SPACE EXPLORATION

E.1.1 identify different ideas about the nature of Earth and space based on culture and science

CULTURE AND SCIENCE

Humans have always been fascinated by entities in the sky. Many ancient tribes created stories to explain the presence and movement of objects in space. The people of the First Nations saw a distinct pattern of stars they called the Great Bear. The Egyptians built the pyramids in alignment with the seasonal position of certain stars.

Practice Questions: 1, NR1

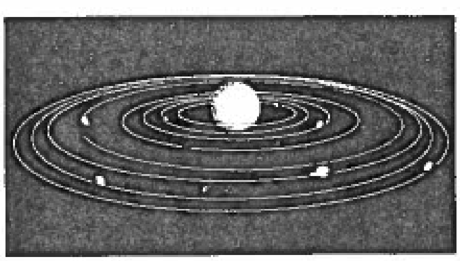
E.1.2 investigate and illustrate the contributions of technological advances—including optical telescopes, spectral analysis, and space travel—to a scientific understanding of space

EARLY THEORIES AND TECHNOLOGICAL ADVANCES

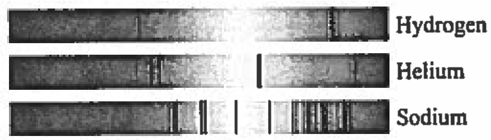
The **geocentric** model of planetary motion was proposed by Aristotle approximately 2 000 years ago. This model has Earth at the centre with the sun, moon, and other planets orbiting it.

In the 1500s, Copernicus proposed the sun-centred, or **heliocentric model**. In this model, all the planets revolve around the sun in a concentric circular pattern.

Later, it was the work of Galileo and Kepler that determined the revolution around the sun to be an elliptical pattern.

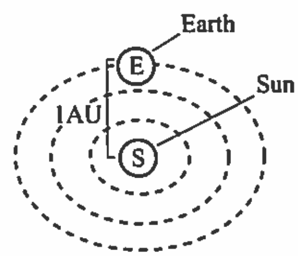


Much of the data collected by early astronomers was gathered using simple instruments such as the quadrant, cross-staff, or astrolabe. It was, however, the invention of the telescope in the early 1600s that provided the necessary tool for studying distant objects. This invention was followed by the discovery of **spectroscopy**, the breakdown of light into its spectrum of colour. The spectrum provided information about the element composition of celestial bodies.



Improved optical and radio telescopes followed, and then came the age of rockets and satellites. Today, advanced computer and space technologies in the form of space stations and rovers are collecting information previously unattainable.

Scientists use the **astronomical unit** (AU) to measure distances within the solar system. The distance from the centre of Earth to the centre of the sun is 1 AU. By comparison, the distance from Mercury to the sun is 0.39 AU and from Pluto to the sun is 39.5 AU.



Distances beyond the solar system are measured in light-years. A **light-year** is the distance light travels in one year. After the sun, the next nearest star to Earth, Proxima Centauri, is 4.2 light-years away. The following calculation expresses the vast distance that Proxima Centauri is from Earth.

$$300\ 000\ \text{km/s} \times 60\ \text{s/min} \times 60\ \text{min/h} \times 24\ \text{h/day} \times 365\ \text{days/year} \times 4.2 = 3.97 \times 10^{13}\ \text{km}$$

Practice Questions: 2, 3

E.1.3 describe, in general terms, the distribution of matter in star systems, galaxies, nebulae, and the universe as a whole

E.1.4 identify evidence for, and describe characteristics of, bodies that make up the solar system, and compare their characteristics with those of Earth

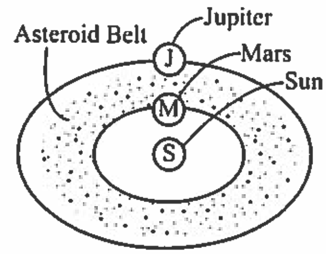
THE SOLAR SYSTEM

It is believed that huge accumulations of dust and gases called **nebulae** are pulled together by gravity to form stars. It appears that stars go through stages of development. They begin as red giants, become white dwarfs, and eventually evolve to supernovas and neutron stars or black holes. Scientific evidence shows they move through this progression.

