Airdrie Academy

N4 Physics

Dynamics and Space

Summary Notes

Name__________________________

Class___________________________

N4 Speed and Acceleration	☺	😐	☹
I can use the formula d = v t			
I can determine average speed and instantaneous speed			
I can interpretation of speed-time graphs to describe motion for objects which are ○ speeding up, ○ slowing down ○ stationary ○ moving with constant speed.			
I calculation of distance from a speed –time graph			
I can use the acceleration formula a = v-u /t			
N4 Relationship between forces, motion and energy	☺	😐	☹
I can use Newton's first law and balanced forces to explain constant speed, making reference to frictional forces.			
I can use Newton's second law to explain the movement of objects in situations involving constant acceleration.			
I can use the formula F=ma in situations where only one force is acting.			
I know the difference between mass of an object and weight			
I can use the formula W = mg			
I can state the risks and benefits associated with space exploration including challenges of re-entry to a planet's atmosphere.			
I can explain the use of thermal protection systems to protect spacecraft on re-entry.			
N4 Satellites	☺	😐	☹
I can describe the range of heights and functions of satellites in orbit around the earth, including geostationary and natural satellites.			
I can explain the dependence of period of orbit on height.			
I can explain the use of parabolic reflectors to send and receive signals.			
I can use the formula d = v t applied to satellite communication.			
I can describe the range of applications of satellite including telecommunications; weather monitoring; the use of satellites in environmental monitoring.			
I can explain the use of satellites in developing our understanding of the global impact of mankind's actions			

N4 Cosmology	☺	😐	☹
I can use the term o planet, o moon, o star, o solar systems, o exo-planet, o galaxy o universe.			
I can describe the scale of the solar system and universe measured in light years.			
I can describe space exploration and its impact on our understanding of the universe and planet Earth			
I can describe the conditions required for an exo-planet to sustain life.			

N4 Speed and acceleration

- Calculations involving the relationship between speed, distance, and time.
- Determination of average and instantaneous speed.
- Interpretation of speed-time graphs to describe motion including calculation of distance (for objects which are speeding up, slowing down, stationary and moving with constant speed.) Motion in one direction only.
- Use of relationship of acceleration, change in speed

Average Speed

Average speed is the distance travelled per unit time.

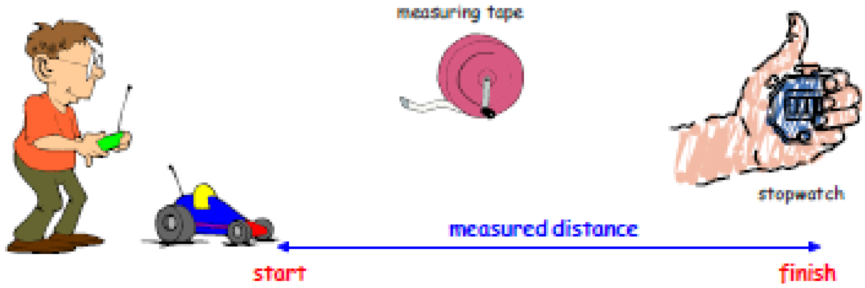
$$v = \frac{d}{t}$$

Symbol	Definition	Unit	Unit symbol
v	speed	metre per second	ms^{-1}
d	distance	metre	m
t	time	second	s

Measurement of average speed

To measure an average speed, you must:

- measure the distance travelled with a measuring tape, metre stick or trundle wheel
- measure the time taken with a stop clock
- calculate the average speed by dividing the distance by the time



Example

Calculate the average speed in metres per second of a runner who runs 1500 m in 300s.

