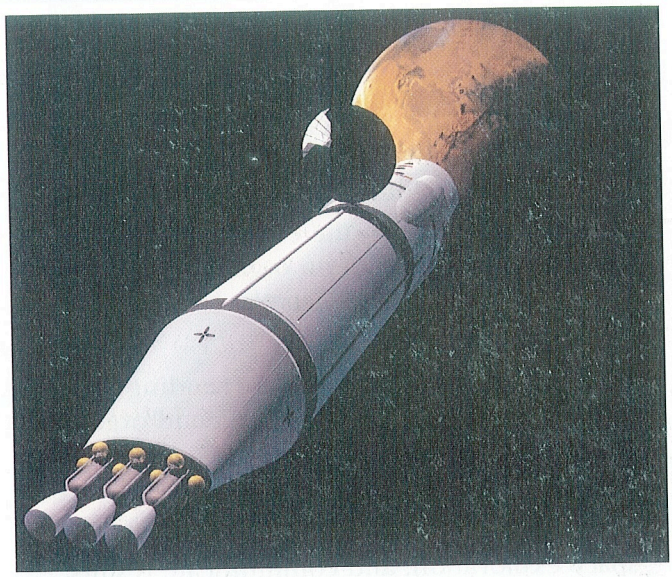


Figure 1
Artist's concept of a spacecraft travelling to Mars

Issue Space Exploration

People in favour of space exploration give many good reasons why it will benefit the human race. People opposing space exploration feel strongly that there are drawbacks that outweigh the benefits. Working in a group, choose either a supporting or an opposing position on space exploration. (9C)

- Brainstorm a list of reasons that support your group's viewpoint. Consider economics, ethics, environmental issues, politics, and available technology as you brainstorm.
- Discuss these as a group and carry out further research where necessary.
- Prepare a 5-min presentation, putting forth your position.

Challenge

What situations should you consider for sustained survival when designing a space colony?

Chapter 16 Review

Key Expectations

Throughout the chapter, you have had opportunities to do the following things:

- Describe and explain the effects of continuous free fall (microgravity) on organisms and other contents of orbiting spacecraft. (16.8, 16.9, 16.11, 16.12)
- Investigate questions related to sending satellites and humans into space, and organize, record, analyze, and communicate results. (16.2, 16.4, 16.6, 16.7, 16.9, 16.10, 16.12)
- Formulate and research questions related to space exploration, and communicate results. (all sections)
- Describe, evaluate, and communicate the impact of research and achievements in space on other fields of endeavour. (16.3, 16.4, 16.5, 16.9, 16.10, 16.11, 16.12)
- Identify the purpose and accomplishments of space initiatives such as satellites, space probes, and the *International Space Station*. (16.1, 16.3, 16.4, 16.5, 16.6, 16.7, 16.13)
- Investigate and provide examples of ways in which Canada participates in space research and international space programs. (16.3, 16.5, 16.7, 16.11)
- Explore careers related to space exploration. (Career Profile)

KEY TERMS

aircraft
free fall (microgravity)
geosynchronous orbit
Global Positioning System
International Space Station
launcher
low Earth orbit
payload
outer space
radar
remote sensing
space probe
spacecraft
spinoff
thrust
weight

Reflecting

- "Space exploration and the related technology contribute to our understanding of Earth and the universe and provide many useful applications for life on Earth." Reflect on this idea. How does it connect with what you've done in this chapter? (To review, check the sections indicated above.)
- Revise your answers to the questions raised in Getting Started. How has your thinking changed?
- What new questions do you have? How will you answer them?

