St Ninian's HS

National 5 Physics

Dynamics and Space

Pupil Notes

2.1 Kinematics

Average Speed

Average speed is the total distance travelled per unit time.

Average speed → $$\bar{v} = \frac{d}{t}$$ ← Distance (m), Time (s)

The standard unit of average speed is metres per second. This can be written as ms^{-1} or m/s. Sometimes alternative units for average speed may be used. These include kilometres per hour (km/h) or miles per hour (mph).

Example

Usain Bolt ran 100 m in 9.58 s, calculate his average speed in metres per second.

$d = 100\, m$

$t = 9.58\, s$

$\bar{v} = ?$

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

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

$$\underline{\bar{v} = 10.44\, ms^{-1}}$$

Experiment to Measure the Average Speed

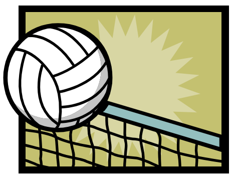
To measure an average speed you should:

1. Measure the distance, d, with a ruler, metre stick or trundle wheel.
2. Measure the time taken, t, with a stop clock.
3. Calculate the average speed by dividing the distance travelled by the time taken.

Instantaneous Speed

The instantaneous speed of an object is the speed of an object as it passes one particular point.

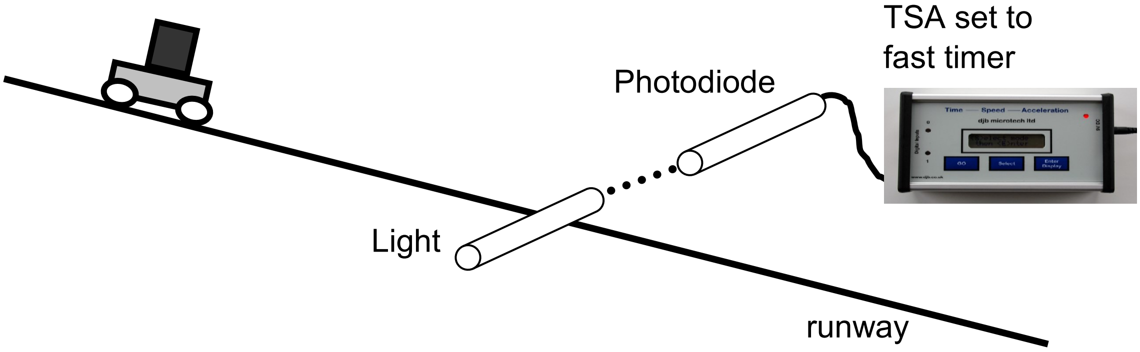
Average speed and instantaneous speed during a journey can be very different. For example, the average speed for a car over an entire journey from Glasgow to Manchester may be 50 mph, however, the instantaneous speed of the car would change. This is because the car may be stationary at traffic lights, slow down for roundabouts or speed up when going down a hill. The speedometer in the car will display the instantaneous speed of the car.



At Wimbledon the instantaneous speed of the tennis ball is found as it crosses the net after the serve.

Experiment to Measure the Instantaneous Speed

Since it is necessary to measure a very short time interval an electronic timer (TSA) is used to avoid issues with human reaction times. A **light gate** is a light source aimed at a photocell. This is connected to an electronic timer (TSA). When the start of the object passes through the light gate the light no longer falls on the photocell and the timer starts and when the end of the object passes through the light gate the light falls on photocell again and the timer stops
Usually a card is placed on the top of the car which will pass through the beam and can be measured accurately.



Step by Step:

- Measure the length of the card on the top of the trolley with a ruler
- Allow the trolley to run down the slope
- Measure time taken for card to pass through light gate with a light gate connected to an electronic timer (TSA/Computer).
- Calculate using;

$$\text{Instantaneous Speed} = \frac{\text{Length of card}}{\text{time taken to pass through the light gate}}$$

Example

A tennis ball of diameter 10 cm passes through a light gate in 0.05 s. Find the instantaneous speed of the ball.

$v = ?$

$d = 10cm = 0.1m$

$t = 0.05s$

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

$$v = \frac{0.1}{0.05}$$

$$\underline{v = 2ms^{-1}}$$

Scalars and Vectors

In Physics all quantities can be divided into two groups, Scalars and Vectors.

A **scalar quantity** has magnitude (size) only.

A **vector quantity** has both magnitude **and direction.**

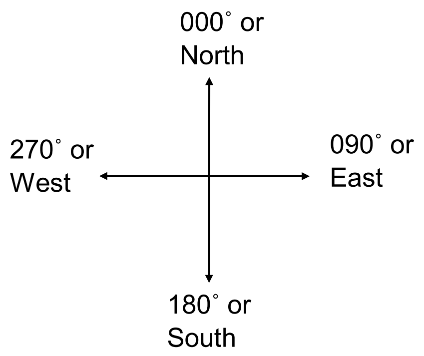
Some examples of scalars and vectors are given in the table below:

Scalar	Vector
Speed	Velocity
Distance	Displacement
Mass	Force (Weight)
Energy	Acceleration
Time	Momentum

Distance and Displacement

Distance is a **scalar** quantity. It simply measures the total distance travelled.

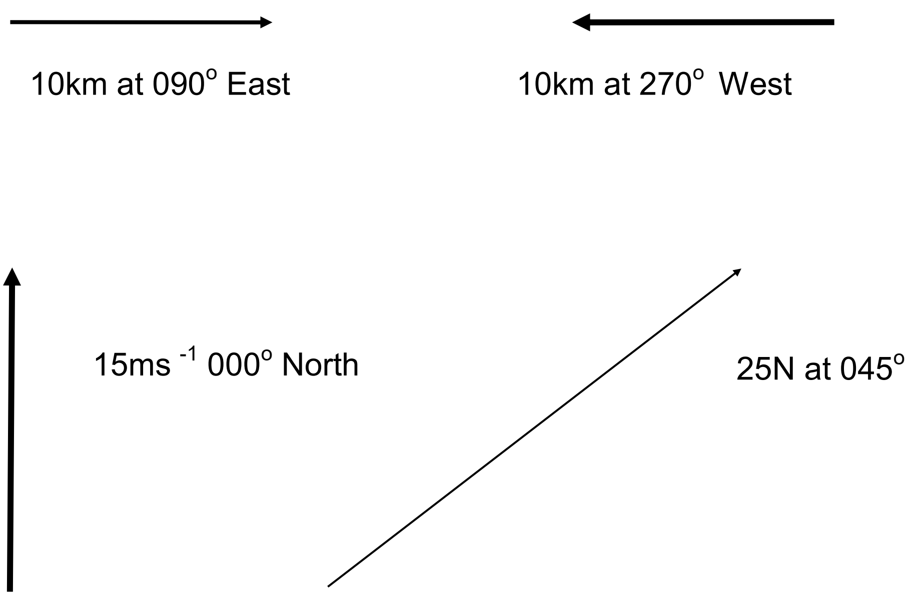
Displacement is a **vector** quantity. Displacement is the length measured from the starting point to finishing point in a straight line. As displacement is a vector, the direction must be stated. The direction of the displacement is usually given as a **bearing.**



Vector Diagrams

Vectors are represented by a line with an arrow. The length of the line represents the size of the vector. The arrow represents the direction of the vector.

The sum of the vectors is called the **resultant.**

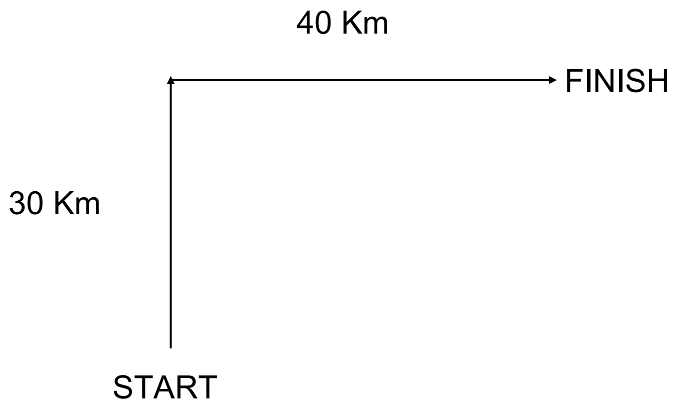


Example

A cyclist travels 30 km due North then turns and travels 40 km due East.