The sun is the nearest star to Earth. It is the basis of the solar system that includes eight planets and their moons. All the planets revolve around the sun in an elliptical orbit and rotate on their axis to produce day and night.

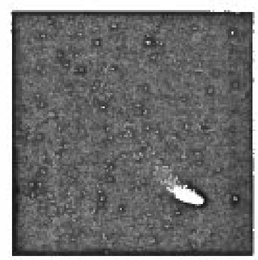
The **terrestrial planets** of Mercury, Venus, Earth, and Mars are closer to the sun and are made of solid material. Jupiter, Saturn, Uranus, and Neptune are much larger but less dense. These planets are made of gases, usually hydrogen and helium and are referred to as **Jovian planets**.

The asteroid belt is found between the orbits of Jupiter and Mars. Asteroids are rocky or metallic and revolve around the sun, as do the other planets.



Fragments of rocks called **meteoroids** are often pulled toward Earth by gravity. As they enter the atmosphere, friction causes the rocks to heat up and shower a streak of light. These shooting stars or **meteors** frequently burn up in the atmosphere. Occasionally, a rock crashes down to Earth's surface as a **meteorite**.

Comets are also found travelling in the solar system. They are made up of dust and ice. The sun's heat causes the ice to vaporize and leave a trail of visible gases. Halley's comet orbits the sun; therefore, it has a predictable schedule and becomes visible every 76 years.



Practice Questions: NR2, NR3, 4, 5, 8

E.1.5 describe and apply techniques for determining the position and motion of objects in space, including

- *constructing and interpreting drawings and physical models that illustrate the motion of objects in space*
- *describing in general terms how parallax and the Doppler effect are used to estimate distances of objects in space and to determine their motion*
- *describing the position of objects in space using angular coordinates*

MEASURING DISTANCES IN SPACE

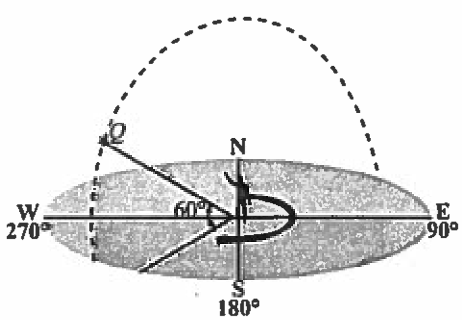
To estimate the distance of an object from Earth, astronomers use the parallax of a star. **Parallax** refers to the apparent shift in position of the star when it is viewed from different places. The speed and direction of motion of an object in space are determined based on the Doppler effect.

The **Doppler effect** is the change in frequency of a wave as it moves toward or away from an observer.

Two important measurements are used to describe the position of objects in space.

1. The **azimuth** is the direction relative to due north (0 degrees).
2. The altitude is the height in the sky of the object measured in degrees from 0 to 90. Zero degrees is at the horizon, while 90 degrees is straight up.

The location of a star is recorded as an azimuth of x degrees and an altitude of y degrees.



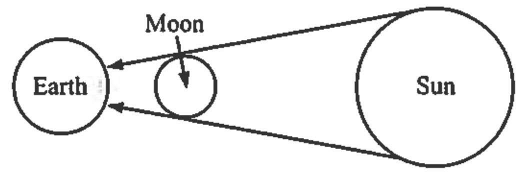
Practice Questions: NR4, 6

E.1.6 investigate predictions about the motion, alignment, and collision of bodies in space, and critically examine the evidence on which they are based

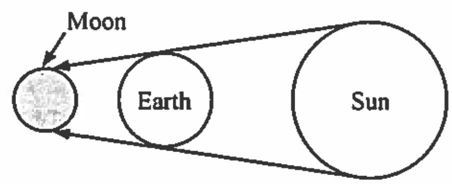
MOTION AND ECLIPSES

Because of the predictable pattern of Earth's revolution around the sun and the moon's revolution around Earth, the sun, Earth, and moon can align in a straight line relative to one another. This produces a shadow called an **eclipse**.

A solar eclipse occurs when the moon aligns itself between Earth and the sun.



A lunar eclipse occurs when Earth aligns itself between the sun and the moon.



