A jumbo jet cruises at 245 metres per second.

World's fastest man.

Sailfish have been measured at speeds of 110 km/h.

Speed & Acceleration

Speed

The speed of any object is its distance travelled in a certain time.

Average Speed

The **average speed** is the speed over the course of a whole journey.

Average speed can be calculated from :

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

The standard unit of speed, v, is metres per second (m/s or ms^{-1}). Distance, d, is measured in metres (m) and time, t, is measured in seconds (s). However sometimes other units for speed are used, such as kilometres per hour (km/h) or miles per hour (mph).

Example

Usain Bolt ran 100 metres in 9.58 seconds, calculate his average speed for the race.

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

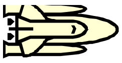
$$= \frac{100}{9.58}$$

$$= 10.4 \text{ m/s}$$

Measuring Average Speed

To measure an average speed :-

- the distance, d, is measured with a metre stick or trundle wheel.
- the time taken, t, to travel the distance is measured with a stopclock.
- the average speed, v, is calculated by dividing the distance, d, by the time, t.



Instantaneous Speed

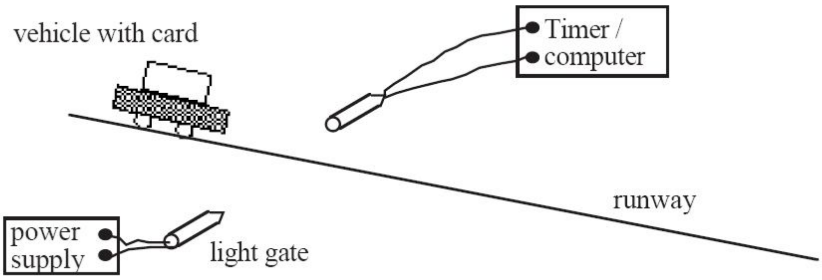
The **instantaneous speed** is the speed you are travelling at a particular instant or moment of your journey.

Average speed is different as it is the speed over the course of the whole journey. Since the instantaneous speed is the speed at a moment, the time taken when calculating instantaneous speed is very small compared with the time for a whole journey. Hence devices have been developed to measure this small time interval (instantaneous speed) accurately, such as the RADAR gun, speed cameras or speedometers. In the class, light gates are used to measure this small time interval required for instantaneous speed.

Measuring Instantaneous Speed

The measurement of instantaneous speed in the class requires the following apparatus

- a laboratory vehicle with mask (card)
- a runway
- a TSA meter or computer
- a light gate



Procedure for measuring instantaneous speed

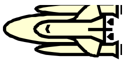
- The **DISTANCE** which is the length of the mask (card) is measured with a ruler and entered into the TSA meter or the computer.
- The trolley is released from the top of the runway.
- The trolley passes through the light gate at the bottom of the runway, the TSA meter will measure the **TIME** taken by the mask (card) to cut the light gate.
- The instantaneous speed is then calculated by the TSA meter or computer using the formula.

Instantaneous speed = length of card / time taken to cut beam

Speedometers help drivers to monitor their own speed.

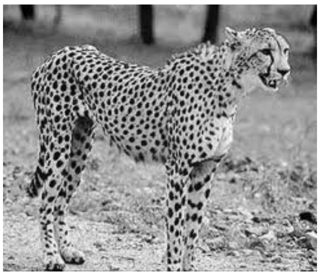
A RADAR gun used by the police to monitor speed.

A light gate attached to a TSA meter. Apparatus you should be familiar with.



Speed is one of the main factors in fatal road accidents.

A bike speedometer which gives both average and instantaneous speed.



Cheetahs can accelerate from 0 to 60 mph in 3 seconds.

Acceleration

The speed of an object is how fast it is travelling and is the distance travelled in 1 second.

The acceleration of an object is the **change** in speed in a time i.e. by how much the speed **changes** in 1 second.

$$\boxed{\text{Acceleration} = \frac{\text{change in speed}}{\text{time}}}$$

The units for acceleration are metres per second per second which is written as ms $^{-2}$ or m/s^2.

The ‘change in speed’ is calculated by subtracting the object’s initial speed, u, from the in final speed, v. In symbols, the formula for acceleration can be written as :

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

Example 1

A car accelerates from 10 m/s to 20 m/s in a time of 4 s. Calculate the acceleration of the car.

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

$$= \frac{20 - 10}{4}$$

$$= 2.5 \text{ m/s}^2$$

Example 2

A girl on a bike accelerates from rest to 12 m/s in a time of 3 s. Calculate her acceleration on the bike.

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

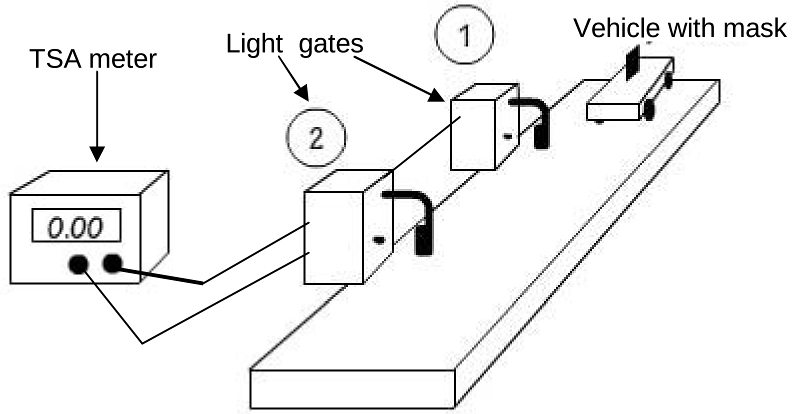
$$= \frac{12 - 0}{3}$$

$$= 4 \text{ m/s}^2$$

Measuring Acceleration

To measure acceleration the initial speed, the final speed and the time for the acceleration are required. To measure acceleration in the class the following apparatus is required :-

- a laboratory vehicle with mask (card)
- a runway
- a TSA meter or computer
- two light gates



- The vehicle with the mask is released from the top of the slope.
- The mask cuts through the first light gate allowing the initial instantaneous speed, **u**, to be measured.
- The mask cuts through the second light gate allowing the final instantaneous speed**, v**, to be measured.
- The time for the acceleration, **t**, is measured between the light gates.
- The TSA meter calculates the acceleration of the vehicle using the formula :-

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

Example 3

A laboratory vehicle accelerates from rest to 1.5 m/s in a time of 0.5 s. Calculate the acceleration of the vehicle.

