**Space**

# Space Exploration

## Summary

| Term | Definition |
|---|---|
| universe | all of space and time and its contents |
| galaxy | a cluster of stars, planets, moons, dust, gas and other objects that are held together by gravity |
| star | a luminous sphere of plasma that is held together by its own gravity and which is undergoing nuclear fusion |
| planet | an object orbiting a star that is massive enough to be rounded by its own gravity, but not massive enough to cause nuclear fusion, and which has cleared its orbit of other smaller objects |
| dwarf planet | an object orbiting a star that is massive enough to be rounded by its own gravity and does not undergo nuclear fusion, but which has not cleared its orbit of other objects |
| moon | a natural satellite of a planet |
| asteroid | a small rocky object orbiting a star (that is not a planet or dwarf planet) |
| solar system | a star, its orbiting planets, their moons, dwarf planets, the asteroids and other objects such as meteoroids and comets, as well as gas and dust |
| exoplanet | a planet that orbits a star other than the Sun |

A **satellite** is a projectile that remains in orbit because its horizontal velocity sufficiently large that, as it accelerates toward the surface of the Earth, the surface ‘curves away’ from it. Satellites orbit the Earth above the atmosphere (>160 km) so that there is no air resistance to slow them down.

The greater the altitude of a satellite the greater the period of the satellites orbit.

Satellites that orbit the equator with a period of 24 hours are **geostationary**. Geostationary satellites remain above the same point on the Earth’s surface at all times.  Geostationary satellites orbit at an altitude of 36 000 km.

Satellites have many uses including: communications (satellite phones, satellite television etc.), weather forecasting, global positioning (GPS), environmental monitoring (vegetation, geology, temperature etc.), imaging (mapping and surveillance), scientific discovery and space exploration (e.g. the ISS and space telescopes).

The challenges of space travel include:

- travelling large distances with the possible solutions of attaining high velocity by using ion drive (producing a small unbalanced force over an extended period of time) or solar sails
- travelling large distances using a gravitational slingshot ('catapult') from a fast moving asteroid, moon or planet
- manoeuvring a spacecraft in a zero friction environment, (e.g. docking with the ISS)
- maintaining sufficient energy to operate life support systems in a spacecraft, with the possible solutions of using solar cells with area that varies with distance from the Sun, or a radioisotope thermoelectric generator (RTG)

The risks associated with manned space exploration include:

- fuel load on take-off – risk of ignition and explosion
- increased exposure to radiation (solar and cosmic) in space, due to reduced protection from Earth's atmosphere and magnetic field
- pressure differential – astronauts need to be maintained in a pressurised environment in the vacuum of space
- re-entry through an atmosphere (see below)

When an object enters the Earth's atmosphere it experiences friction with the atmosphere. The work done ($E_w = Fd$) by friction changes kinetic energy into heat. To protect spacecraft returning from space heat shielding is required. There are two main types of heat shielding:

dissipation – Some heat shields (e.g. on the Space Shuttle) absorb the heat using insulating tiles which then re-radiate the heat back into the atmosphere. These tiles have a high specific heat capacity and a high melting point.

ablation – Some heat shields (e.g. those on Apollo and Soyuz spacecraft) use the heat to vaporise the heat shield and carry away the energy. The materials used in these heat shields have a high specific latent heat.

Newton's second law ($F = ma$) can be used to solve problems involving unbalanced force, mass and acceleration relating to space travel, rocket launch and landing.

Newton's third law ("every action has an equal and opposite reaction") can used to explain propulsion systems in spacecraft.

e.g. A rocket engine exerts backwards force on exhaust gases and a the exhaust gases exert an equal and opposite force forward on the rocket engine.

Weight is the force of gravity acting on an object. The weight of an object depends on both its mass and the value of gravitational field strength at that point ($W = mg$). The value of gravitational field strength decreases with altitude. The value of gravitational field strength is different on the surface of different planets.

When an object is in freefall it appears to be weightless. For example the astronauts inside a spacecraft appear to be weightless because both the astronauts and the spacecraft are falling towards the Earth at the same rate.

Space

# Cosmology

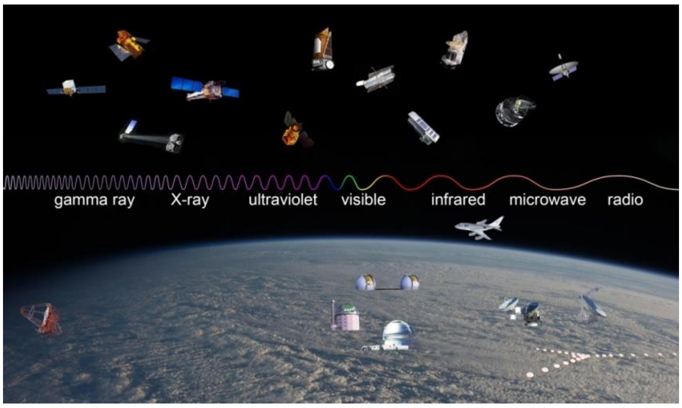
# Summary

Distances in space are so enormous that we use units known as light-years to measure them. A **light-year** (ly) is the distance travelled by light in one year (around $9{\cdot}5 \times 10^{15}$ m).

For example: Proxima Centauri (the nearest star, apart from the Sun) is 4·3 light-years away; our galaxy (the Milky Way) is around 100 000 light-years across and the next nearest spiral galaxy (Andromeda) is 2·5 million light-years away.

The Universe is thought to have begun in an event, known as the **Big Bang**, around 13·8 billion years ago when all matter, and even space and time itself, came into existence. The universe began at a single point in space-time, known as a singularity; since then the universe has expanded and (according to observations) will continue to expand.

Our current understanding of the Universe comes from observations of it using **telescopes**.




Today we use telescopes which cover all parts of the **electromagnetic spectrum** to investigate astronomical objects.

Telescopes detecting different parts of the spectrum require different detectors.

e.g.

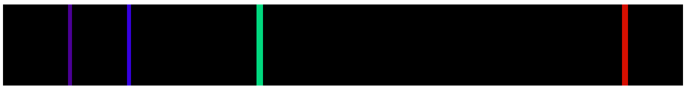
| Part of spectrum | Detector(s) |
|---|---|
| radio | aerial |
| microwave | aerial |
| infrared | photodiode<br>thermochromic film |
| visible light | photodiode<br>CCD (charge-coupled device)<br>photographic film |
| ultraviolet | fluorescent chemicals<br>photodiode |
| X-rays | photographic film |
| gamma | Geiger-Muller tube<br>photographic film |

One of the techniques used in astronomy is **spectroscopy**

A **continuous spectrum** is made up of all the colours of the spectrum (red, orange, yellow, green, blue, indigo and violet).

continuous spectrum

A **line spectrum** consists of a spectrum with only certain colours present (emission line spectrum) or a continuous spectrum with certain colours missing, which appear as black line in the spectrum (absorption line spectrum).



emission line spectrum

absorption line spectrum

Every element produces a unique line spectrum. Studying line spectra therefore allows the elements present in a light source (e.g. a star) to be identified.

Astronomers use spectroscopy to determine properties of stars and galaxies, such as their type, distance, age and speed, as well as to identify exoplanets.