- *(a) Draw a diagram to represent the journey of the cyclist.*
- *(b) Calculate the total distance travelled by the cyclist.*
- *(c) Find the cyclist's final displacement from his starting position.*

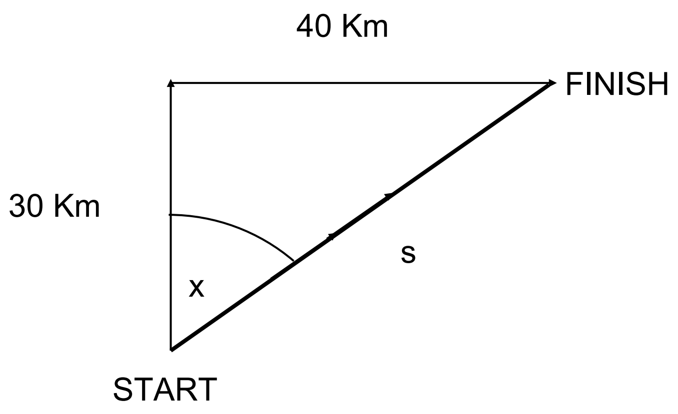
(a)



(b) Total Distance = 30 km + 40 km

Total Distance = 70 km

(c)



$$s^2 = 30^2 + 40^2$$

$$s^2 = 2500$$

$$s = 50\,km$$

$$\tan x = \frac{opp}{adj}$$

$$\tan x = \frac{40}{30}$$

$$\tan x = 1.33$$

$$x = \tan^{-1} 1.33$$

$$x = 53^o$$

Displacement = 50 km at a bearing of 053^o

Speed and Velocity

Speed is a **scalar** quantity, it is the distance covered by an object per unit time.

$$\text{Average Speed} = \frac{\text{distance}}{\text{time}}$$

Velocity is a **vector** quantity. Velocity is the **displacement of an object** per unit time. As Velocity is a vector it therefore requires a direction, this will be the same as the direction of the displacement.

$$\text{Average Velocity} = \frac{\text{Displacement}}{\text{time}}$$

When a 400m runner completes a lap of the track the distance travelled is 400m, however the displacement is 0m as he is back exactly where he started.

Example

In the previous example the cyclist took 5 hours to complete his journey. Calculate:

(a) The average speed.

(b) The average velocity.

(a) Distance = 70 km

Time = 5 hr

Average Speed = ?

$$\text{Average Speed} = \frac{\text{distance}}{\text{time}}$$

$$\text{Average Speed} = \frac{70}{5}$$

Average speed = 14 km/hr

(b) Displacement = 50 km (053°)

Time = 5 hr

Average Velocity = ?

$$\textit{Average Velocity} = \frac{\textit{Displacement}}{\textit{Time}}$$

$$\text{Average Velocity} = \frac{50}{5}$$

Average Velocity = 10 km/hr at a bearing of 053°

Acceleration

Acceleration is defined as the **change in velocity per unit time.**

$$\text{Acceleration} = \frac{\text{Change in velocity}}{\text{time taken}}$$

Units for acceleration are ms $^{-2}$ or m/s ^{2}

The ‘change in velocity’ is calculated by finding the object’s final velocity (v) – initial velocity (u). In symbols the equation can be written:

Final Velocity (ms^{-1})

Initial Velocity (ms^{-1})

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

Acceleration (ms^{-2})

Time (s)

Acceleration is a **vector quantity.**

If the object is **decelerating**, then the final speed is less than the initial speed, then acceleration is in the opposite direction to motion of the object and acceleration will be **negative.**

This equation can be rearranged in terms of the final velocity, v.

$$v = u + at$$

It is easier to use the equation in this form when calculating either v or u .

Example 1

A Jaguar can reach 27ms^{-1} from rest in 9.0 s.
What is its acceleration?

$t = 9s$

$u = 0ms^{-1}$

$v = 27ms^{-1}$

$a = ?$

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

$$a = \frac{27 - 0}{9}$$

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

Example 2

A girl on her scooter is travelling at 6 ms^{-1}. She accelerates at a rate of 3ms^{-2} for 5 s
Calculate the final velocity of the scooter.

$t = 5s$

$u = 6ms^{-1}$

$v = ?$

$a = 3ms^{-2}$

$$v = u + at$$

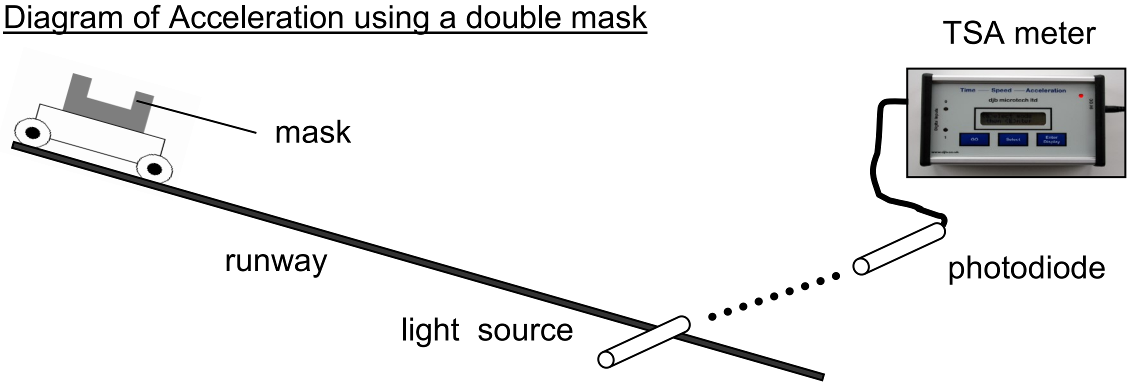
$$v = 6 + (3x5)$$

$$v = 6 + 15$$

$$\underline{v = 21ms^{-1}}$$

Experiment to measure Acceleration using a double mask

<u>Diagram of Acceleration using a double mask</u>



- Measure the length of the card on the mask and input into the TSA.
- Allow the trolley to run down the slope.
- The first part of the mask will allow the initial instantaneous speed, u to be measured as it passes through the light gate.
- The second part of the mask will allow the final instantaneous speed, v to be measured as it passes through the light gate
- Measure time taken for the change in speed using a light gate connected to an electronic timer.
- Calculate acceleration using;

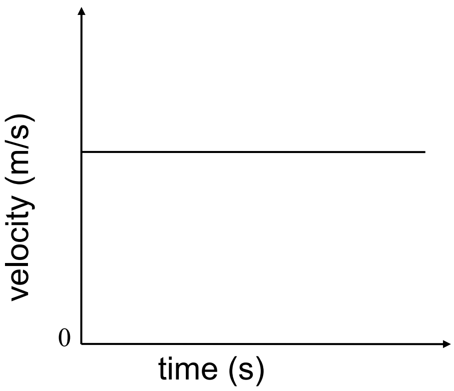
$$a = \frac{v - u}{t}$$

Velocity - time graphs

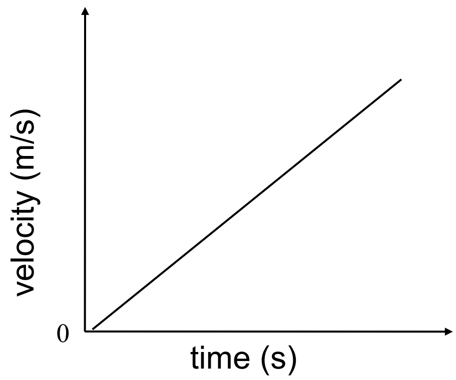
Information about the motion of an object can be obtained from both velocity-time and speed-time graphs. However, a speed time graph would not be able to display a change in direction as speed is a scalar.

We use them to:

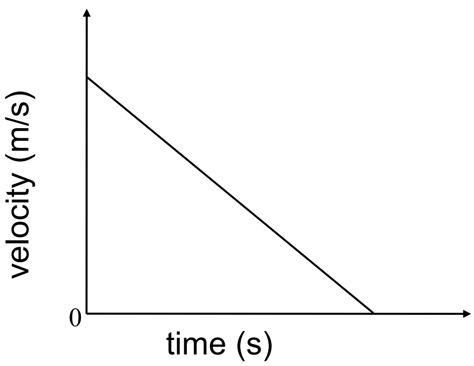
- Describe the motion of the object.
- Calculate values for accelerations and decelerations.
- Calculate distances travelled and resultant displacements **using area under graph**.
- Calculate the average velocity for a journey.