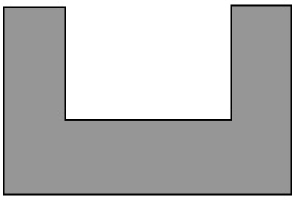
$$a = \frac{v - u}{t}$$

$$= \frac{1.5 - 0}{0.5}$$

$$= 3\ m/s^2$$

Acceleration is used as an indicator of car performance.

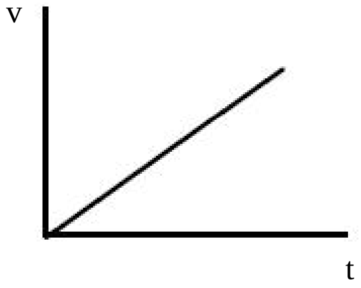
The Jaguar XKR travels from 0 to 60 mph in 4.9 seconds.



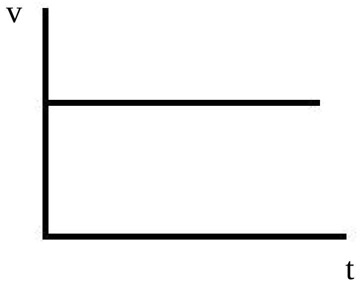
How can a double mask be used to measure acceleration ?

Speed-Time Graphs

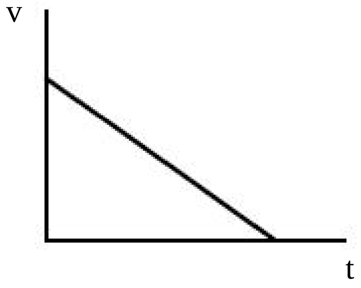
Graphs are a good way of displaying data as information can be taken from them easily. Graphs are used in a number of subjects (or situations). Speed-time graphs are no different.
The shape of speed-time graphs displays the motion of an object as seen below.



This graph displays the speed increasing over time—**ACCELERATION**.

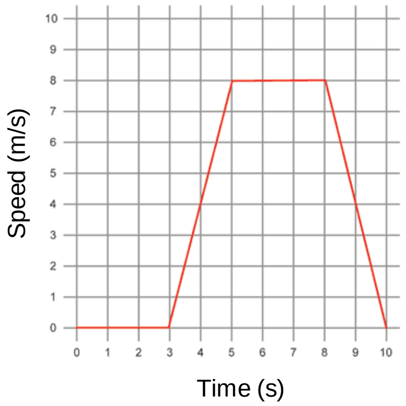


This graph displays the speed remaining constant over time—**STEADY SPEED**.



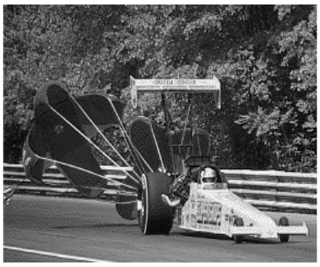
This graph displays the speed decreasing over time—**DECELERATION**.

The following graph shows how the speed of an object changes with time.

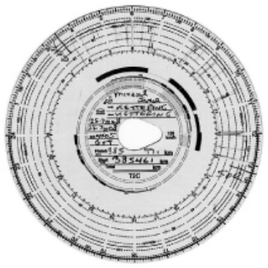


- 0 to 3 seconds the object is stationary.
- 3 to 5 seconds the object is accelerating.
- 5 to 8 seconds the object is moving at a constant speed.
- 8 to 10 seconds the object is decelerating.

Cruise control is a good way of maintaining a constant speed in cars.



How do dragsters decelerate quickly ?



Tacographs are used to monitor long distance drivers.

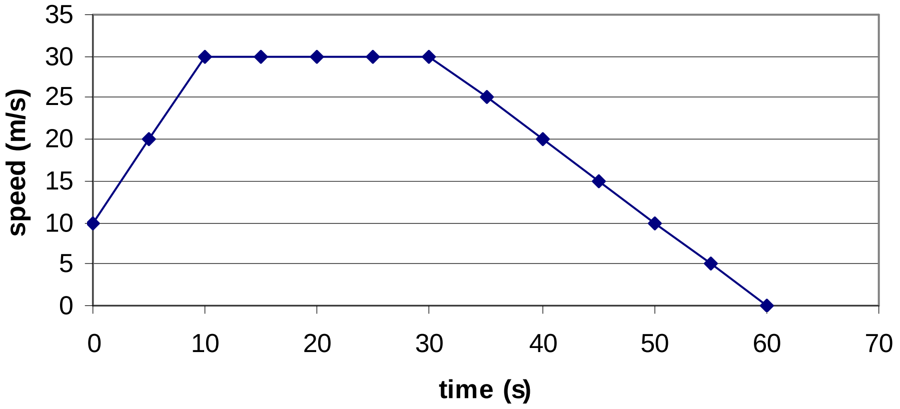
The following information can also be obtained from a speed-time graph :-

- acceleration
- distance travelled from the area under the graph
- average speed

The example below will show you how to do it.

Example

The graph for the motion of a helicopter over 60s is shown below.



(a) Calculate the acceleration between 0 and 10 seconds.