$$v = \frac{d}{t}$$

$$= \frac{1500}{300}$$

$$= 5\ ms^{-1}$$

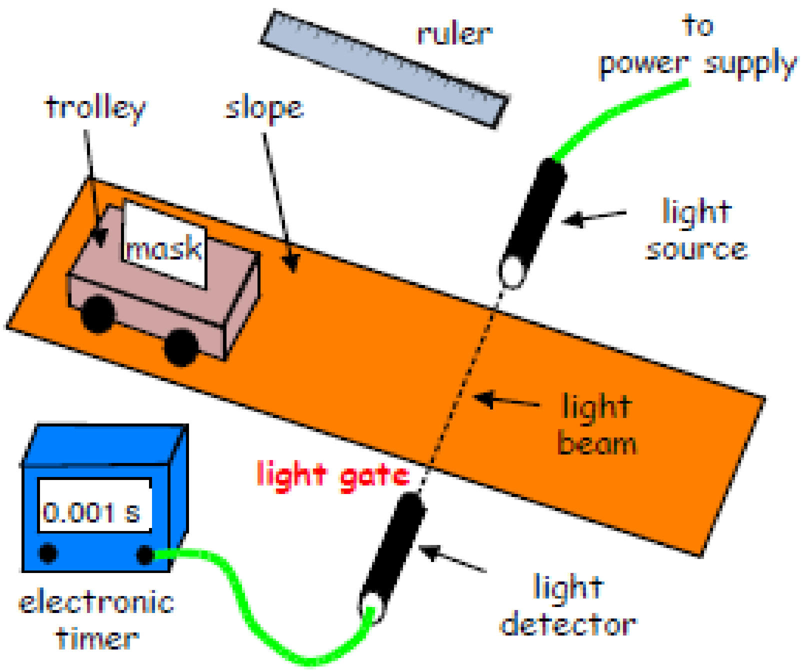
Instantaneous Speed

The **average speed** of an object is the average for the whole journey (total distance travelled divided by time taken).

The **instantaneous speed** of an object is its speed at one particular point during the journey.

Average speed and instantaneous speed are often very different e.g. the average speed for a car over an entire journey from Glasgow to Edinburgh could be 40 mph, but at any point in the journey, the instantaneous speed of the car could be 30 mph, 70 mph, 60 mph or 0 mph if the car is stationary at traffic lights.

To measure instantaneous speeds, it is necessary to be able to measure **very** short times. With an ordinary stop clock, human reaction time introduces large errors. These can be avoided by using electronic timers. The most usual is a light gate **and timer.**
The timer measures how long an object takes to cut the light beam. The distance travelled is the length of the object which passes through the beam.



Example

In the above experiment, the following measurements are made:
Length of card: 10 cm, Time on timer: 0.25 s

Calculate the instantaneous speed of the vehicle.

$$v = \frac{\text{length of card}}{\text{time on timer}}$$

$$= \frac{0.10}{0.25}$$

$$= 0.004 \ ms^{-1}$$

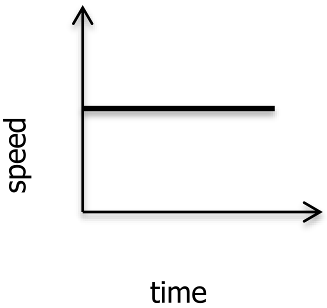
Speed Time Graphs

Speed time graphs are useful to physicists because they can be used to:

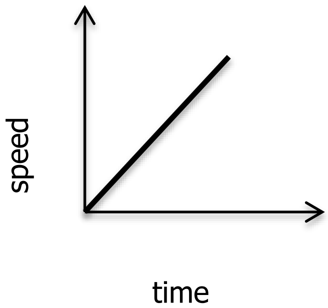
a) describe the motion of the object
b) calculate the acceleration of the object
c) calculate the distance travelled by the object

The shape of the graph indicates whether the vehicle is accelerating, decelerating or moving at a constant speed.

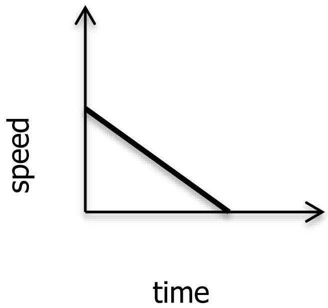
Constant speed



Increasing speed



Decreasing speed



Acceleration describes **how quickly** speed changes.
The units of acceleration are the units of speed (metres per second) divided by the units of time (seconds). The result is metres per second per second.
This is usually called metres per second squared and is written **ms^{-2}**.
An acceleration of 2 ms^{-2} means that every second, the velocity increases by 2 ms^{-1}.