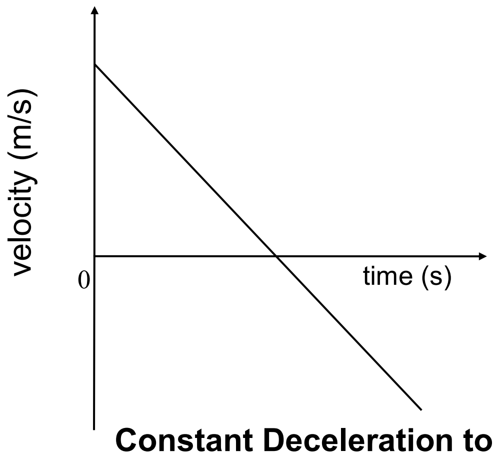
Constant Velocity



Constant Acceleration



Constant Deceleration

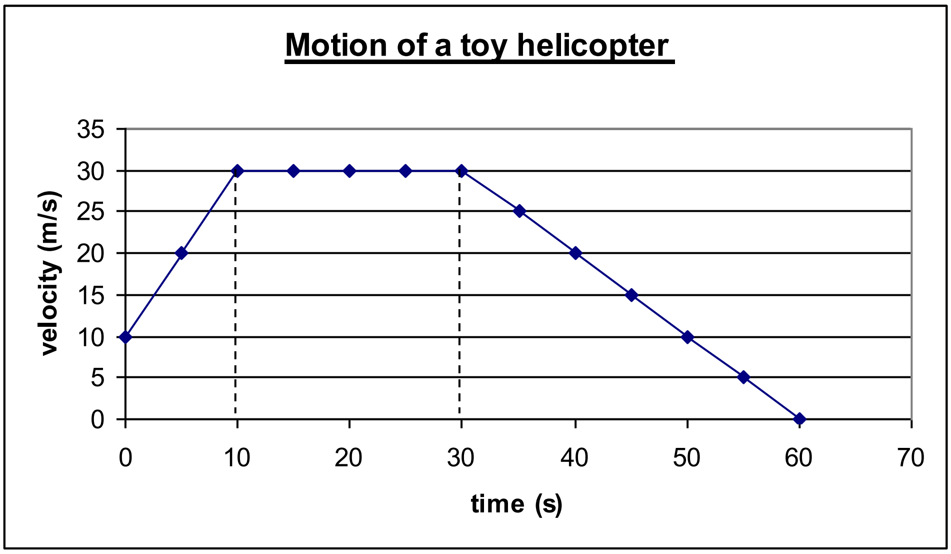


Constant Deceleration to rest followed by constant acceleration in opposite direction.

Note: The gradient of a velocity-time graph can be useful. The greater the gradient (steeper the slope) the greater the acceleration. Also a negative gradient indicates a deceleration.

Example

A graph for the motion of a toy helicopter is shown.



(a) *Describe the motion of the car during the 60 seconds.*
(b) *Calculate the acceleration between 0 and 10 seconds.*
(c) *Calculate the acceleration between 30 and 60 seconds.*
(d) *Calculate the final displacement of the car from the starting position.*
(e) *Calculate the average velocity during the 60 seconds.*

(a) *0 s to 10 s constant acceleration from 10ms^{-1} to 30ms^{-1}*
10 s to 30 s constant velocity of 30 ms^{-1}
30 s to 60 s constant deceleration from 30 ms^{-1} to 0 ms^{-1}

(b)

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

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

$$\underline{a = 2 \ ms^{-2}}$$

(c)

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

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

$$\underline{a = -1 \ ms^{-2}}$$

(d) *Displacement = area under the graph*

= (b x h) + (1/2 x b x h) + (b x h) + (1/2 x b x h)

= (10 x 10) + (1/2 x 10 x 20) + (20 x 30) + (1/2 x 30 x30)

= 100 + 100 + 600 + 450

= 1250 m

(e)

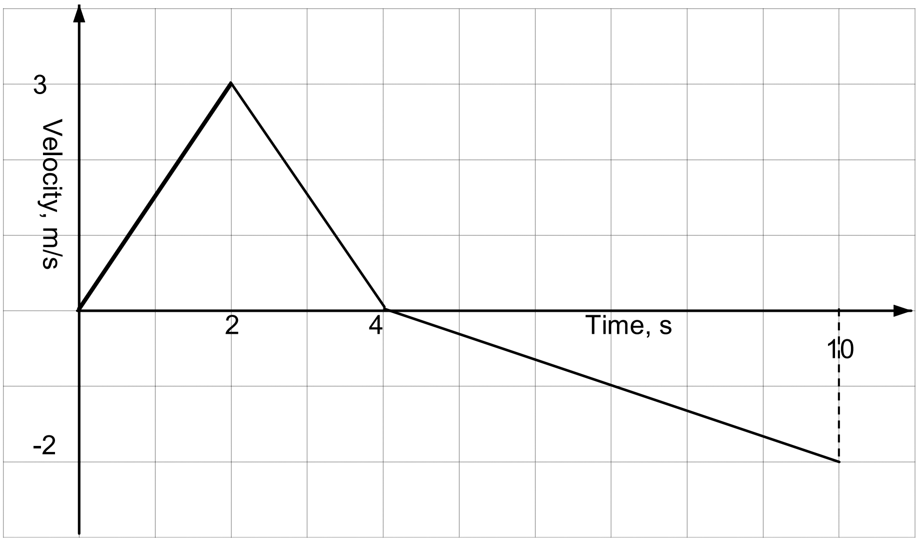
$$v = \frac{s}{t}$$

$$v = \frac{1250}{60}$$

$$v = 20.8\ ms^{-1}$$

Velocity - time graphs and Displacement

The graph below shows the change in velocity of a boy on a skateboard. He accelerates from rest, decelerates up a slope and then reverses back down the hill in the initial direction. This is indicated by the negative direction from 4 s to 10 s.



Calculate the displacement of this journey.

(Displacement = area under the graph

= (1/2 x b x h) + (1/2 x b x h) - (1/2 x b x h)

= (1/2 x 2 x 3) + (1/2 x 2 x 3) - (1/2 x 6 x 2)

= 3 + 3 - 6 (opposite direction)

= <u>0 m</u>

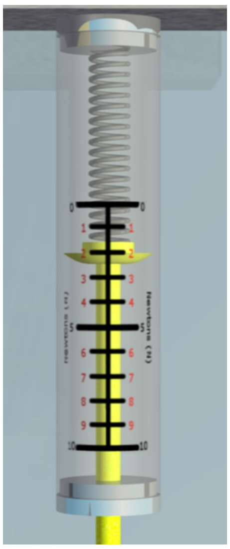
2.2 Dynamics

A force can:

- Change the shape of an object.
- Change the speed of an object.
- Change the direction of travel of an object.

Measuring Force

The size of a **force** is measured using a **Newton Balance.** The units of Force are **Newtons, N.**



Inside a Newton Balance is a spring, the spring will stretch when a force is applied to the hook. When the force is increased the spring will stretch more and the reading will also increase. The extension of the spring is directly proportional to the force applied to it.

Mass

Mass is the quantity of matter present in a body - the total of all the protons, neutrons and electrons it is made from. Mass is measured in kilograms (kg).

Weight

Weight is a force which is caused by the pull of gravity on an object. Since weight is a force it is measured in Newtons, N. On Earth, the weight of 1 kilogram is approximately 9.8 Newtons.

Gravitational field strength

Gravitational field strength (g) is defined as "the weight per unit mass". The gravitational field strength is the force that gravity exerts on every kilogram. On Earth the gravitational field strength is 9.8 N/kg.

$$g = \frac{Weight}{mass}$$

Example

Helen Sharman was the first Britain in space when she visited the Mir space station on an eight day journey in May 1991, the 27 year old had a mass was 55 kg. The gravitational field strength on the surface of Earth is 9.8 N/kg. The gravitational field strength on the surface of the Moon is 1.6 N/kg. Calculate:

(a) her mass if she landed on the moon,
(b) her weight on the surface of the Earth.
(c) her weight if she landed on the moon.

(a) Mass always remains constant, m = 55 kg.