Understanding Concepts

1. Make a concept map to summarize the material that you have studied in this chapter. Start with the words "space exploration."
2. What are the purposes of space stations?
3. During blast-off, an astronaut feels heavier than usual; later, lighter than usual. Explain why.
4. What is "artificial gravity"? How might it be created on a spacecraft?
5. List benefits of studying space medicine.
6. Classify each of the following vehicles as Earth-based, atmosphere-based, low Earth orbit, or geosynchronous orbit: the *International Space Station*; a space shuttle; a helicopter; a sailboat; a TV satellite; a remote-sensing satellite.
7. State the purpose or function of: remote sensing satellites, RADARSAT, GPS satellites, and an orbiting observatory.
8. Compare an aircraft engine and a rocket engine, explaining why an aircraft cannot fly in space.
9. Describe situations in which you have experienced free fall.
10. Why are robotics and vision systems important on the *International Space Station*?
11. What would happen to a spacecraft in orbit around Earth if its speed becomes too slow? Explain.

12. Can a human be a payload? Explain your answer.

13. Which electromagnetic waves, infrared or radar, would be better for viewing the heights of mountains and craters on the moons of planets? Why?

14. Why are remote sensing satellites that use radar not used to predict daily weather patterns?

15. (a) Why is the expression "zero gravity" misleading for an astronaut inside a spacecraft in an Earth orbit?

    (b) Under what condition(s) would the expression "zero gravity" not be misleading?

16. During the last few days, identify ways you have benefited from space exploration. (Include both direct benefits and spinoffs.)

17. If you were standing on your head, your blood distribution would change. Relate this change to what an astronaut experiences in orbit around Earth.

18. At the same instant, one car drives horizontally off a cliff at a high speed and another falls straight down.

    (a) Compare the times the cars take to land.

    (b) Relate your answer to space vehicles that travel around Earth.

19. A sports event takes place in Australia, and at almost the same time you are able to watch that event on television. Describe how this form of telecommunication works.

20. Space probes are sent to explore asteroids and comets. How does this exploration help in the study of the origin of the solar system?

21. Why are we more protected from the Sun's harmful radiation on Earth than astronauts are in space?

22. The air pressure in an *ISS* suit is less than atmospheric pressure. Find out why, and what advantages and disadvantages this brings.

Applying Skills

23. If a satellite takes 90 min to travel once around the world, for about how long will it be in view, each orbit? Show your calculations.

24. Describe what conditions would allow you to observe a satellite or the *ISS* travelling across the sky. Draw a diagram to illustrate your answer.

25. Find the results of a Canadian research project, involving students growing seeds that had been in space.

26. Select a career in the field of astronomy or space science, and find out what aptitudes and qualifications you would need to enter this career. If possible, interview someone in this career and prepare an audio report on the person's professional life.

27. Write a short science fiction story about space exploration using as many of the key terms as you can.

28. Describe what steps you would take to discover what fuels are used to launch a space shuttle.

29. Describe how to access information on the Internet about RADARSAT.

30. Assume you are an astronaut on the Moon carrying out an investigation to determine the factors affecting how fast objects fall. Describe in detail the steps you would take. Show that you understand what a controlled experiment is.

31. Draw a graph to predict how the speed of a balloon (vertical axis) depends on the air pressure inside the balloon.

Making Connections

32. Create a chart of Canadian contributions to the study of the universe, giving the Canadians' names and outlining their work.

33. List two or three careers in the space industry that require a background in (a) engineering and (b) technical studies.

34. Choose five interesting space spinoffs and for each, name at least one possible career associated with it.

35. To find out more about how the human body reacts in space, investigate Dr. Dave Williams' research on flight STS-90.

36. Defend or oppose one of the following statements:

    (a) Space exploration benefits the human race.

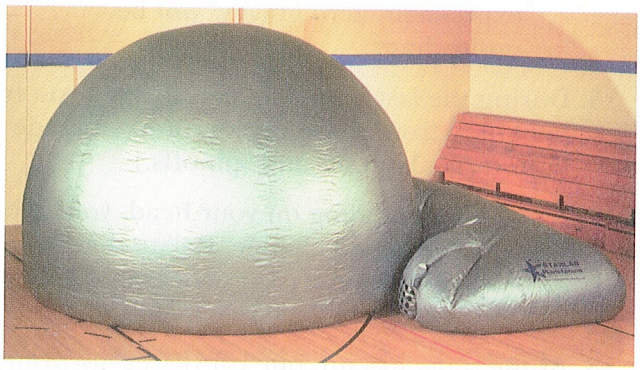
    (b) Money spent on space exploration would be better spent cleaning up the global environment.