If a vehicle is slowing down, the final speed will be smaller than the initial speed, and so the acceleration will be negative.
A negative acceleration is a deceleration.

Acceleration is the change in **speed** in unit time.

$$a = \frac{\Delta v}{t} \qquad a = \frac{v - u}{t}$$

Symbol	Definition	Unit	Unit symbol
v	final velocity	metre per second	ms^{-1}
u	initial velocity	metre per second	ms^{-1}
a	acceleration	metre	ms^{-2}
t	time	second	s

Example
A train accelerates from rest to 40 m/s in a time of 80 s.

Calculate the acceleration.

u = 0 ms^{-1}

v = 40 ms^{-1}

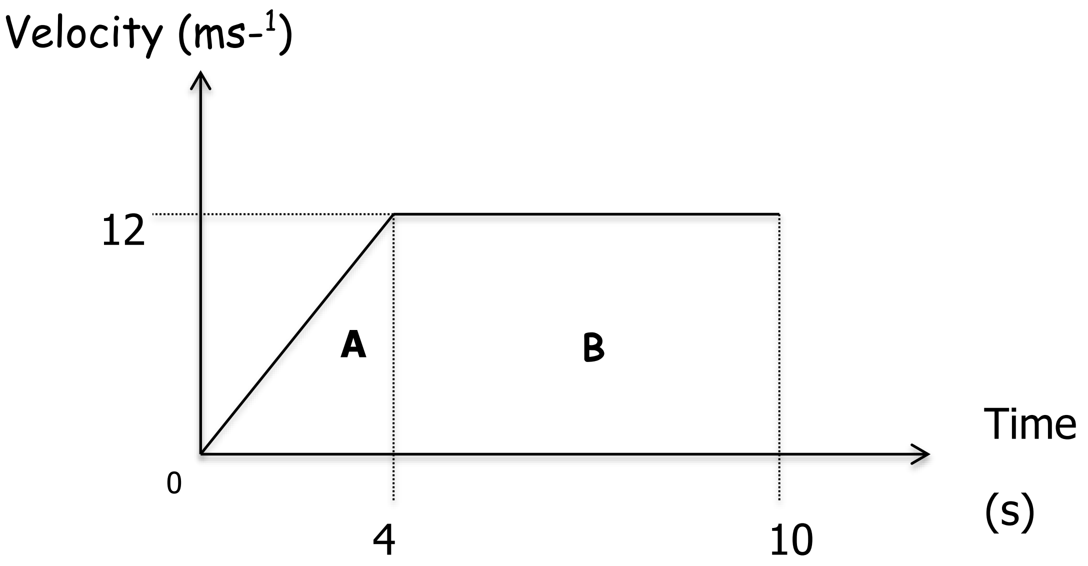
t = 80 s

$$a = \frac{v - u}{t} = \frac{40-0}{80} = 0.50\ ms^{-2}$$

Acceleration can be calculated using data from the graph. The acceleration is equal to the gradient of the slope.

The **displacement** travelled is calculated by the **area under the velocity time graph**.

Example



From the graph calculate:

$$a = \frac{v - u}{t}$$

(a) the acceleration for section A

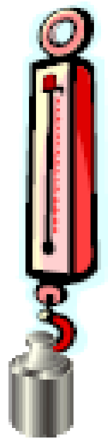
$$a = \frac{12 - 0}{4} = 3.0\ ms^{-2}$$

(b) distance for the whole journey

Distance = area A + area B
= ($\frac{1}{2}$ x 12 x 4) + (12 x 6)
= 24 + 72
= 96 m

N4 Relationship between forces, motion and energy

- The use of Newton's first law and balanced forces to explain constant speed, making reference to frictional forces.
- The use of Newton's second law to explain the movement of objects in situations involving constant acceleration.
- Calculations using the relationship between force, mass and acceleration in situations where only one force is acting.
- Calculations using the relationship between weight, mass and gravitational field strength within our solar system.
- Risks and benefits associated with space exploration including challenges of re-entry to a planet's atmosphere. The use of thermal protection systems to protect spacecraft on re-entry.