Planets, comets, asteroids, and meteoroids are in constant motion in space. Occasionally, some space matter leaves its orbit and falls to Earth. It is believed that the Barringer Crater in Arizona was formed by the impact of a meteorite that fell to Earth about 50 000 years ago. More frequent are smaller meteorite collisions with Earth. Thousands of tiny meteorites hit Earth each year.

Practice Question: 7

E.2.1 analyze space environments, and identify challenges that must be met in developing life-supporting systems

SPACE ENVIRONMENT

Space is a harsh and dangerous environment. There are many challenges that must be met in order for people to safely work and live.

There is no air or atmospheric pressure in space. There is no food or water. Everything people need to survive must be taken with them. Spacecraft must also have systems to dispose of and recycle waste safely, including human waste.

Earth's atmosphere keeps it warm and protects living things from most cosmic radiation. In space, there is no protection. It is extremely cold and has dangerous cosmic radiation and micrometeorites. The walls of a spacecraft and space suits used for space walks must be constructed of materials that can withstand these hazards.

The microgravity environment of space is also hard on the bones and muscles of astronauts. Astronauts living in space for extended periods of time must exercise intensely to overcome these effects.

Objects in space are very far apart. This means that astronauts may be in space for extended periods of time as they travel from one place to another. In the days of the Apollo missions to the moon, astronauts were in space between 8 and 12 days at a time. Currently, astronauts may be on the International Space Station for months at a time. In the future, missions to Mars will be up to two years long. This extended time means that they are exposed to the dangers of space for longer and longer durations.

Practice Question: 9

E.2.2 describe technologies for life-support systems, and interpret the scientific principles on which they are based

LIFE-SUPPORT SYSTEMS IN SPACE

The International Space Station (ISS) has a number of different life-support systems. These systems are designed to meet the challenges of living and working in space.

Oxygen is both shipped to the ISS in pressurized tanks and created onboard using recycled water. The oxygen and hydrogen are separated using a process called electrolysis. As a backup, there is a system called a perchlorate candle that produces oxygen through a chemical reaction.

Recycled wastewater is used to produce drinking water. The system for purifying the water on the space station mimics the natural water cycle on Earth.

Scientists are also experimenting with growing food in space. This will be necessary for long manned flights such as missions to Mars where it will be impossible to take all the food they would need for the entire journey. They are experimenting with hydroponic systems where plants grow in a liquid environment. These plants may also one day provide not only food, but a system to produce oxygen and remove carbon dioxide from the air, just as they do on Earth.

Practice Question: 12

E.2.3 describe technologies for space transport, and interpret the scientific principles involved

SPACE TRANSPORT

The main types of space transport are rockets, space shuttles space stations, and space probes.

ROCKETS

A rocket is a transport vehicle that carries astronauts and satellites into space. To overcome the force of gravity, an object needs to be travelling at least 28 000 km/h. Burning solid fuels such as oxygen and nitrogen creates the propulsion required. The gas is compressed and pushed out through the boosters. This causes a reaction that moves the rocket forward.

The power of rockets to lift objects into space is described by **Newton's third law of motion,** which states that every action causes an equal and opposite reaction.

The motion of satellites and interplanetary spacecraft in space is described by the laws of motion formulated by Kepler, which state that the closer a satellite is to Earth, the faster it orbits.

Multistage rockets consist of two or more sections called **stages**. In multistage rockets, each stage is separated and discarded once its fuel has been consumed. Successively discarding the stages reduces the weight of the fuselage and increases the mass ratio of the rocket. This is an efficient method of increasing the speed of the rocket.

A rocket consists of three main parts:

- Payload—crew and cargo
- Fuel—combination of gases
- Mechanical structure—combustion chamber and tanks

SPACE SHUTTLES, SPACE STATIONS, AND SPACE PROBES

There are three main types of spacecraft in use: space shuttles, space stations, and space probes.

The **space shuttle** is a reusable rocket-launched vehicle designed to go into Earth's orbit, transport people and cargo between Earth and orbiting spacecrafts, and glide to a landing back on Earth. Space shuttles have been used to service and repair orbiting satellites, to return previously deployed spacecrafts, and to conduct scientific experiments in space.