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

$$= \frac{30 - 10}{10}$$

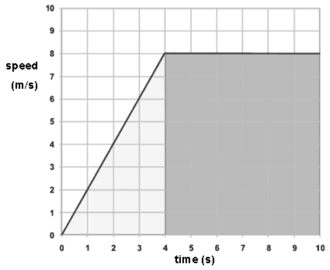
$$= 2 \text{ m/s}^2$$

(b) Calculate the acceleration between 30 and 60 seconds.

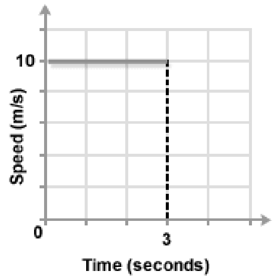
$$a = \frac{v - u}{t}$$

$$= \frac{0 - 30}{30}$$

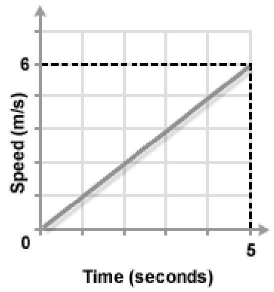
$$= -1 \text{ m/s}^2$$



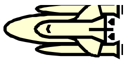
Distance is worked out from the area under a speed-time graph.



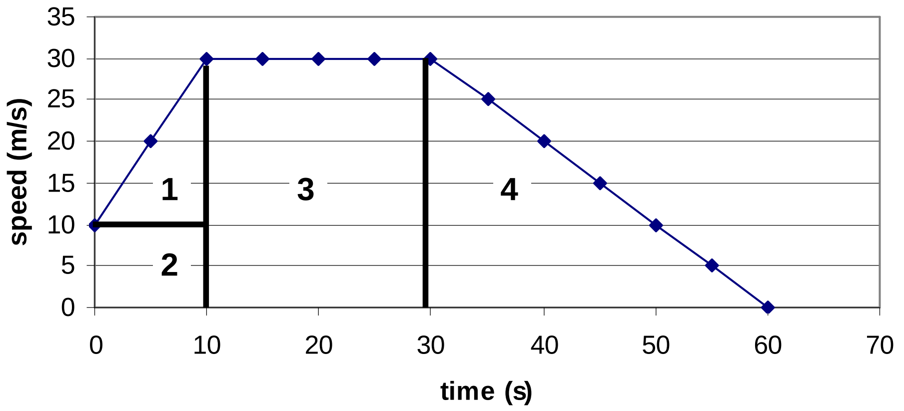
Distance = l x b
= 3 x 10
= 30 m



Distance = 1/2 x l x b
= 1/2 x 5 x 6
= 15 m



(c) Calculate the distance travelled by the helicopter over the 60 seconds.



Distance = Area under the speed – time graph

$= \text{area } 1 + \text{area } 2 + \text{area } 3 + \text{area } 4$

$= (1/2 \times 10 \times 20) + (10 \times 10) + (20 \times 30) + (1/2 \times 30 \times 30)$

$= 100 + 100 + 600 + 450$

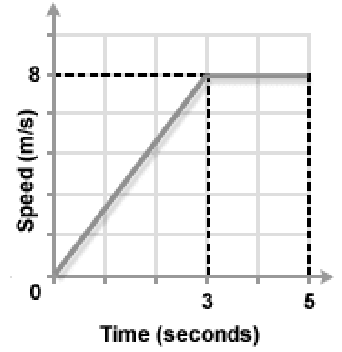
$= 1250 \text{ m}$

(d) Calculate the average speed during the 60 seconds.

$v = d/t$

$= \frac{1250}{60}$

$= 20.8 \text{ m/s}$



Calculate the distance travelled from this graph.

Average speed camera.

The top speed of a race horse is approximately 80 km/h.

Forces

Effects of Forces

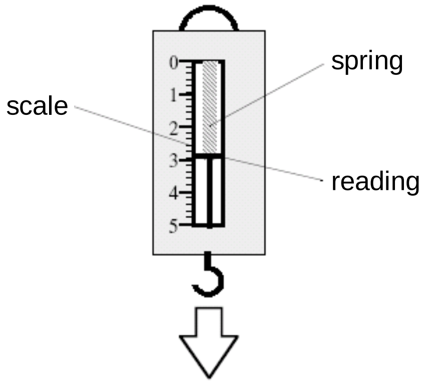
You cannot see a force but the effects of a force are clearly seen. They will cause a change in the

- Shape of an object
- Speed of an object
- Direction of movement of an object

The weight of the car is changing the shape of the tyre.

Measuring Forces

Forces can be measured using an instrument called a spring balance (a Newton Balance when the scale is in newtons).



When a pulling force is applied to the Newton Balance the spring stretches (changes shape). The pointer on the spring moves over the scale as the spring stretches. When the pointer stops moving the size of the force can be read from the scale.

Sir Isaac Newton, the greatest scientist of his era.

All forces are measured in newtons (N).

Weight and Mass

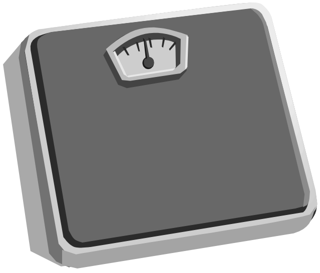
Mass is the amount of matter an object has and is measured in **kilograms** (**kg**). **Mass does not change it remains the same**.

Weight is the force of gravity working upon an object and is the Earths pull on the mass. Since weight is a force it is measured in **newtons** (**N**).

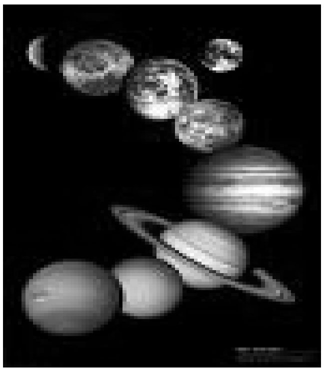
Weight can be calculated using the formula:-

$$\boxed{\text{Weight} = \text{mass} \times \text{gravitational field strength}}$$

$$\mathbf{W = m \times g}$$



Bathroom scales measure mass in kilograms - not weight.