Challenge

Bringing Your Ideas Together

Scientists and technologists share ideas in many ways. They may design simulations to understand concepts and to predict future events. They may develop technologies that improve our lives or that can be used to make further scientific investigation possible. They may conduct research and record and communicate what they discover. You can choose one of these approaches in the challenges described below:

1 Planetarium Shows

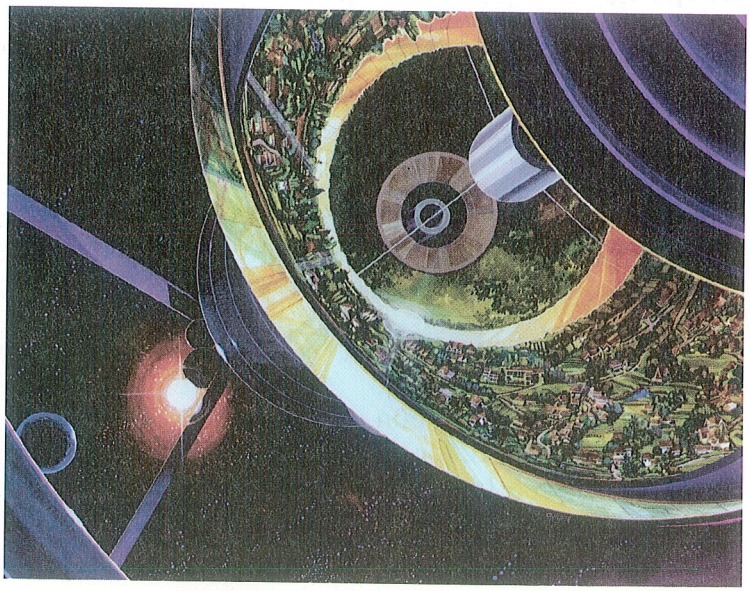


A planetarium is a structure in which people can learn more about astronomy. Often the night sky is simulated, with points of light representing the stars and other objects in the sky. By moving the lights, the appearance of the night sky at various times and dates can be represented. Planetariums usually offer a variety of shows designed for different purposes and audiences.

Your job is to design and prepare three shows that could be used in a planetarium. One show should be designed to teach grade 6 students about the solar system. The other two shows should be designed for the general public. You must include a script for each show and be prepared to present one of them.

Your simulations should include:

- models or other representations of year-round constellations, seasonal constellations, planets, comets, and other natural objects discussed in this unit
- representations of human-made objects such as satellites and space probes
- a model that demonstrates the motions of as many of the objects as possible
- design features that take into consideration the size, construction, and layout of a large planetarium



2 A Space Research Colony

You are part of a company that has designed a colony that would conduct research in outer space. The company is preparing to display its plans at the International Space Conference, in the hope of attracting investors for the project.

Design and create a display depicting a sustainable space research colony suitable for permanent human habitation.

Your display should include:

- a representation of the destination of your choice in outer space
- a demonstration of how the colony will be adapted to the environment of the destination chosen
- a plan that outlines how colonists will achieve self-sufficiency in both the short and long terms
- evidence of how knowledge gained from existing space explorations and space technology will be used
- proposals for the type of research that would be best suited for the destination you chose
- models and diagrams of relevant components

3 A Space Technology Information Package

Vast amounts of money are spent on technology related to space exploration. The merits of this expenditure are frequently debated in public. Your company has been commissioned by the Canadian Space Agency to develop an information package about the usefulness of space technology. You are to demonstrate how the use of space technology contributes to our understanding of the universe and how applications of that technology benefit us in our everyday lives. The package is designed for distribution to the general public.

Design an information package that outlines the diverse tools used both in space exploration and the study of astronomy and the influence they have had on our lives.