Newton's Laws

Forces can only be detected by their effects.
They can change:

- the shape of an object (stretch it, squeeze it etc)
- the speed of an object
- the direction of movement of an object

A force is a vector quantity because it has a direction and size .

Forces are measured in units called **Newton's** (N).
Forces can be measured with a **newton balance** or **spring balance**.

The Force of Friction

Friction is a **resistive** force, which opposes motion.
Friction acts between any two surfaces in contact. When one surface moves over another, the force of friction acts between the surfaces and the size of the force depends on the surfaces,
e.g. a rough surface will give a lot of friction.

Friction is a very common force.

If there is no friction between surfaces then the surfaces can move easily over each other.
This can be achieved by placing a layer of a different material between the surfaces.

An example of this is putting wax on snowboards.

Mass and Weight

Mass measures the amount of matter in an object. It is measured in **kilograms** (kg). The value of mass does not change from place to place.

Weight is a force caused by gravity acting on an object's mass. On Earth, it measures the pull of the Earth on the object. It is measured in **Newton's**.
Weight always acts vertically downwards and depends on

- the **mass of the object**
- the **strength of the gravitational field** at that place.

The **strength of gravity** in a particular place is called **the gravitational field strength.** This tells you the weight of 1 kg. Its symbol is **g** and its unit is Newton's per kilogram, **Nkg^{-1}**.

The gravitational field strength is different for different planets within our solar system.

	Gravitational field strength on the surface in N kg^{-1}
Earth	9.8
Jupiter	23
Mars	3.7
Mercury	3.7
Moon	1·6
Neptune	11
Saturn	9
Sun	270
Venus	8.9

Mass and weight are connected by the following formula:

$$W = mg$$

Symbol	Definition	Unit	Unit symbol
W	weight	newton	N
m	Mass	kilograms	kg
g	gravitational field strength	Newton's per kilogram	Nkg^{-1}

Example

Calculate the weight on Mars of a component for the Mar's Rover, if its mass on Earth is 5.6 kg.

Gravitational field strength on Mars is 3.7 Nkg^{-1}

$m = 5.6$ kg

$g = 3.7\ Nkg^{-1}$

$W = mg$

$W = 5.6 \times 3.7$

$W = 20.72$

$W = 21$ N

Friction

Friction is a force which opposes the motion of an object. This means that it acts in the opposite direction to motion. Friction acts between any two surfaces in contact. When one surface moves over another, the force of friction acts between the surfaces and the size of the force depends on the surfaces,
e.g. a rough surface will give a lot of friction.

Friction caused by particles of air is called air resistance.
It depends mainly on two factors:
• the shape and size of the object
• the speed of the moving object.

Air resistance increases as the speed of movement increases.

Increasing and Decreasing Friction

Where friction is making movement difficult, friction should be reduced. This can be achieved by:

- lubricating the surfaces with oil or grease
- separating the surfaces with air, e.g. a hovercraft
- making the surfaces roll instead of slide, e.g. use ball bearings streamlining to reduce air friction.

Where friction is used to slow an object down , friction can be increased by:

- choosing surfaces which cause high friction
  e.g. sections of road before traffic lights have higher friction than normal roads
- increasing surface area and choosing shape to increase air friction, e.g. parachute.

Newton's First Law

"States that an object will remain at rest or move with constant velocity unless acted upon by an external force "

Two forces which are equal in size but which act in opposite directions are called **balanced** forces.

Balanced forces have the same effect as **no force** at all. When the forces on an object are balanced (or when there are no forces at all), then neither the speed nor direction of movement will change. Newton's First Law explains why a passenger in a bus (not wearing a seat belt) will continue to move forward after the bus has applied its brakes. The force was applied to the bus and not to the passenger. Therefore the passenger will continue moving forwards until a force stops them (usually from the seat in front of them).