The Solar System

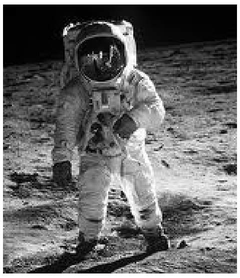
Gravitational field strength (**g**) is measured in N/kg.
On Earth a mass of one kilogram has a weight of approximately ten newtons.
This means the gravitational field strength on Earth is 10 N/kg.

Example

A man has a mass of 80kg. Calculate his weight on Earth.

$$\begin{aligned} W &= m \times g \\ &= 80 \times 10 \\ &= 800N \end{aligned}$$

However if this man visited other planets in the Solar System his weight would change because gravitational field strengths changes from planet to planet.



Buzz Aldrin on the moon with a spacesuit of mass 150kg. He still weighed less on the moon than his usual weight on Earth.

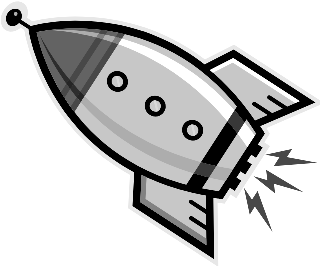
Planet	Gravitational Field Strength (N/kg)
Mercury	3.7
Venus	8.8
Earth	10
Mars	3.7
Jupiter	25.9
Saturn	11.4
Uranus	10.9
Neptune	11.9

His mass, however, would stay the same.

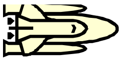
Example

An alien weighs 2331 N on Jupiter. If the gravitational field strength on Jupiter is 25.9 N/kg, what is the mass of the alien?

$$\begin{aligned} m &= \frac{W}{g} \\ &= \frac{2331}{25.9} \\ &= 90 \text{ kg} \end{aligned}$$



Want to lose weight, go to the moon.



Friction

No surface when examined with a powerful microscope will ever appear perfectly smooth. So when two surfaces rub against one another some very tiny high points on both surfaces catch onto each other. Friction is the force between two surfaces when one surface slides over another surface.

Friction is a resistive force which acts in the opposite direction to the movement of an object. The size of the force depends on the surfaces the:

- contact between the surfaces
- size of the areas in contact with one another
- texture of the surfaces

Friction, also, causes **kinetic energy** to change to **heat energy**.

Air Resistance

When an object moves through the air, friction is caused by collisions with air particles. This is called **air resistance**. Air resistance depends on the:

- the shape / size of the object
- the speed of the moving object

As the speed of a moving object increases the air resistance also increases.

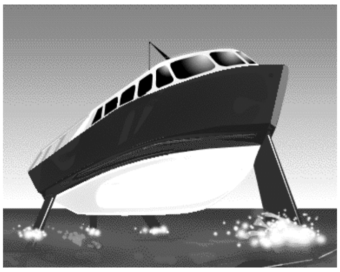
Reducing Friction

Friction is greater when there is a good contact between two surfaces. Thus, to reduce friction we must reduce the contact between the surfaces.
Friction is reduced in the following ways:

- separating the surfaces using an air cushion
  (e.g. air hockey, hovercraft)
- lubricating the surfaces
  (e.g. oiling a bicycle chain, water on a slide)
- smoothing the surfaces
  (e.g. waxing skis)
- reducing the size of the areas in contact
  (e.g. ice skate blades, wheels)
- streamlining to reduce air resistance
  (e.g. track cyclist helmets)

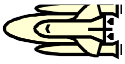
To increase friction you must improve contact between the surfaces. Doing the opposite of the points above would do that.

Striking a match relies upon friction.



Hydrofoils on a boat reduce contact between the hull and the water.

Parachutists use their chute to increase air resistance.



Do you find your bicycle brakes useful ?

Friction is Useful

Any movement that relies on one surface pushing against another would be impossible without FRICTION.

We need friction – we need **<u>very good contact</u>** between 2 surfaces when

Walking or running	Soles of shoes & ground
Braking	Brake pads & wheel
Driving (steering, accelerating)	Tyres & road
Using ladders	Base of ladders & ground

Why is friction a nuisance in car engines ?

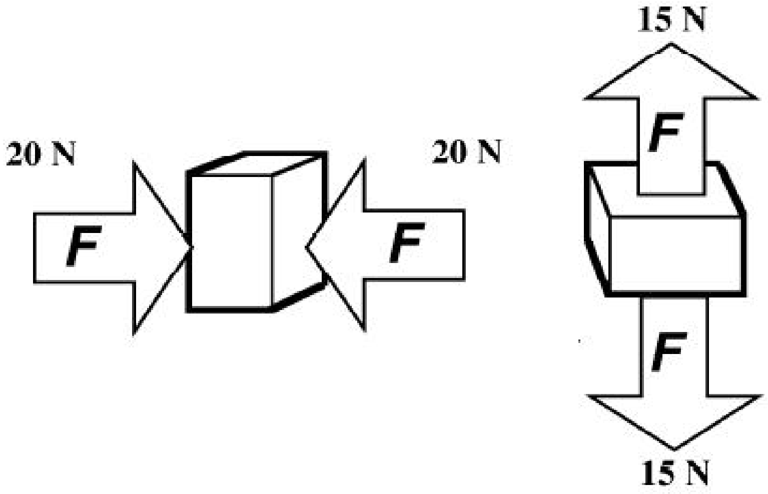
Friction is a Nuisance

We do not want friction - we want **<u>poor contact</u>** between surfaces when

Skiing	Ski & snow
Skating	Blade & ice
Cycling	Chain & cog
Surfing	Surf board & sea water

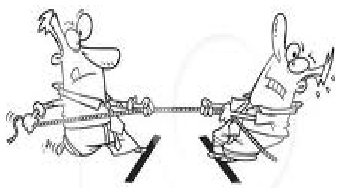
Balanced Forces

When two forces are the same size as each other and act on the same object but in opposite directions, they balance each other. These forces are called **balanced forces**.