Your information package should include:

- an organizational tool for accessing the information
- examples of the uses of space technology
- links to Canada's role in the development of space technology
- illustrations of what we have learned about the universe using the technology
- examples of applications of the technology that positively affect our daily lives

Assessment

Your completed challenge will be assessed according to how well you:

Process

- understand the specific challenge
- develop a plan
- choose and safely use appropriate tools, equipment, and materials when necessary
- conduct the plan applying technical skills and procedures when necessary
- analyze the results

Communication

- prepare an appropriate presentation of the task
- use correct terms, symbols, and SI units
- incorporate information technology

Product

- meet established criteria
- show understanding of concepts, principles, laws, and theories
- show effective use of materials
- address the identified situation/problem

Unit 4 Review

Understanding Concepts

1. In your notebook, write the letters (a) to (k), then indicate the word(s) needed to complete each statement below.

(a) The ___?___ is everything that exists, including all the matter and energy everywhere.

(b) The four planets closest to the Sun can be called the ___?___ planets or the ___?___ planets.

(c) ___?___ was the first scientist to use a telescope to obtain evidence that stars were much farther away than planets.

(d) The ___?___ is a broad band of energies that can travel in a vacuum.

(e) The process used by stars to produce energy is called ___?___ .

(f) Stars start and end their lives as clouds of dust and gas called ___?___ .

(g) ___?___ is the force of attraction between all objects that have mass.

(h) A payload is to a ___?___ as an arrow is to a ___?___ .

(i) A satellite in ___?___ orbit appears to remain stationary when viewed from Earth.

(j) ___?___ is the force of gravity acting on an object. In the metric system its unit is the ___?___ .

(k) A ___?___ is a benefit that comes from space science and technology research.

2. Indicate whether each of statements (a) to (o) is TRUE or FALSE. If you think the statement is FALSE, rewrite it to make it true.

(a) Our Sun is the only star that has planets orbiting around it.

(b) An object that is 30 astronomical units from the Sun could be either a gas giant or a comet.

(c) The light-year is a unit of time.

(d) A comet's tail is visible only when the comet's path is close to the Sun.

(e) When using triangles to measure distances to objects in the sky, the longest baseline possible to observers on Earth is Earth's diameter at the equator.

(f) The speed of electromagnetic waves in a vacuum is 3×10^5 km/s.

(g) Auroras are caused by light pollution.

(h) Most stars are bigger than the Sun.

(i) The Sun is in the galaxy called the Milky Way.

(j) In the lives of stars, a red supergiant results from stars that have a smaller mass than the Sun.

(k) Both stars and planets form from nebulas.

(l) Evidence of an expanding universe comes from red shift of the spectra of stars and galaxies.

(m) Space probes have been sent to explore stars nearest to the solar system in our galaxy.

(n) RADARSAT uses waves that belong to the invisible part of the electromagnetic spectrum.

(o) The problems of increased body length and harmful radiation disappear after astronauts have been in orbit for a week or more.

3. Describe the similarities and/or differences between each pair of objects listed below:

(a) star constellation; star cluster

(b) Earth's rotation; Earth's revolution

(c) asteroid; comet

(d) galaxy; star cluster

(e) interplanetary distance; intergalactic distance

(f) solar flare; solar prominence

(g) apparent magnitude; absolute magnitude

(h) neutron star; black hole

(i) aircraft; spacecraft

(j) vacuum; atmosphere

(k) natural satellite; artificial satellite

(l) space shuttle; space station

(m) geosynchronous orbit; low Earth orbit

For Questions 4 to 10, choose the best answer and write the full statement in your notebook.