(b) w = ?
m = 60 kg
g = 9.8 N/kg

$$W = mg$$
$$W = 60 \ x \ 9.8$$
$$\underline{W = 588 \ N}$$

(c) w = ?
m = 60 kg
g = 1.6 N/kg

$$W = mg$$
$$W = 60 \ x 1.6$$
$$\underline{W = 96 \ N}$$

Friction

Friction is the force between two surfaces when one surface moves over another surface. Friction is a resistive force which always acts in the opposite direction to the movement.

The size of the force depends on the type of surface, e.g. a rough surface will cause more friction. It also depends on the size of the surface area in contact with the other surface.

Fiction is a very common force in action in our everyday lives. If there is no or very little friction between surfaces then the surfaces can move easily over each other. To do this a layer of a different material may be placed between the two surfaces.

For example:

- A layer of air can be placed between the air hockey table and the puck.
- The base of skis can have a layer of wax applied.

Air Resistance

Air resistance is similar to friction, it is caused when an object moves through the air and collides with air particles.

The factors affecting air resistance are:

- the shape and size of the moving object.
- the speed of the moving object.

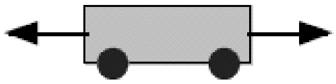
Air resistance will increase as the speed of the moving object increases.

Air resistance can be decreased by streamlining the shape to reduce air friction. e.g. Track cyclist helmet.

Force is a vector. It must have a size and direction.

Balanced Forces

Balanced forces are equal in size but in **opposite directions.** They cancel each other out and have no overall effect. The resultant / unbalanced force is 0 N.



<u>Newton's First Law</u>

Newton's 1st Law states: "An object will remain at rest or move at a constant velocity in a straight line unless acted on by an unbalanced force."

What this means is that if the forces acting on an object are balanced then that object will remain stationary. If the object is moving then it will continue to move in a straight line at a constant velocity.

If you were the passenger in a car, and not wearing your seat belt, you would continue moving forward after the brakes had been applied. The braking force was applied to the car, however the force was not applied to the passenger.

<u>Newton's Second Law</u>

Newton's Second Law states 'When an object is acted on by a constant **unbalanced force** the body moves with constant acceleration in the direction of the unbalanced force.'

This law describes how an object will accelerate if there is an unbalanced force acting on it. The object will accelerate in the direction of the unbalanced force.

- The greater the unbalanced force, the greater the acceleration.
- The smaller the mass, the greater the acceleration.

These two relationships are combined to give.

$$F_{un} = ma$$

One Newton is defined as the **force** that makes a mass of **1 kg accelerate** at a rate of **1 ms^{-2}.**

Example

A sledge of mass 8 kg accelerates at a rate of 2 ms^{-2}. Calculate the unbalanced force acting on the slope.

F_{un} = ?

m = 8 kg

a = 2 ms^{-2}

$$F_{un} = ma$$

$$F_{un} = 8 \times 2$$

$$\underline{F_{un} = 16\ N}$$

Free Body Diagrams and Newton's Second Law

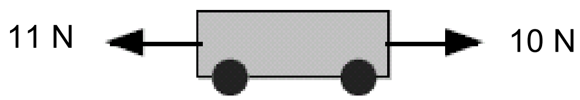
A "Free body diagram" can be used to analyse the forces acting on an object. The size and direction of the forces are labelled on the diagram. This enables us to calculate the resultant force, and then apply Newton's Second Law.

When more than one force acts on an object, they can be replaced by one force, which has the same effect. The overall force is called th resultant force or unbalanced force.

Combining forces in a straight line

To combine forces acting in one direction:

- Draw a free body diagram, then draw arrows to represent the direction of each force.



Use arithmetic, either adding or subtracting, to find the size and direction of the resultant force.

$$F_{un} = 1\ N\ \ \text{Left}$$

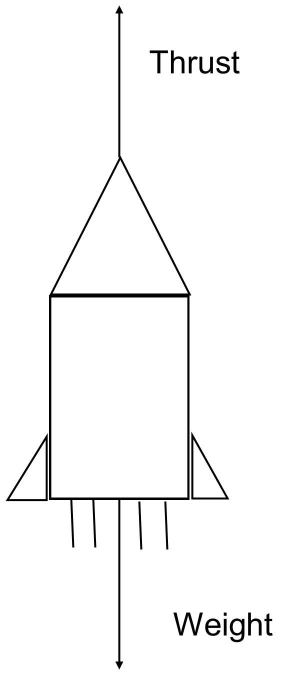
For vertical problems always remember to calculate the downwards force. This is not usually given in a question but can be found by calculating the weight of the object using the mass and gravitational field strength.

Example

A space rocket of mass 2.5×10^6 kg lifts off from the Earth with a thrust of 3.5×10^7 N.

(a) Draw a free body diagram showing the vertical forces acting on the rocket during lift off.
(b) Calculate the resultant force acting on the rocket.
(c) Calculate the initial acceleration of the rocket.

(a)



(b) $W = mg$

$W = 2.5 \times 10^6 \times 9.8$

$W = 2.45 \times 10^7$ N

Fun = thrust - weight

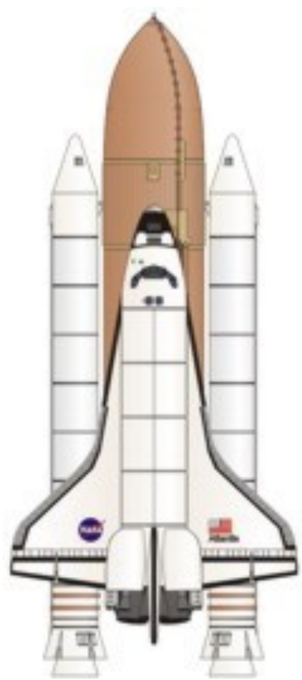
$= 3.5 \times 10^7 - 2.45 \times 10^7$

$= 1.1 \times 10^7$ N

(c) $F_{un} = ma$

$1.1 \times 10^7 = 2.5 \times 10^6 \times a$

$a = 4.4$ ms^{-2}



Forces at Right Angles

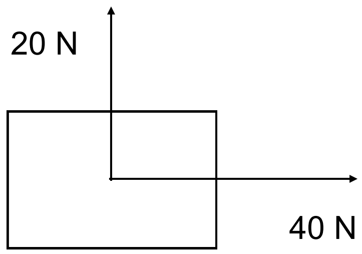
The resultant force arising from two forces acting at right angles can be found by

(a) Drawing the force vectors "nose-to-tail"
(b) Calculating the magnitude using Pythagoras
(c) Calculating the direction using trigonometry (SOH-CAH-TOA)

Alternatively, a scale drawing could be used to find the magnitude and direction.

Example

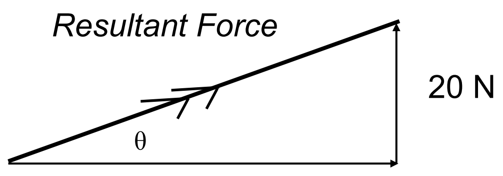
Two forces act on an object at right angles to each other as shown.



Calculate

(a) The magnitude of the resultant force
(b) The direction of the resultant force, relative to the 40 N force.

First arrange vectors "nose-to-tail" and draw resultant from tail of the first to nose of last.



(a)

$$Magnitude\ of\ force = \sqrt{40^2 + 20^2}$$
$$= 44.7\ N$$

(b)

$$\tan x = \frac{20}{40}$$
$$x = 26.6^o$$

Resultant force = 44.7 N at 26.6^o above 40 N force.

Acceleration Due to Gravity and Gravitational Field Strength

Weight is the **force** which causes an object to accelerate downwards. The value of the acceleration caused by weight can be calculated from Newton's second law,

$$a = \frac{F_{un}}{m}$$
$$a = \frac{W}{m}$$
$$a = \frac{mg}{m}$$
$$a = g$$

This demonstrates that the acceleration due to gravity on Earth is 9.8 ms^{-2}.