Newton's Second Law

When the forces are balanced an object will remain at rest or travel at a constant speed in a straight line. But when the forces are not balanced the velocity cannot remain constant. It will change.

$$F = m\,a$$

Symbol	Definition	Unit	Unit symbol
F	force	newton	N
m	mass	kilograms	kg
a	acceleration	metres per second squared	ms^{-2}

Example

A bike of mass 100 kg accelerates at a rate of 1.6 ms^{-2} Calculate the force acting on the bike

a = 1.6 ms^{-2}

m = 100 kg

F = ma
= 1.6 ×100
= 160 N

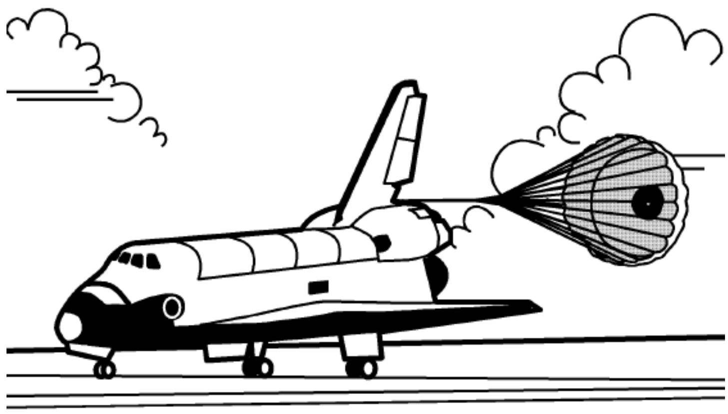
Risks of Space exploration

Space travel is not easy and there are many problems that can occur. The first inflight disaster was the 1986 Challenger disaster. A failure in the rings holding the solid rocket boosters allowed hot gases to escape leading to the break-up of the external fuel tank. This caused the entire space craft to tilt towards the air stream and subsequently break up. The most recent U.S. disaster was the 2003 Columbia disaster. Due to a piece of insulation breaking off and damaging the leading edge of one of its wings the Columbia broke up in the atmosphere during re-entry.

As a spacecraft re-enters the earth's atmosphere, it is traveling very much faster than the speed of sound

The chief characteristic of re-entry is that the heat energy is so great (temperatures can reach 1650 °C) that a special thermal protection system is used to keep the spacecraft intact.

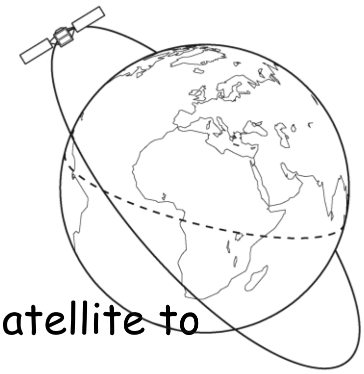
On the Shuttle, special silicon tiles are placed on the aluminium skin to insulate the interior. On the leading edge of the wings, carbon-carbon composite material is used to withstand the heat. The high forces and high heat dictate that the Shuttle has short, blunt wings. The Shuttle flies at a high angle of attack during re-entry to generate drag to dissipate speed.



N4 Satellites

- The range of heights and functions of satellites in orbit around the earth, including geostationary and natural satellites.
- The dependence of period of orbit on height.
- The use of parabolic reflectors to send and receive signals.
- Use of the relationship between distance, speed and time applied to satellite communication.
- Range of applications of satellite including telecommunications; weather monitoring; the use of satellites in environmental monitoring.
- The use of satellites in developing our understanding of the global impact of mankind's actions.

A **satellite** is an object which **orbits another object**.
The Moon is a natural satellite which orbits Earth.
The largest man made satellite is the International Space Station (ISS).



The **period** of a satellite is the **time** taken for the satellite to **complete one** orbit.

The **period** of a satellite depends on the **height of the satellite above the object** it is orbiting. The **higher** the orbit of the satellite the **greater** the period and vice versa.