The forces that are acting on the objects above are balanced forces. In each case the overall force is 0N. This means the object will **remain stationary** or will travel at a **constant speed**.

This is Newton's first law of motion.



In a tug of war when neither team moves, the forces are balanced.

Examples of Balanced Forces

- A car travelling at its maximum speed. The engine force is equal and opposite to the forces of friction acting upon the car.
- A helicopter hovering. The weight of the helicopter is balanced by the lift provided by the blades.
- A skydiver falling through the air at a constant speed. This is because their weight is balanced by the air resistance acting on their body.

Newton's Second Law

Newton's second law of motion deals with unbalanced forces acting upon an object and states:

'When a mass is acted upon by an UNBALANCED FORCE, the mass moves with constant acceleration.'

This relationship is summarised by the formula:

$$F = ma$$

F represents the unbalanced force and is measured in newtons (N). Mass, **m**, as always is measured in kilograms (kg) and acceleration, **a**, is measured in ms^{-2}.

Example 1

A trolley of mass 2 kg accelerates at a rate of 2.5 ms^{-2}.
Calculate the resultant force acting on the trolley.

$$F = m\,a$$

$$= 2 \times 2.5$$

$$= 5\ N$$

Example 2

A car has a mass of 750 kg and the engine force acting is 2.5 kN. If the frictional force is 625 N, calculate the acceleration.

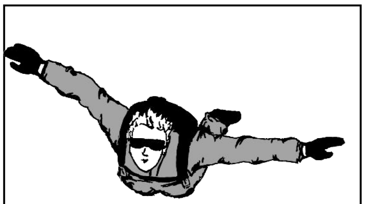
$$F = 2500 - 625 = 1875\ N$$

$$a = F/m$$

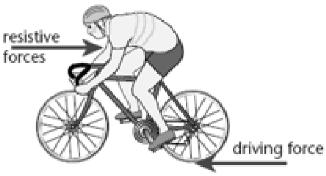
$$= 1875/625$$

$$= 3\ ms^{-2}$$

A helicopter hovering.



At what velocity do skydivers fall when their forces are balanced ?



The unbalanced force on the cyclist is the difference between the driving force and the resistive forces.

Seat Belts

A **seat belt**, sometimes called a **safety belt**, is a harness which keeps the occupant of a vehicle safe against harmful movement that may occur because of a collision or a sudden stop. The seat belt holds the driver (or passenger) and provides an unbalanced force which slows the driver down at the same rate as the car. This reduces the likelihood and severity of injury in a collision.

Without a seat belt the occupant of the car would continue to travel at the speed of the car, before the collision, until they strike the windscreen or dashboard.

Seat belts are used in cars to provide a **backwards force** to keep the passenger safe if the car stops suddenly.

Even dummies wear seat belts.

Satellites

Satellites are objects which orbit a planet. When we think of satellites, we tend to think of man-made ones. We forget our moon is a natural satellite of our planet and that there are many other natural satellites throughout space. Man-made satellites affect our daily lives without us even knowing. Satellites have many uses and transmit various signals back to ground. Signals which help with weather forecasting, communication and navigation.

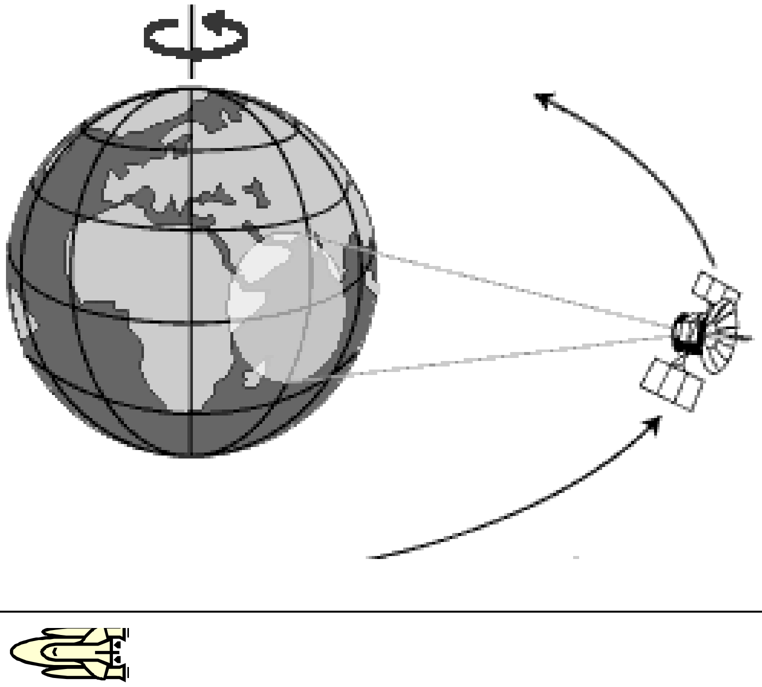
Period of a Satellite

Man-made satellites are placed in orbits at different heights. The height is determined by the job of the satellite. Some are close to the surface of the Earth, while others are further away. The time a satellite takes to orbit a planet is called its period. The period depends on the height of the satellite above the surface.

If the satellite is at a high altitude, it will have a longer distance to travel around the Earth. It will, therefore, take a long time to go around – it will have a long period. However if the satellite is closer to the surface, in a lower orbit, then it will take less time to go around – it will have a short period.