4. Pointer stars:

(a) can be used to locate planets in the night sky

(b) are found only in the year-round constellations

(c) can be used to locate constellations and other stars

(d) appear to be pointed

(e) all of the above

5. Compared with the terrestrial planets, the gas giants tend to:

(a) be hotter, rotate faster, and have a lower density

(b) be colder, rotate faster, and have a lower density

(c) be colder, rotate slower, and have a lower density

(d) be colder, rotate slower, and have a higher density

(e) be hotter, rotate faster, and have a higher density

6. Which does not belong in this list?

(a) radio waves

(b) visible light

(c) X rays

(d) sound waves

(e) infrared radiation

7. The order of stars from coolest to hottest is

(a) blue, yellow, red

(b) red, blue, yellow

(c) yellow, red, blue

(d) blue, red, yellow

(e) red, yellow, blue

8. A possible order of events in the evolution of stars is

(a) nebula, energy produced through fusion, core collapse

(b) core collapse, energy produced through fusion, nebula

(c) nebula, core collapse, energy produced through fusion

(d) energy produced through fusion, core collapse, nebula

(e) energy produced through fusion, nebula, core collapse

9. The force caused by expanding gases leaving a rocket engine is called

(a) chemical energy

(b) gravity

(c) thrust

(d) friction

(e) air resistance

10. The best explanation of why orbiting astronauts appear to be floating is that they are experiencing

(a) microgravity

(b) weightlessness

(c) no gravity

(d) continuous free fall

(e) none of the above

11. Which planets are the most likely targets for exploring by robotic rovers in the near future? Give reasons for your choices.

12. Some planets cannot be explored by robotic rovers. What ways can be used to study these planets at close range?

13. Which planets tend to have the greatest number of moons? Explain why this situation occurred as the solar system developed.

14. (a) What are sunspots?

(b) How can they be safely observed?

(c) What evidence do they provide of the Sun's rotation?

15. Stars move at great speeds. Why did people long ago believe that stars were fixed in place?

16. Can two stars with the same luminosity have different apparent magnitudes? Explain.

17. How are the temperatures and colours of stars related? Give examples.

18. Which types of stars tend to become supernovas? What happens after that stage?

19. The inner planets and gas giants formed at about the same time. Which stages of their formation were similar, and which were different? Explain why there was a difference.

20. According to the present theory, what are the main stages of the evolution of the universe?

21. What happens to low Earth orbit satellites if their orbits become too low? Why?

22. (a) Describe the conditions needed for you to feel you are weightless for a short period of time.

(b) Relate your answer in (a) to what astronauts experience in orbiting spacecraft.

23. (a) As you observe the night sky in the Northern Hemisphere, which star appears not to move?

(b) Why does it appear not to move?

(c) How long do constellations take to appear to travel once around that star?

24. You are conducting an investigation to compare the motions of planets and constellations seen in the night sky.

(a) How would the motions compare if you made observations three hours apart?

(b) How would the motions compare if you made observations three weeks apart?

(c) Explain the difference between observations (a) and (b) above.

25. What is the Hubble Deep Field? Why is it important?

26. If you see two stars through a telescope and one looks bluish, the other yellowish, what can you say about the difference between the stars?

27. What is the relationship between the speed of a satellite and the height of its orbit?

Applying Skills

28. In observing the night sky, it is important to judge the differences between stars and planets. Describe the main ways you have learned to distinguish stars and planets.

29. A student records these observations in a log book: "The constellation was 3 fists to the right of south, and 4 fists up from the horizon." Describe what these observations mean.

30. A certain comet, visible tonight, has a period of 185 years.

(a) Draw a diagram showing the basic orbit of the comet around the Sun. Include Earth in your diagram as well as the comet's tail at a few locations.

(b) Predict when the comet will again be visible.

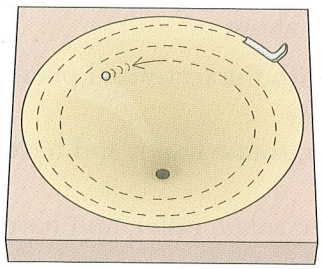
31. Write these measurements out in long form

(a) 3.4×10^6 km

(b) 7.9×10^{12} kg

32. Describe a safe way to make observations of the Sun when it is high in the sky.

33. The figure below shows a device in which a rolling ball moves faster and faster, finally getting gobbled into the centre. How is this a model of a black hole? In what ways is the model not realistic?