Example

An astronaut drops a hammer on the Moon where the gravitational field strength is 1.6 ms^{-2}. The hammer lands on the surface of the Moon 2.2 s after being dropped. Calculate the velocity of the hammer at the instant it strikes the surface of the Moon.

u = 0 ms^{-2}
v = ?
a = 1.6 ms^{-2}
t = 2.2 s

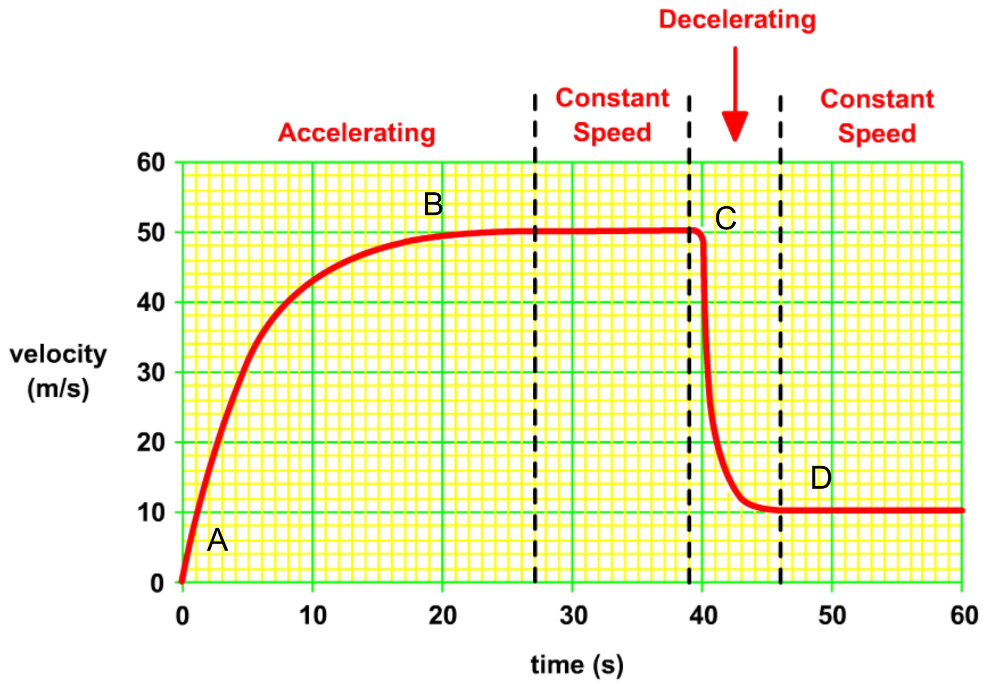
$$v = u + at$$
$$v = 0 + (1.6x2.2)$$
$$\underline{v = 3.52\ ms^{-2}}$$

Freefall and Terminal Velocity

An object falling from a height on Earth will **accelerate** due to its weight. This is called **free-fall**. The air resistance acting on an object will increase as the velocity increases. Therefore the unbalanced force on the object will decrease, producing a smaller acceleration.

Eventually, the air resistance will balance the object's weight, then the forces will be balanced so the object will fall at a **constant velocity.** This final velocity is called **terminal velocity.**

The velocity-time graph below is for a parachutist undergoing free-fall before opening her parachute.



Point A parachutist jumps from plane and undergoes acceleration due to gravity (free-fall)

Point B air resistance has increased to balance weight – constant velocity: **terminal velocity 1**

Point C parachutist opens parachute – increased air resistance causes deceleration

Point D weight and air resistance balanced again so new slower constant velocity reached: **terminal velocity 2**

Newton's Third Law

"For every action, there is an equal and opposite reaction".

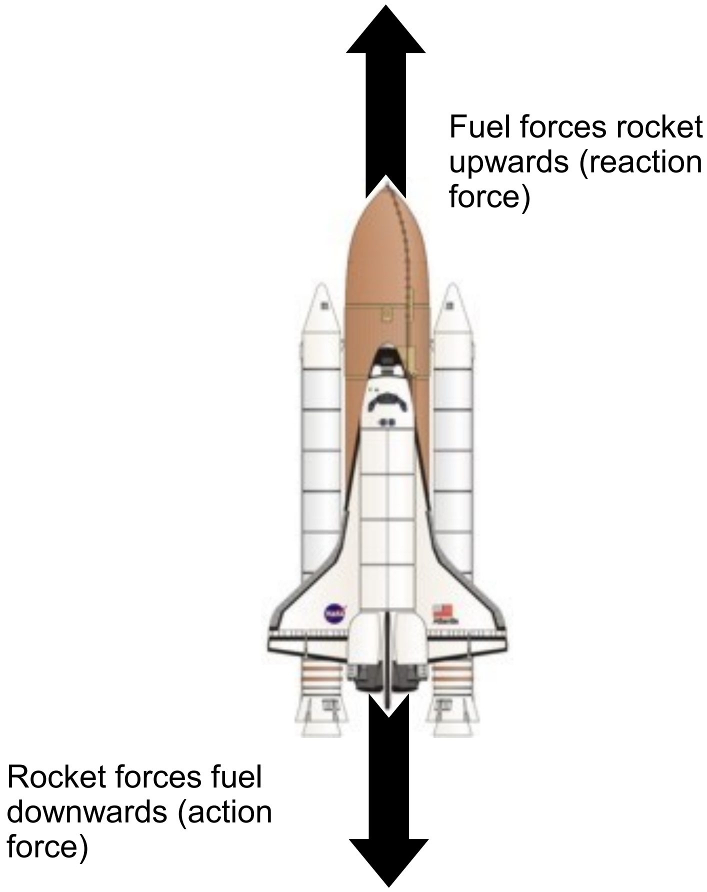
Newton noticed that forces occur in pairs. He called one force the action and the other the reaction. These two forces are always equal in size, but opposite in direction. They do not both act on the same object.

If object A exerts a force (the action) on object B, then object B will exert an equal, but opposite force (the reaction) on object A. These action and reaction forces are also known as **Newton Pairs.**

Examples

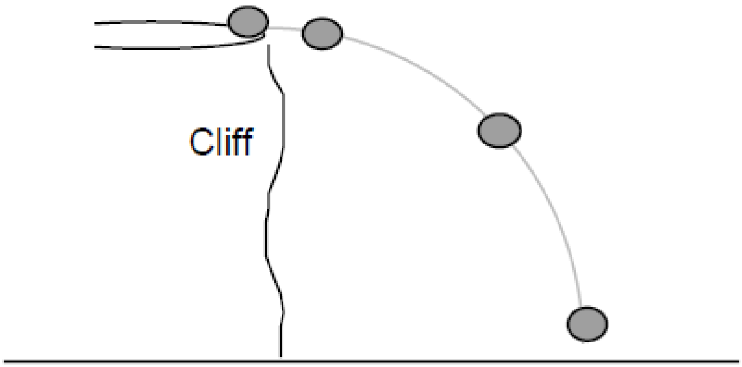

Force of runner on ground (action force)
Force of ground on runner (reaction force)


Force of ball pushes back on golf club (reaction force)
Force of golf club on ball (action force)


Fuel forces rocket upwards (reaction force)
Rocket forces fuel downwards (action force)

Projectile Motion

When an object is moved through the air with a forward motion it will also be pulled down towards the Earth by the force of gravity. This results in the path of the projectile being curved.

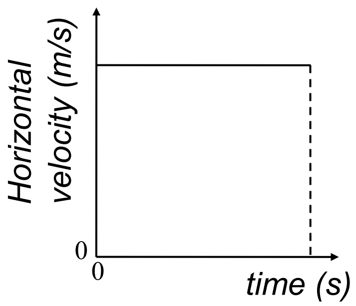


In projectile motion the horizontal and vertical motions are treated separately.

Horizontal Motion

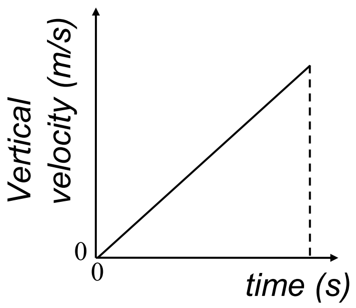
Since there are no horizontal forces acting on the object the horizontal velocity is constant.

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



Vertical Motion
The object will have a constant acceleration due to gravity, therefore the equation below should be used.

$$v = u + at$$



To find the distance travelled (horizontally or vertically) calculate the area under the graph.

Example

A plane is travelling horizontally at 150 ms^{-1}, a food parcel falls from the plane and hits the ground 10 seconds later.

Calculate

(a) the vertical velocity of the food parcel just before it strikes the ground.
(b) the horizontal distance travelled by the food parcel after being dropped
(c) the height that the food parcel was dropped from.