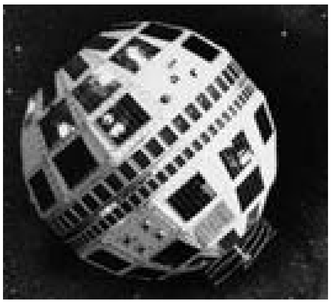
Geostationary Satellites

A geostationary satellite is one which takes 24 hours to orbit the Earth. To achieve this orbit, the satellite must be at an altitude of 36,000 km. It travels around the Earth at the same speed as the Earth is rotates. This means that a geostationary satellite always stays above the same point on the Earth's surface. This makes geostationary satellites suitable for telecommunications as they can maintain communications between two ground stations on opposite sides of the planet.



The natural satellite of our planet - the Moon.

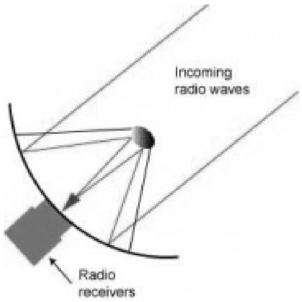
Sputnik 1 launched in 1957 - the first man-made satellite in space sent radio waves.



Telstar 1 launched in 1962 -the first communications satellite.

Satellites rely upon solar cells for power.

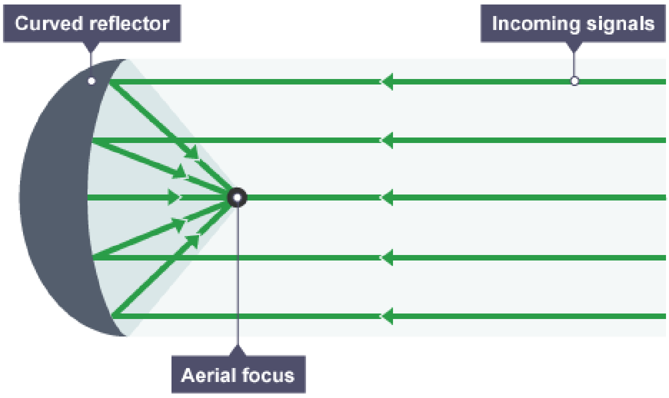
Satellite TV made curved reflectors common place.



A radio telescope uses radio waves to image the sky.

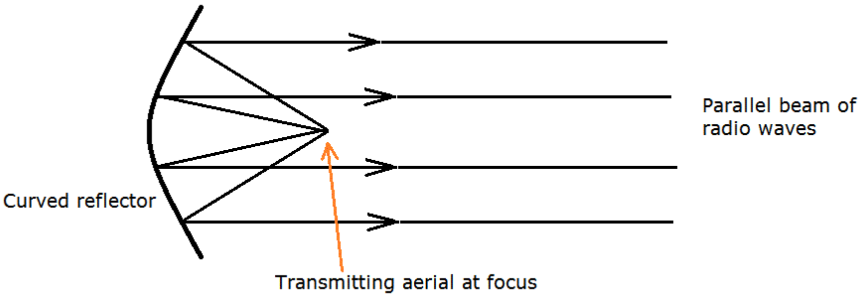
Curved Reflectors

The signals from satellites travel great distances and an aerial cannot pick up a strong enough signal. A curved reflector can bring the radio waves to a focus just like curved mirrors cause light rays to meet at a focus.

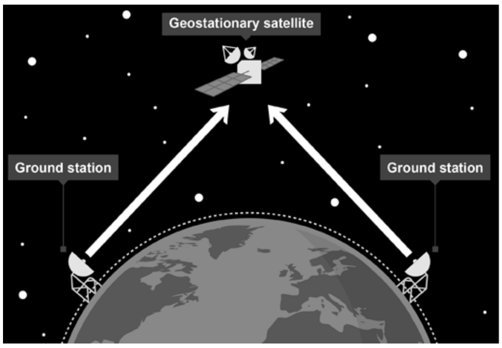


A strong radio signal can be detected if the aerial is positioned at the focus of the curved reflector. More of the wave energy is also collected when these aerials are used, which improves the signal.

These reflectors are also used for transmitting signals. The signals move in the opposite direction and are sent in a beam towards the satellites in space.



Ground stations send signals to the satellite using a curved dish transmitter to transmit a strong signal. At the satellite the weakened signal is collected by a curved dish receiver. It is then amplified and finally retransmitted, at a different frequency, back to the ground using another curved dish transmitter.



Uses of Satellites

Satellites are now used widely. They have many uses and they send a lot of information, which is of use, back to the ground. For example:

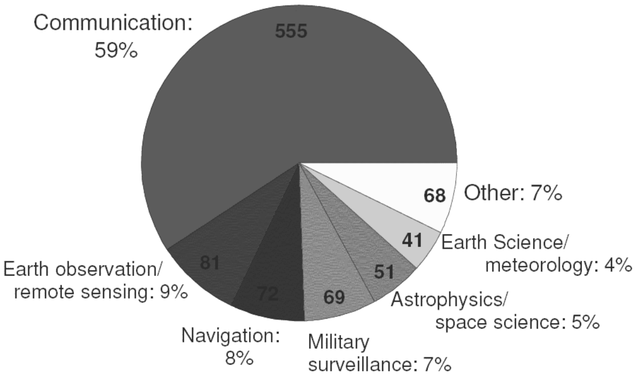
- **Weather Forecasting**
  Satellites help to accurately predict the weather by providing forecasters with both atmospheric and climatic information. This information may watch the progress of large weather systems such as fronts, storms or hurricanes.

- **Global Positioning Systems (GPS)**
  Satellites accurately find the location of objects on Earth. This technology has been put to use in satellite navigation systems in cars, boats and planes.

- **Space Exploration**
  Astronomy satellites have many different applications. They can be used to make star maps, study mysterious phenomena such as black holes and quasars and to take pictures of the planets in the solar system.

- **Reconnaissance**
  Reconnaissance satellites are used to spy on other countries. They provide intelligence information on the military activities of foreign countries.