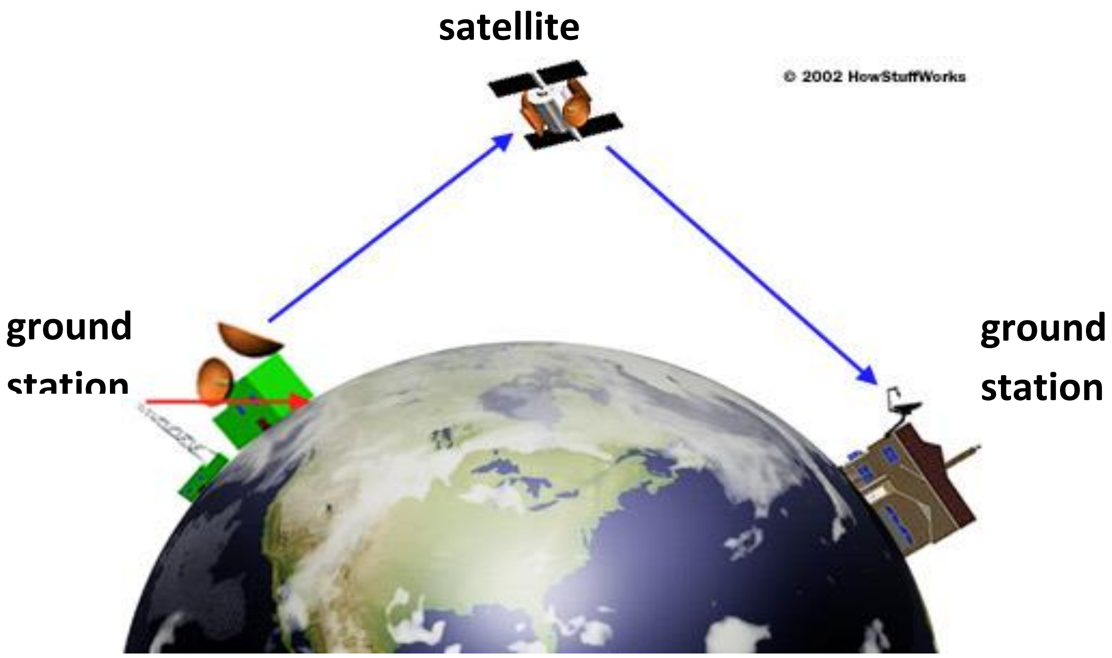
A **geostationary satellite** is a satellite which:

- has a period of 24 hours
- orbits at roughly 36000 km above the earth's surface which is much higher than other satellites
- stays above the same point on the earth's surface at all times.

Satellite Communication

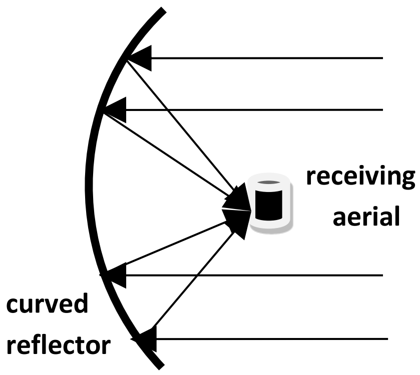
Ground stations send microwave signals to the satellite using a curved dish transmitter to transmit a strong signal. At the satellite the signal is **collected** by a curved dish receiver, then **amplified** and finally **retransmitted** (at a different frequency) back to the ground using another curved dish transmitter. The transmitting and receiving aerials are placed at the **focal point of the curved reflector.**

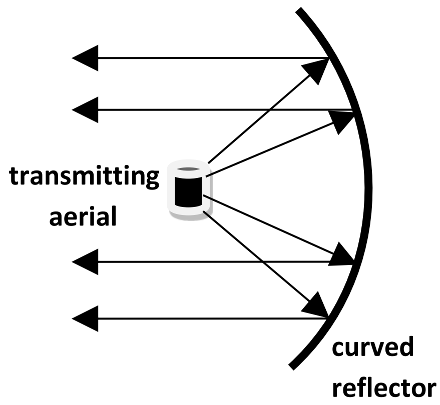
The signal is sent at a speed of 300 000 000 ms^{-1}. This allows the equation d = vt to be used with satellite communication.