(a) Vertically

$u = 0\ ms^{-1}$
$a = 9.8\ ms^{-2}$
$t = 10\ s$
$v = ?$

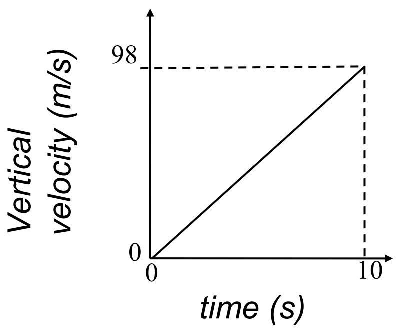
$$v = u + at$$
$$v = 0 + (9.8 \times 10)$$
$$\underline{v = 98\ ms^{-1}}$$

(b) horizontally

$d = ?$
$v = 150\ ms^{-1}$
$t = 10\ s$

$$v = \frac{d}{t}$$
$$150 = \frac{d}{10}$$
$$\underline{d = 1500\ m}$$

(c) Vertical distance will require a velocity time graph. The vertical velocity of the parcel goes from 0 ms^{-1} to 98 ms^{-1} in a time of 10 s.



Vertical height = area under the graph

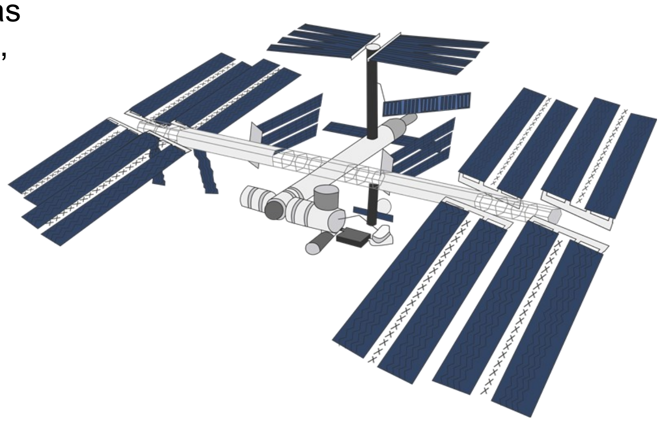
= 1/2 x 10 x 98

= $\underline{490\ m}$

Satellites and Projectile Motion

Isaac Newton conducted a thought experiment. He reasoned that if an object was fired from a high enough height, with such a large horizontal velocity it would never reach the ground. It would fall back towards Earth at the same rate as the Earth curved away from the object, therefore it will continue to circle the Earth until horizontal velocity decreases.

An example of this is a satellite, such as the International Space Stations (right), which will remain in orbit around the Earth because it is in constant free-fall due to the Earth's gravity.



Apparent Weightlessness

Astronauts in orbit around the Earth are in a constant state of free-fall. The spaceship, the astronauts and everything inside are all accelerating towards the Earth due to gravity.

This is known as apparent weightlessness. The effects are because of gravity, and **not** because they have escaped from the gravitational field of Earth.

Satellites

Geostationary Satellites

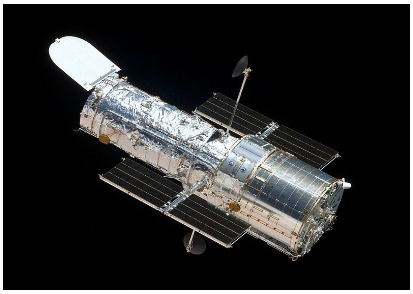
A geostationary satellite remains above the same point of the Earth's surface. It has a period of rotation of 24 hours. They orbit the Earth 36,000 km above the surface and are used in telecommunications.

Polar Orbiting

Polar satellites have a low altitude and orbit around both the North and South Pole regions of Earth. They are ideal for collecting climate data as information can be obtained at regular intervals throughout the day. They are also used for land mapping.

Satellite Telescopes

Telescopes can be placed in orbit around the Earth to allow astronomers to obtain amazing images from space. These telescopes are not affected by light pollution or the Earth's Atmosphere. Possibly the most famous space telescope is the Hubble Telescope.



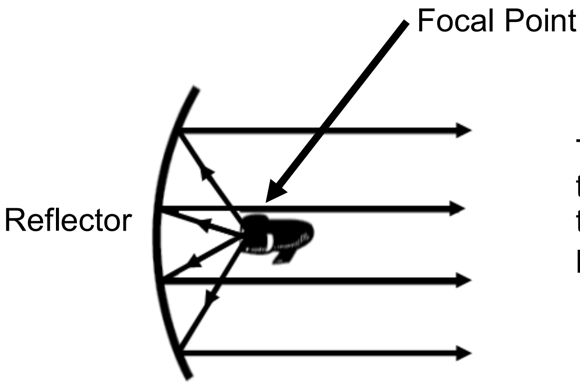
The Hubble Telescope

Curved Reflectors

Many different types of signals can be transmitted and received by curved reflectors. The curved shape of the reflector ensures that all incoming rays are reflected to the same point. (remember: angle of incidence = angle of reflection).

Curved reflectors can be used for transmitting and receiving signals.

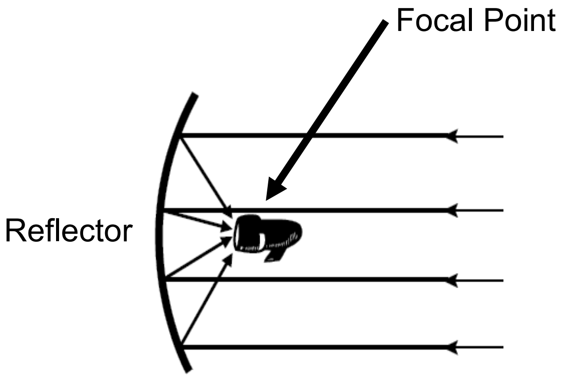
Transmitters



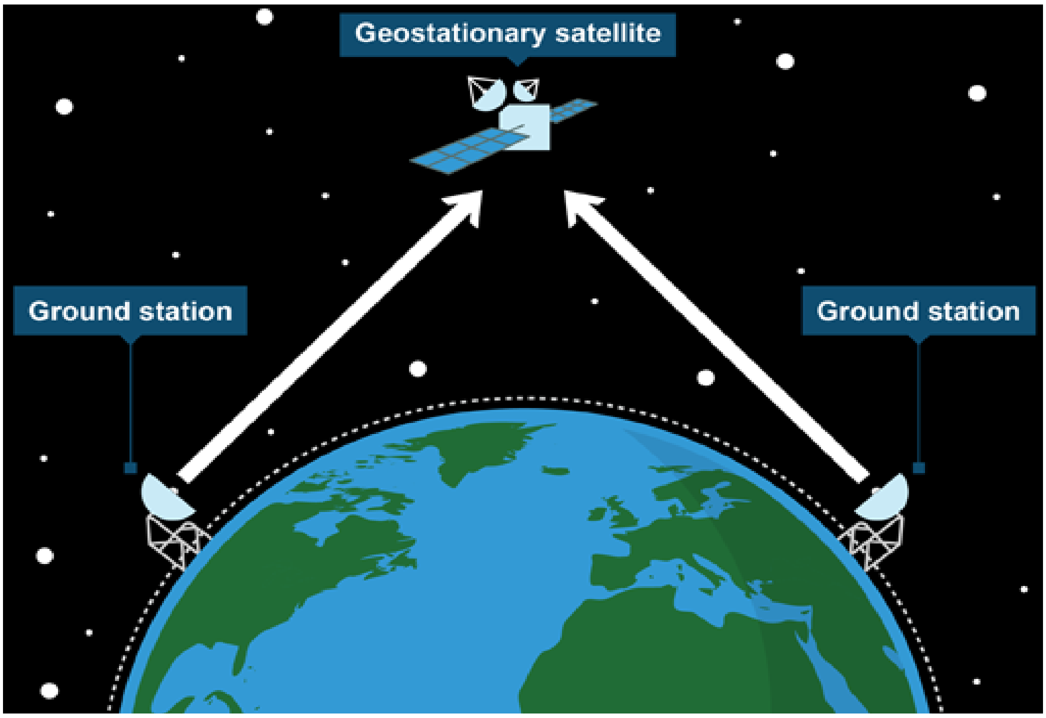
The signal is transmitted from the focus of the parabolic reflector. The waves are then reflected off the curved reflector as a parallel signal.