The pie chart, below, shows how satellites are put to use :



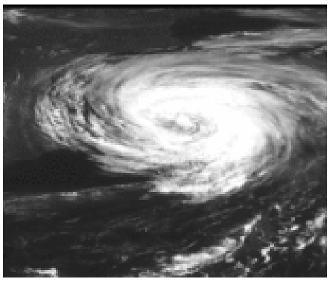
Example

A geostationary satellite orbits at 36 000 km. Calculate the time taken by a radio signal to reach the satellite.

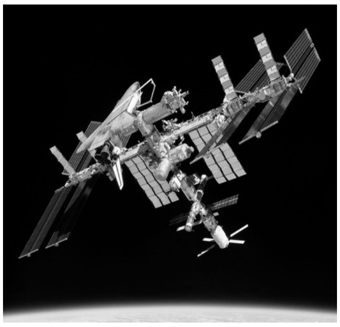
$$t = \frac{d}{v}$$

$$= \frac{36\ 000\ 000}{300\ 000\ 000}$$

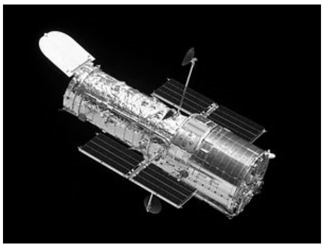
$$= 0.12s$$



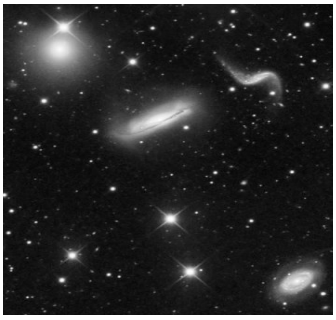
An image from a weather satellite showing a hurricane.



International Space Station



Hubble space telescope, an astronomy satellite, provides images of the universe.



A cluster of galaxies - each galaxy holding possibly millions of stars.

Cosmology

The Universe

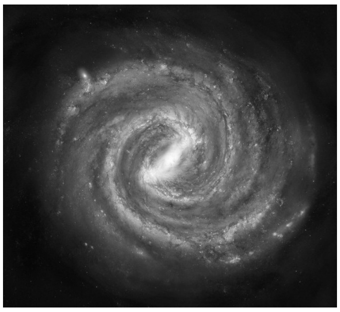
The **Universe** is all of space. It contains many galaxies separated by vast expanses of empty space.

A **galaxy** is a large cluster of thousands, or millions of stars (e.g. our galaxy is the Milky Way).

A **star** is a large body of matter that is undergoing nuclear fusion and emitting light and heat. The Sun is a star.

A **planet** is a large body in orbit around a star.

A **moon** is a natural satellite of a planet. Earth has one moon.



An artist's impression of our galaxy—the Milky Way.

The Solar System

The sun and many other stars have a solar system. A **solar system** consists of a central star and all the objects held to the star by gravity.

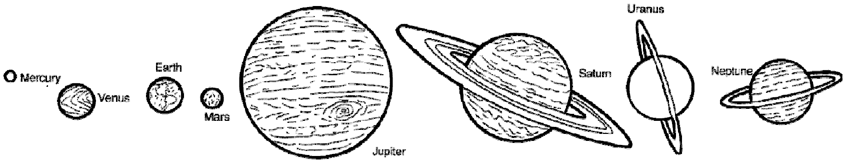
Our solar system has 8 planets;

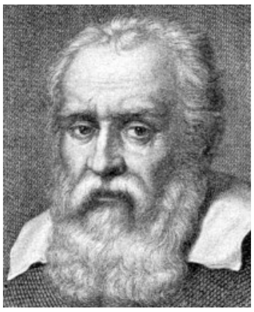
Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune.

Pluto was once classed as a planet, but astronomers now consider it to be a dwarf planet.

If you want to remember the order of the planets from the Sun the following memory aid may prove useful

__M__y __V__ery __E__ducated __M__other __J__ust __S__aid __U__h-oh __N__o __P__luto





Galileo was the first physicist to discover physical details about our the Solar System.

And now for **exo-planets**...

Distance in Space

The distances involved in space are huge. The distances are so large we measure use the unit, light years. A light year is the distance that light travels in a year.

A light year is the speed of light in metres per second multiplied by the number of seconds in a year.

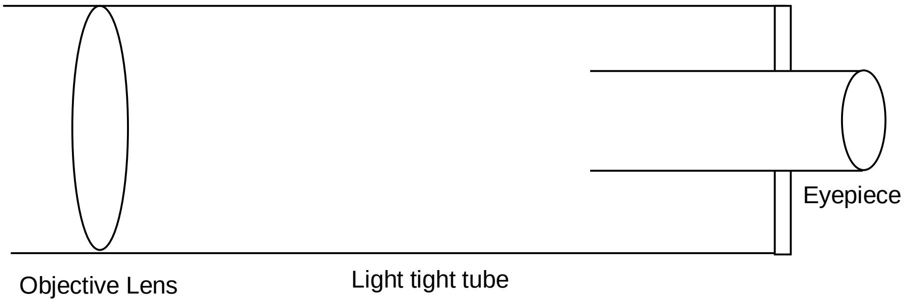
1 light year = 300 000 000 x 365.25 x 24 x 60 x 60
= 9 460 000 000 000 000 m

Distance	*Time for light to travel*
Earth to the moon	1 second
Earth to the Sun	8 minutes
Earth to the nearest star (after the sun)	4.3 years
Earth to the other side of the galaxy	100 000 years
Earth to the Andromeda Spiral	2 000 000 years

The Telescope

Telescopes are used by astronomers to magnify distant objects. They make the image bigger and brighter. This allows the astronomer to see fine detail and faint objects.