Curved reflectors are used to increase the strength of a received signal from a satellite or other source. The curved shape of the reflector collects the signal over a large area and brings it to a **focus**.

The receiving aerial is placed at the focus so that it receives a strong signal.





Curved reflectors are also used on certain transmitters to transmit a strong, parallel signal beam. In a dish transmitter the transmitting aerial is placed at the focus and the curved shape of the reflector produces a parallel signal beam.

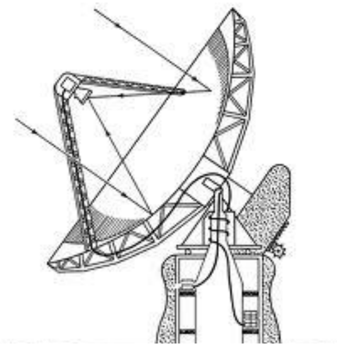
<u>Applications of Satellites</u>

Satellites are being used by many countries in different ways. For example:

- **Sending a television or radio signal across the country or to another country**
  Three geostationary satellites, placed in orbit above the equator permits worldwide communication with satellites communicating with ground stations in different continents.
- **Navigation**
  There are many Global Positioning Satellite (G.P.S) systems available to put in a car so that you don't get lost. This uses the basic equation d = vt to establish your position.

- **Weather monitoring**
  The **weather satellite** is a type of satellite that is primarily used to monitor the weather and climate of the Earth.

Global environmental change is one of the most pressing international concerns of the 21st century. For many years, various types of satellites have been used to detect and monitor worldwide changes including:



- the effects of global warming
- depletion in the ozone layer and
- large scale changes in land cover.

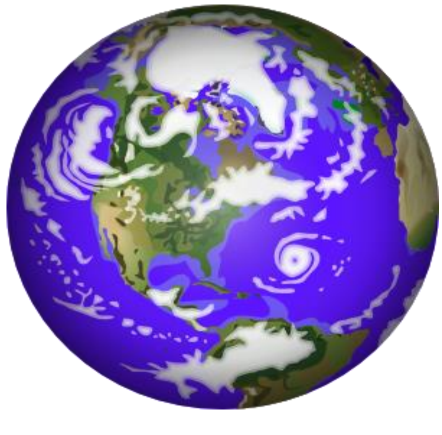
These changes have been down to both:

- natural occurrences and
- as a consequence of the impact of our actions.

Satellites which are used to monitor such events orbit at heights much smaller than 36000 km and do not stay above the same point on the Earth's surface. This allows continuous observation and monitoring of the Earth's land, atmosphere, oceans and ice caps.

For example, the 2002 oil spill off the northwest coast of Spain was watched carefully by the European ENVISAT satellite, which, though not a weather satellite, flies an instrument (ASAR) which can see changes in the sea surface. It orbits at a height of approximately 800 km. With this information collected by the satellite, rescue teams and environmental agencies can attend the scene quickly and minimise the damage caused.

Other disasters, both natural and otherwise can be detected and monitored in a similar way.



Radio Telescopes

Radio astronomy is the study of celestial objects that emit radio waves. Astronomical phenomena that are invisible to the eye can be observed. Radio waves penetrate dust, so regions of space that cannot be seen in visible light can be investigated. Using radio telescopes astronomers analyse and explore the black holes that live at the hearts of most galaxies.

These telescopes are huge curved reflectors designed to capture many radio waves. These are arranged in very large arrays of many individual telescopes to allow improved resolution of data capture.

N4 Cosmology

- Description of planet, moon, star, solar systems, exo-planet, galaxy and universe.
- Scale of the solar system and universe measured in light years.
- Space exploration and its impact on our understanding of the universe and planet Earth.
- Conditions required for an exo-planet to sustain life.