34. Describe briefly how each of the following devices helps in the exploration of the universe:

(a) an orbiting observatory

(b) a ground-based observatory

(c) a radio telescope

35. Describe how any or all of the following have helped you understand ideas in this unit:

(a) modelling

(b) performing student-designed investigations

(c) drawing scale diagrams

(d) graphing

(e) operating computer simulations

(f) researching information on the Internet

36. **Table 1** indicates the speed, orbital radius (from the centre of Earth), and period of revolution of four types of artificial satellites and the Moon.

(a) Determine the information needed to complete the table.

(b) What patterns do you observe in your completed table?

(c) For the artificial satellites, plot a line graph of period of revolution (vertical axis)

Table 1

Satellite	Orbital Radius	Period of Revolution	Average Speed
remote sensing	6.67×10^3 km	1.5 h	?
Iridium	7.18×10^3 km	1.7 h	?
GPS	2.67×10^4 km	12 h	?
geosynchronous	4.24×10^4 km	24 h	?
the Moon	3.84×10^5 km	656 h	?

against the orbital radius. Use the line on the graph to determine (i) the period of a satellite with an orbital radius of 3.5×10^4 km and (ii) the orbital radius of a planet with a period of 10 h.

(d) For each satellite, including the Moon, calculate the ratio of radius^3 to period^2. What do you discover?

37. Make a list of three important questions you would like answered to help you understand more about (a) astronomy and (b) space exploration.

Making Connections

38. What were some skills achieved by astronomers in ancient times?

39. What is the evidence that astronomy is a very old science?

40. (a) What are observatories used for?

(b) Does Canada operate or help operate any observatories outside the country? If so, where?

41. Professional astronomers rely on amateur astronomers to find objects such as comets in the sky. Why?

42. Give examples in which Canadians have participated in discoveries and/or research in astronomy.

43. Many devices you use in your daily life are digital, just like devices used in astronomy and space exploration. Give examples of digital devices and describe why they are called "digital."

44. How has Canada's space technology helped in each of these endeavours?

(a) robotics

(b) resource management

(c) navigation

(d) telecommunications

45. In what ways will future space probes help increase our understanding of the universe?

46. List three general areas that involve careers in space technology. Within each area, name one specific career, some of its aspects, and the education required for it.

47. Explain the advantages of using robotics rather than piloted probes to explore the planets and other bodies in the solar system.

48. Explain this statement: "Visual systems and robotics often operate together."

49. Choose an area of scientific research carried out by astronauts aboard the *International Space Station*. Describe what you know about that research.

50. You are the leader of a team of scientists, engineers, and technologists who are developing spinoffs of the space industry. Make a list of five problems you would like the team to work on.

51. Robotic rovers designed to roam across the irregular surface of Mars will have to be "smart"; in other words, they will have to make their own decisions about whether it is safe to move forward. Explain why such rovers could not be adequately controlled by Earth-based controllers.

52. Research the latest developments in communications systems that make use of geosynchronous satellites. How are they improvements on older systems?

53. Find out about one of the many traditional religions or cultures that base their calendar on the movements of the Sun and Moon. Create a display showing how the dates of various celebrations are fixed.

54. Do spacecraft have to be aerodynamic in shape? Explain.

55. Many satellites are powered by electricity converted by big shiny panels from solar energy. Investigate the advantages and disadvantages of this source of energy, and suggest what design challenges the spacecraft engineers face and how they might overcome these challenges.

56. Research into the specialized areas of science (such as fluid physics, or crystal growth) that make use of the free fall conditions in an orbiting laboratory.

57. What probes are in outer space this year? Research their purpose, and find out what kinds of data they are sending to Earth. How are these data changing our ideas about space?

58. Investigate the "What's New" page of the Canadian Space Agency's web site to check on the progress of the *ISS*. Prepare periodic verbal reports for your class, focussing on Canada's contribution.