Receivers

The receiving aerial is placed at the focus of the curved reflector. The waves are all reflected off the curved reflector to the focus, meaning more energy is received.



A common application of curved reflectors is to send and received signals from satellites.



As the signal picked up by the receiver in this situation is from a distant transmitter it can be very weak. Using a curved reflector helps to increase the strength of the signal by focusing the waves onto the aerial. This ensures that a higher quality signal is received.

2.3 Space

Electromagnetic Spectrum

Detecting electromagnetic waves from space plays a crucial part in our continued understanding of our Universe. We looked at the electromagnetic spectrum in the Waves and Radiation Unit.
Recall:

Radiation	Detector
Gamma Rays	Geiger-Muller tube
X-rays	Photographic film
Ultraviolet	Fluorescent materials, CCDs
Visible light	Photographic film, CCDs
Infrared	Charge-coupled diodes (CCDs)
Microwaves	Aerial/Antenna, Diode
Radio & TV Waves	Aerial

Collecting Data from Space

Astronomers collect data from many parts of the electromagnetic spectrum. Each type of radiation requires special telescopes to detect the signals. The information collected from using different parts of the electromagnetic spectrum is pieced together to give fuller picture of our Universe.

Radio Telescopes

Weak radio signals from space are detected by large curved parabolic dishes. The aerial is placed at the focus of the dish, where the radio waves are converted to an electrical signal and analysed by computer. These dishes are often placed in a row to allow scientists to collect enough data. In Cheshire there is a 76m diameter radio telescope at Jodrell Bank.

Information from radio telescopes has allowed astronomers study the first detection of the radiation left over from the Big Bang. It helped in the discovery of Quasars in the 1950's and Pulsars in 1967.

Microwaves

Microwave telescopes need to be situated on top of the mountains as microwaves would be absorbed by the atmosphere by the time they reach sea level.

Infrared Radiation

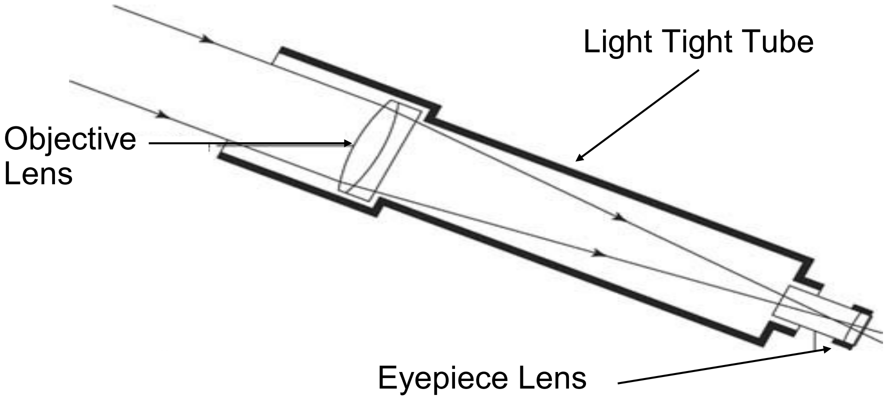
Infrared waves have a longer wavelength than visible light and cannot be detected by the human eye. Infrared waves are mostly absorbed by the atmosphere, resulting in these telescopes being situated on high mountains. Infrared observations are used to peer into star-forming regions and into central areas of our galaxy.

Visible Light - Optical Telescopes

Visible light from objects such as stars can be viewed using optical telescopes.

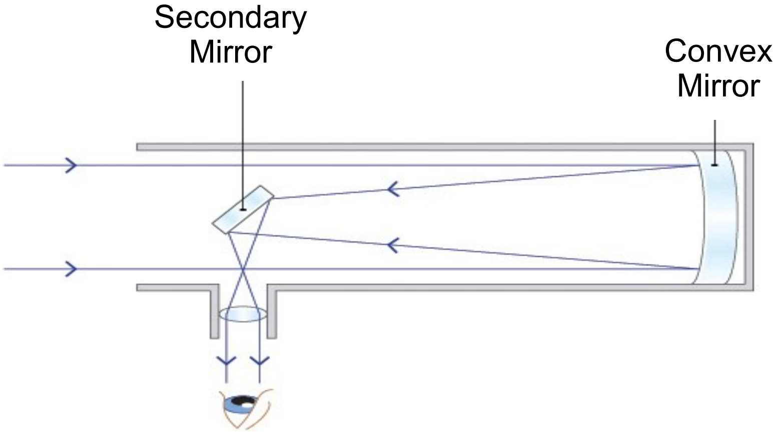
Refracting Telescope

Light passes through the wide objective lens. The eyepiece lens magnifies and



Reflecting Telescope

A large convex mirror is used in a reflecting telescope instead of an objective lens. The convex mirror is used to collect the distant light and is then reflected by a secondary mirror onto the eyepiece lens.



Ultraviolet Radiation
Major sources of U.V. include; very young massive stars, some very old stars, bright nebulae, white dwarf stars, active galaxies and quasars. UV telescopes allow us to learn more about these objects and further our understanding of the universe.

Gamma and X-Rays
X-Rays and Gamma Rays are absorbed by the Earths atmosphere so they are observed by satellites in orbit. Major sources of Gamma Rays include solar flares, pulsars and remnants of supernova.
and day. However, they are difficult and expensive to launch and maintain.
If anything goes wrong, sometimes only astronauts can repair them.

Space Exploration

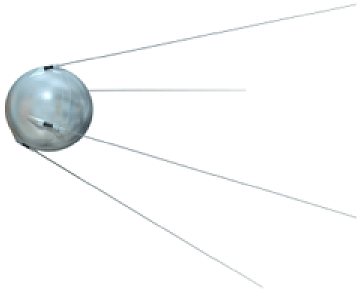
Many areas of science and technology have made advances due to technological breakthroughs resulting from the manned exploration of space. Humankind continues to examine the Universe in a bid to further our knowledge of the Universe.

Benefits of Space Exploration

NASA has had to patent many applications to accomplish their tasks. Some examples include: water filters, ear thermometers, scratch resistant lenses, memory foam, shoe insoles, long distance communication, smoke detectors, enriched baby food and cordless tools.

Other benefits have included the development of satellites and associated technologies.

The Soviet Union launched the first artificial satellite, Sputnik 1 (right), in October 1957 just to prove they could. Four months later, the United States responded with Explorer 1. 2,500 satellites have since been sent into orbit, including the Hubble Telescope and the International Space Station. These have allowed us to make improved observations of our planet.



Technology has advanced greatly as a result of satellite information including:

- Communications - instant, worldwide phones and tv.
- Position - GPS and Sat Nav to tell you where you are
- Predicting weather
- Environmental monitoring
- Climate monitoring - satellites can monitor change because they can monitor the concentration of greenhouse gases in the atmosphere

Risks of Space Exploration

Space exploration is a risky business. Space is a vacuum and humans cannot exist in a vacuum. This means that we have to create crafts and suits which provide an environment where humans can survive.

Another danger in space comes from temperature. It can vary from being extremely cold to very hot. The suits and craft are designed to keep the environment at the temperature that we can live in. So excellent cooling and heating systems are required in space.

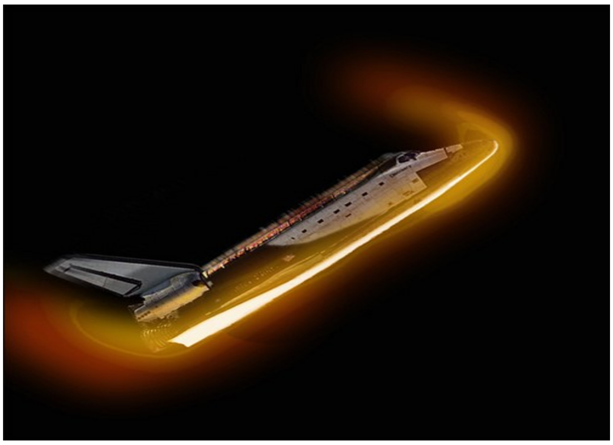
Other risks involved in space exploration include:

- Micrometeorites – danger from impact damage (to spacecraft and to astronauts during spacewalks)
- Solar flares and radiation – danger from ionising radiations
- No atmosphere – we need air to breathe
- Space debris – danger from impact damage
- Re-entry

Re-entry

When spacecraft return to Earth they are travelling at high speed. They have a lot of kinetic energy. When they enter the Earth's atmosphere there is a huge amount of heat generated as the kinetic energy is turned into heat. This heat is caused by the friction between the particles in the atmosphere and the outer surface of the space shuttle.