There are many different bodies moving around in the universe. Below is a list of some of them with a definition of what they are:

Star	A hot ball of burning matter which emits light. The sun is an example of a star.
Planet	A spherical ball of rock and/or gas which orbits a star. Earth is an example of a planet.
Moon	A lump of matter which orbits a planet. Our moon orbits Earth.
Solar System	A solar system consists of a star and all the objects orbiting it as well as all the material in that system.
Galaxy	A large cluster of stars, some of which have planets orbiting them. The Milky Way is an example of a galaxy.
Exo Planet	A planet outside our Solar System.
The Universe	Consists of many Galaxies separated by empty space.

If you consider the growing population and dwindling resources of our home planet, some scientists believe that finding exo planets capable of sustaining life should be a top priority.

Scientists need to consider the basic needs of life and if these needs can be delivered by an exo plant.

The basic needs for human life are:

- Oxygen
- Water
- Food
- Shelter
- Warmth.

In our search for a new home scientists need to identify an exo planet which has:

- A similar atmosphere to ours
- The potential to build shelter
- The potential to grow and nurture a sustainable food source.

Light Year

The **Light Year** is a measure of distance and is the distance that light travels in one year.

Example

How many metres are in a light year?

$$d = v\,t$$

$$= 3 \times 10^8 \times 60 \times 60 \times 24 \times 365$$

$$= 9.46 \times 10^{15}\ \text{m}$$

As the distances in the universe are very large we need to use the term light year instead of metres or even miles.

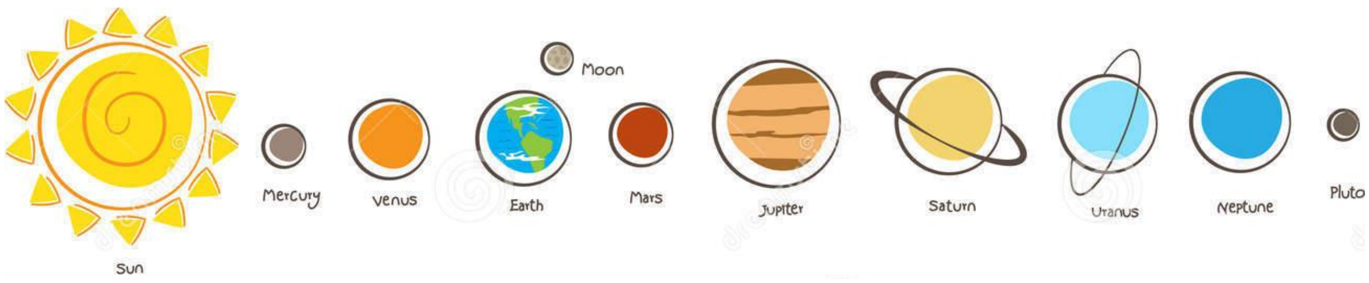
Approximate distance from Earth to:

Proxima Centauri (nearest star outside the solar system)
4.2 light years

Canis Major Dwarf (nearest galaxy to the Milky Way)
25000 light years

The edge of the known Universe
46 billion light years.

Space Exploration



According to current estimates, the universe is approximately 13.7 billion years old and consists of approximately 100 billion galaxies, each containing approximately 100 – 1000 million stars!!

Our understanding of the immediate and distant universe comes mainly from two activities, **space exploration** and **looking up**.

We have launched satellites, sent a man to the Moon and probes beyond the furthest planet in our solar system, built a Space Station that is visible from the ground, landed a "rover" on Mars; and launched the Hubble Space telescope, which has arguably produced the greatest pictures ever taken.
There are thousands of people employed researching and developing the next generation of satellites, space station modules, probes, space telescopes and many other devices to aid our understanding of the universe.

All of our understanding of stars and galaxies comes from using telescopes to look up at the sky. Some of these telescopes are in space (The Hubble Telescope) but most are in ground-based arrays. These arrays consist of tens or hundreds of curved reflector telescopes that can scan the sky to observe not just visible light but radiation from all parts of the visible spectrum.