Space stations are facilities that enable humans to live in space for long periods of time.

Space stations are used as laboratories where scientific and engineering experiments can be conducted. One day, they will be used as servicing centres where spacecrafts can be repaired, upgraded, or even constructed, and as spaceports where spacecrafts can pick up and deliver people, cargo, and fuel on the way to or returning from distant destinations.

Space probes are unmanned satellites or remote-controlled landing devices that explore objects and areas in space. Space probes have been used to carry out remote sensing on Mercury and Jupiter. They have been used to collect samples of soil on Mars, to collect data on Venus, and study the nature of Saturn's rings.

Practice Questions: 13, 14, 15, 16

E.2.4 identify materials and processes developed to meet needs in space, and identify related applications

Technology Needs in Space and Their Spinoffs

Space exploration requires specialized mechanical, computer, communications, and medical technology. There are many technologies that people use in their day-to-day activities that are spinoffs from the technologies used in space exploration.

- Specialized computer chips used for images in the Hubble Space Telescope are used for digital imaging in diagnosing medical conditions, such as some types of cancer.
- Air monitoring equipment for space is used to check for industrial pollution emissions.
- Water purification systems used for recovering and purifying water in space are used as commercial and residential purifiers.
- Food preservation and packing techniques for meeting needs in space are used for emergency reserves on Earth.
- Structural analysis equipment used to detect structural defects in spacecraft is now used in the automobile industry for checking welding joints.
- Robots for repair and assembly in space are used in the automobile industry for the assembly of parts.
- Wireless communication technology developed for space is now used in GPS technology on Earth.
- Protective material for space suits is being used for firefighters' suits.

Practice Question: 17

E.2.5 describe the development of artificial satellites, and explain the major purposes for which they are used

Artificial Satellites

Any object purposely placed in Earth's orbit or in orbit around other planets is called an **artificial satellite**. The first artificial satellite was launched in 1957. Since then, thousands of satellites have been rocketed into Earth's orbit. Artificial satellites play an important role in communication, military intelligence, and scientific studies.

The telecommunication industry uses communications satellites to carry radio, television, and telephone signals. Navigational satellites point out locations of objects on Earth, while weather satellites help meteorological departments forecast the weather. Satellites can also be used for research purposes. Landsat and RADARSAT, two Canadian satellites, have been used for activities such as monitoring environmental changes, tracking forest fires, and even monitoring soil quality.

Practice Questions: 10

E.3.1 explain, in general terms, the operation of optical telescopes, including telescopes that are positioned in space environments

Optical Telescopes

A telescope is a device that allows distant objects to be seen as if they are much closer and brighter. Telescopes are used to observe celestial objects.

Most telescopes work by collecting and magnifying the visible light that is given off by stars or reflected from the surface of planets. These telescopes use light and are called **optical telescopes**. There are two main types of optical telescopes: refracting and reflecting telescopes.

Refracting telescopes use convex lenses to collect light from a distant object and focus it so it can be seen clearly. The first telescope ever invented was a refracting telescope.

Reflecting telescopes use curved mirrors to bring reflected light waves to a focal point in order to view distant objects.

Optical interferometry is a technique that uses several telescopes to improve the resolution of images. In this technique, signals from telescopes in separate locations are combined. Optical interferometers are useful for making relatively bright, closely paired objects visible.

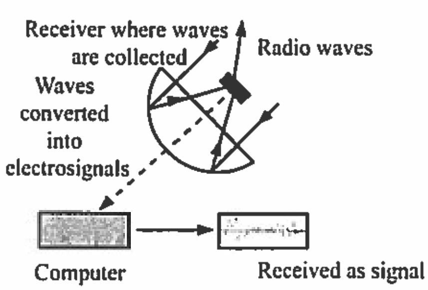
The **Hubble Space Telescope** (HST) is named after American astronomer Edwin P. Hubble. It was launched on April 24, 1990, and orbits about 600 km above Earth. In the Hubble telescope, a series of mirrors are used to focus light from very distant objects. The telescope is 4.3 m in diameter and 13 m in length. In July 1994, HST provided astronomers with the first convincing evidence of the existence of black holes. It also provided amazing images of Jupiter when the comet Shoemaker Levy 9 impacted the planet in July 1994. These images have helped scientists obtain data for spectral analysis of Jupiter's atmosphere.