Without shielding, the spacecraft would simply burn up. Scientists and engineers have carried out a lot of research to design materials that will insulate the spacecraft from the heat of re-entry.



Silica tiles can be used to protect the shuttle and the astronauts from the heat generated upon re-entry. The tiles are painted black so that heat is lost to the surroundings. The air around the shuttle heats up. The temperature increase of the shuttle is therefore not as great.

Cosmology

Cosmology is the study of the Universe. It is important that you fully understand the terms listed in the table below:

Term	*Description*
Planet	An object which orbits a star
Star	A ball of hot gas undergoing nuclear fusion, emitting heat and light (e.g. The Sun)
Galaxy	Cluster of stars (e.g. our galaxy is the Milky Way and is spiral shaped)
Universe	All of space
Satellite	An object in orbit around a planet
Moon	A natural satellite
Solar System	Consists of a central star orbited by planets.

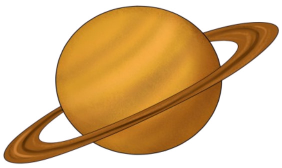
The Light Year

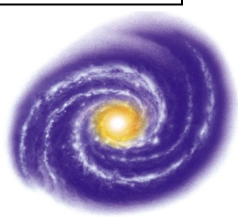
Distances in the universe are very large indeed. They are too large to be measured in kilometres. Because of this scientists have agreed another unit of distance—the ***light year***.

The 'light year' is a measurement of distance; 1 light year is the distance that light travels in one year.

Useful Information:

Destination	Journey Time for Light
Moon	1.2 seconds
Sun	8 minutes
Next Star (Proxima Centauri)	4.3 years
Other Side of Galaxy	100 000 years





The Light Year (continued)

Example

a) Calculate the number of metres in 1 light year
b) Proxima Centauri, the next closest star after the Sun, is 4.3 light years from the Earth. Calculate the distance in metres.

(a) d = ?

v = 3x108 ms-1

t = 1 year
= 365.25 x 24 x 60 x 60 s

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

$$3x10^{8} = \frac{d}{365.25x24x60x60}$$

$$\underline{d = 9.47x10^{15}m}$$

(b) 1 light year = 9.47 x 10^{15} m

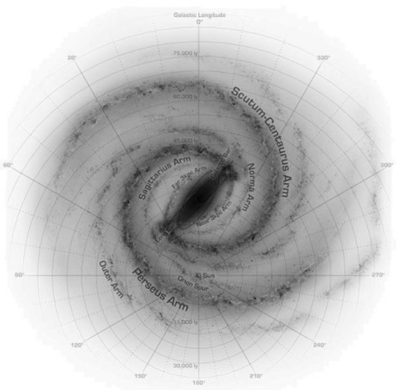
4.3 light years = 4.3 x 9.47 x 10^{15}

= $\underline{4.07 \times 10^{16} \text{ m}}$

The Milky Way

Our galaxy is called the Milky Way. This is known as a spiral galaxy due to its shape. The Milky Way, like all other galaxies is held together by gravity.

A typical galaxy will contain around 100 billion stars.



Big Bang Theory

The Big Bang Theory is a currently accepted theory to explain what happened at the very beginning of our Universe.

Discoveries in Astronomy and Physics have shown beyond a reasonable doubt that our Universe did in fact have a beginning. The Universe began as a singularity around 13.7 billion years ago.

A singularity is a zone which is difficult to understand even for leading physicists. It is believed that singularities exist at the centre of Black Holes.

All of the material from the big bang was dispersed in all direction, and has been continuing to expand outwards ever since. As the Universe expanded it cooled going from something very small and hot to our present Universe.

Evidence Supporting the Big Bang Theory

1. Expanding Universe

In 1929 Edwin Hubble discovered using ***Doppler Red Shift ,*** that on large scales, everything in the Universe is moving away from everything else. From this came Hubble's Law.

Doppler red-shift demonstrates that galaxies are moving away from us. The light from galaxies appears to be redder than scientists would expect. Therefore they concluded that the decrease in frequency of the light indicates that the galaxies are moving away from us.

2. Cosmic Microwave Background Radiation

When space is viewed through a microwave telescope it shows that microwave radiation is evenly distributed throughout the universe. This is consistent with the idea that radiation emitted just after the big bang was spread out in all directions. This radiation is known as ***Cosmic Microwave Background Radiation***.

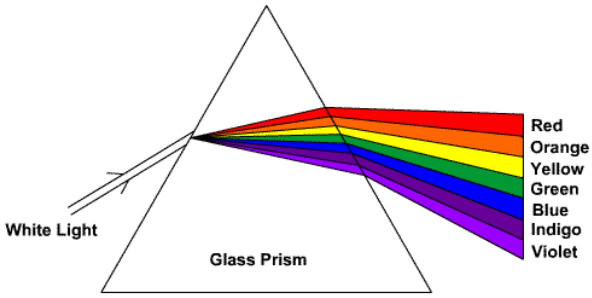
3. Abundance of Light Elements

The Big Bang theory states that matter started in a very simple form and that the simplest elements would have formed first. All other elements would later form in stars. This would mean that there would be more light elements such as hydrogen and helium than any other elements in the universe. The fact that there is an abundance of these materials is evidence to support the Big Bang theory.

Spectra

Continuous Spectra

White light is made up of a range of colours. These colours can be separated by splitting white light with a **prism** to obtain a continuous **spectrum**. Scientists can analyse light emitted by stars and other objects in space by looking at the light emitted from them using through a **prism**



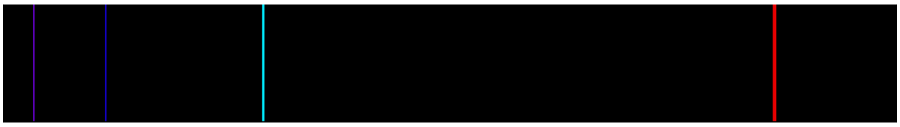
Red light has the longest wavelength and the lowest frequency and violet light has the shortest wavelength and the highest frequency.

Spectra can also be produced using a **diffraction grating.**

Line Spectra

A **line absorption spectrum** consists of a complete (continuous) spectrum with certain colours missing which appear as black lines in the spectrum.

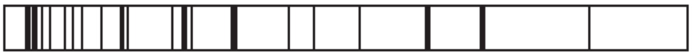
A **line emission spectrum** consists of lines of light of distinct colours rather than a continuous spectrum.



A device called a spectroscope (shown to the right) is used to view spectral lines from light sources.

Identifying Elements with Line Spectra

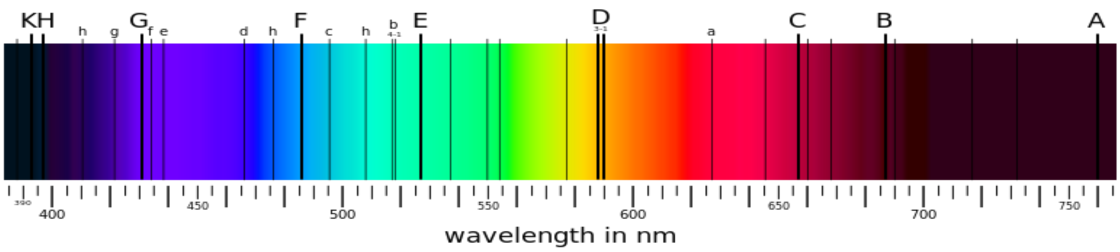
Each element in the periodic table emits a unique set of wavelengths of visible light. This is called a line spectrum. Astronomers can identify elements present in distant stars. Using known element spectra elements present in unknown sources can be identified.



Spectral lines of radiation from distant star

The spectral lines from a distant star can be seen above. Using the spectra from individual elements (shown below) the elements present in the star can be identified.

Using this method Helium was discovered to be present in the Sun before it had been discovered on Earth. Scientists had a mysterious set of bands which could not be attributed to any known element. They called this unknown element Helium, derived from Helios, the Greek god of the Sun.



The image above shows the absorption spectrum produced by our Sun. The dark lines represent the elements that make up the Sun. These are known as Fraunhofer Lines after the German Scientist Joseph Von Fraunhofer.