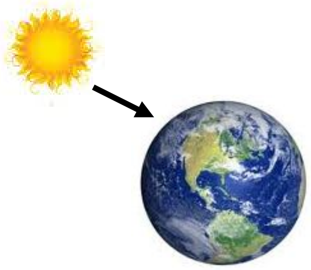
Astronomical telescopes have a basic construction. They have a large objective lens and a small eyepiece lens. These are fitted at opposite ends of a ‘light tight’ tube. The eyepiece lens is usually mounted in a sliding draw tube. Adjusting the draw tube will focus the telescope.



The **objective lens** has a large diameter which allows it to collect light from the distant object and forms an image inside the tube. Generally the bigger the lens, the better the telescope.

The **light tight tube** holds the lenses in place and blocks out other light sources.

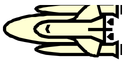
The **eyepiece lens** magnifies the image formed by the objective lens. It acts like a small, powerful magnifying glass.



Light takes about 8 minutes to reach us from the sun.

Proxima Centauri, the next nearest star, as seen by Hubble.

Two of Galileo’s telescopes in a science museum in Florence.



Detecting Signals from Space

Astronomers , in addition to visible light, also observe the other waves of the electromagnetic spectrum.

Gamma Rays	X-Rays	Ultra-violet	Visible Light	Infrared	Micro-waves	Radio & TV Waves

Looking at other forms of radiation reveals more about space.

Radio telescopes have large dish aerials.

Radio Telescopes

Weak radio signals from space are detected by large curved dishes (radio telescopes). The aerial is placed at the focus of the dish, where the radio waves are converted to an electrical signal. Usually a number of these dishes, placed together, are required so that enough data is collected for analysis by computer.

Information from radio telescopes has allowed scientists to study the radiation left from the big bang and has helped with the discovery of quasars and pulsars.

Microwave Telescopes

Microwave telescopes are placed on top of high mountains because microwaves are easily absorbed by the atmosphere. Microwave dishes have to be accurately shaped.

Sombrero galaxy
in infrared.

Infrared Telescopes

Most infrared radiation, like microwaves, is absorbed by the atmosphere resulting in the telescopes being placed on high mountains or on satellites above the atmosphere. All objects in space with a temperature emit infrared.

Infrared telescopes are able to see stars that are hidden in dusty regions of space. They have revealed information about other galaxies, as well as information about the centre of our galaxy - the Milky Way. When the infrared radiation is detected by the telescope it is converted into light which can be viewed by humans.

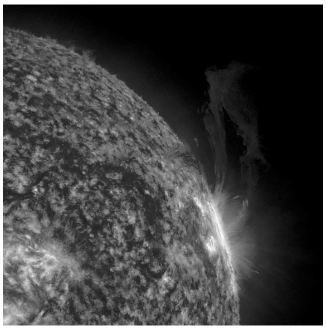
E-ELT will be the largest optical telescope in the world?

Optical Telescopes

Optical telescopes, like the refracting telescope mentioned on page 18, gather visible light information. Some use lenses only and others use a combination of lenses and mirrors. Our interest in and understanding of space has benefitted from these telescopes. Many significant discoveries have been made because of optical telescopes.

Ultraviolet

Most sources of ultraviolet radiation (massive stars, active galaxies and bright nebulae) are observed from satellites since some wavelengths of ultraviolet are absorbed by the atmosphere. Again when the ultraviolet radiation is detected it is converted into light which can be viewed.



UV image of the sun showing a solar flare.

X-rays and Gamma Rays

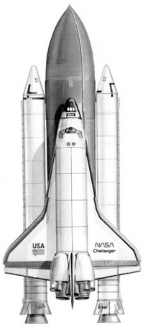
All x-rays and gamma rays are absorbed by the Earth's atmosphere so they are observed by satellites.

Most ordinary stars emit weak X-rays but extremely hot gases and active galaxies give out strong X-rays which can be easily observed.

Major sources of gamma rays include solar flares, pulsars, remnants of supernovae and active galaxies.

Space Exploration

Telescopes, satellites and space exploration through probes, like Curiousity, and space travel, moon landings, have provided scientists with the opportunity to develop their understanding of the Earth and the universe.



The space shuttle - the first re-useable spacecraft.

Some of the technology which has been put to use in space exploration has benefitted our everyday lives, in areas such as :

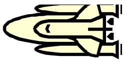
- Weather forecasting
- GPS
- Solar power
- Home insulation

Space Travel

Space exploration, in particular travel, has sometimes come at a cost. The space shuttle Challenger disaster in 1986 made it clear that there are risks associated with space flight. The re-entry of a space craft into the atmosphere of the Earth is particularly dangerous. The space shuttle Columbia disintegrated during re-entry in 2003.

Meteorite heating up on the atmosphere - a shooting star.

During re-entry, when a craft has a high speed, a huge amount of friction acts upon the rocket as it passes into the atmosphere, which slows it down. This causes a lot of the kinetic energy to change to heat energy and the outside of the rocket can reach a temperature of 1300 ^{0}C.



The Space Shuttle

The Shuttle was the first re-useable spacecraft. Engineers had to work on the design to ensure that it could be used over and over. The engineers had to consider the heat energy which built up during re-entry. Steps were taken to protect the Orbiter, the part of the shuttle that returns. Its shape resembles an ordinary aircraft.

- The Shuttle Orbiter is made from aluminium alloy covered in special tiles to protect it from the intense heat generated during re-entry.
- The Shuttle needs around 34 000 thermal protection tiles (all of different shape and size).
- The tiles are made form a material called silica, which has a high melting point.
- The tiles are painted black so that the heat is lost to the surroundings—the air around the tile heats up. Therefore the temperature increase of the shuttle is not as large.

Dr. Robert H. Goddard fired his liquid oxygen-gasoline rocket on March 16, 1926.

Apollo 11, the first manned lunar mission.

Space shuttle Endeavour makes its final landing.