Practice Questions: 19, 20, 21

E.3.2 explain the role of radio and optical telescopes in determining characteristics of stars and star systems

RADIO TELESCOPES

A **radio telescope** consists of a radio receiver and an antenna system that is used to detect radio frequency radiation. Radio wavelengths are longer than those of visible light, so radio telescopes have to be very large to attain the resolution of optical telescopes.



An advantage of radio telescopes is that they use radio waves and not visible light waves. Radio waves are not as easily distorted as light waves, and they are detectable at any time of day. Radio waves can detect objects that do not emit visible light. These telescopes can also be combined in **radio interferometry** to produce high resolution images. A group of many telescopes is called an **array**.

Optical and radio telescopes provide information about the objects in space.

Practice Questions: 22, 23

E.3.3 describe and interpret, in general terms, the technologies used in global positioning systems and remote sensing

SATELLITE TECHNOLOGIES

The **Global Positioning System** (GPS) is a space-based navigation system. It consists of 24 satellites that are orbiting Earth. At any point in time, three satellites are above a certain area and can relay information about the relative position of a receiver on Earth. Information collected from the three satellites is processed using triangulation.

Remote sensing is another technology involving satellites. Satellites orbiting relatively near Earth use sensors to measure the amount of energy, reflected from Earth's surface. This data provides information about the environment and can show changes that occurred on Earth's surface.

Practice Questions: 18

E.4.1 recognize risks and dangers associated with space exploration

Risks and Dangers Associated with Space Exploration

There are many risks and dangers associated with space exploration. In space, there is no air, no food, and no water. Furthermore, there are deadly hazards such as solar and cosmic radiation, micrometeorites, and extreme temperatures.

Accidents related to space travel result in huge economic loss and often the loss of human life. In February 2003, the space shuttle *Columbia* sustained damage to the heat-resistant tiles on the underside of the craft. When it re-entered Earth's atmosphere, it exploded and burned up over Texas. The entire seven-member crew perished.

Practice Question: 11

E.4.2 describe Canadian contributions to space research and development and to the astronaut program

Canadian Contributions to Space Exploration

Canada's involvement with the space program started in 1962 with the launch of the satellite Alouette 1.

In 1972, Canada launched its first communications satellite Anik. The RADARSAT and Landsat satellites were later launched for the purposes of monitoring environmental changes on Earth's surface. Perhaps Canada's greatest contribution to the program has been the design and construction of the robot arms Canadarm 1 and Canadarm 2. Canadarm 1 was designed for the space shuttle and has been used to repair the Hubble Space Telescope. Canadarm 2 has been used for constructing the International Space Station. Canada was also responsible for making the ramp used during the Mars Pathfinder mission.

Some famous Canadian astronauts include Marc Garneau, who was the first Canadian in space, and more recently, Chris Hadfield, who became the first Canadian to walk in space in 2001.

Practice Question: 24

E.4.3 identify and analyze factors that are important to decisions regarding space exploration and development

Space Exploration Issues and Concerns

Space exploration helps to ensure that humanity can continue to grow and expand even beyond what the natural world here on Earth can provide. At some point in the future, Earth alone may not be able to provide sufficient resources to sustain life. Space contains many mineral resources such as gold, iron, and platinum that could be used. Scientists are also looking for ways of capturing solar energy in space and redirecting it to Earth.

The quest to explore space has led to many great technologies. Medical imaging, bar coding, vision screening, ear thermometers, cordless tools, lithium batteries, and robotic arms are some of the technologies developed from the space program. These technologies are used on Earth for the benefit of humankind. Global positioning systems, remote-sensing, weather forecasting, and satellite communication have opened a great avenue for future development.

Since space contains so many valuable resources, questions arise concerning the ownership of space and what countries these resources belong to. An ethical concern about space exploration is the money spent when worldwide poverty exists.

Environmentalists discuss the topic of protecting space from unnecessary alteration and who will ultimately be responsible for cleaning up space junk and pollution.

Practice Questions: 25, 26