Dynamics & Space Summary Notes

Speed

Speed is the **distance** travelled by an object per **second** (usually expressed in metres per second, m/s or ms^{-1}).

Average Speed

The average speed of an object is the average for the whole journey (total distance travelled divided by time taken). e.g. average speed of car between Glasgow and Edinburgh

Instantaneous Speed

The instantaneous speed of an object is its speed over a very short time interval e.g. speed cameras measure the speed of a vehicle at a particular point in a journey to ensure that it is within the speed limit.

Speed during a journey

During a journey the instantaneous speed of a vehicle will change. For example at one point a car may be travelling along a street at 30 mph and when it is stopped at traffic lights its speed is 0 mph. These speeds can be very different from the average speed which may be something like 8 mph.

Speed, Distance and Time Equation

From the definition: $\text{speed} = \frac{\text{distance}}{\text{time}}$

In symbol form: $\mathbf{v = \frac{d}{t}}$ $\mathbf{d = v\,t}$ $\mathbf{t = \frac{d}{v}}$

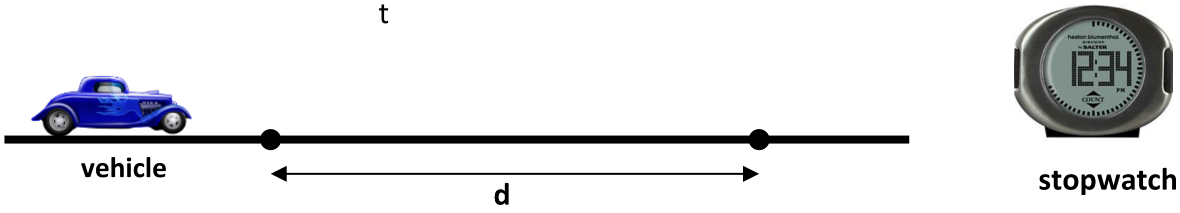
Quantity	Symbol	SI Unit
speed	v	m/s or ms^{-1}
distance	d	m
time	t	s

Example: Calculate the average speed of a car which takes 3 minutes to travel 1000m.

List	**Equation**	d = v t (as written in data book)
d= 1000 m	**Substitute**	1000 = v x 180
v = ?	**Answer & units**	v = 5.56 ms^{-1}
t = 3 minutes = 180 s		

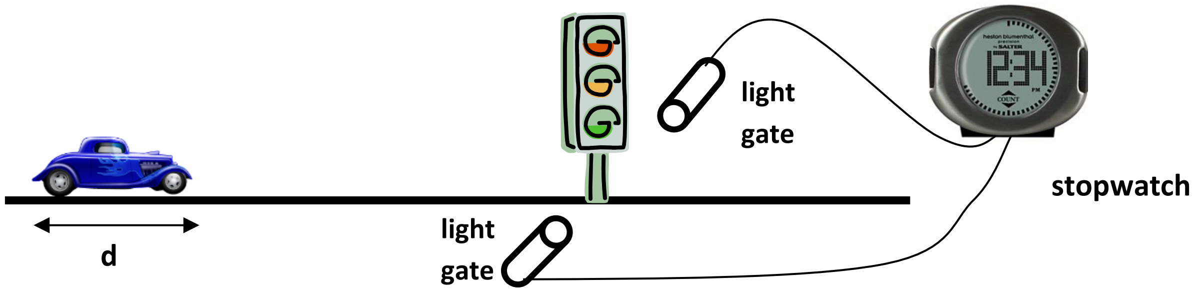
Measuring Average Speed ($\bar{v}$)

- Measure distance (**d**) travelled with a trundle wheel or metre stick.
- Measure time (**t**) taken for the vehicle to travel the distance (d) with a stopwatch.
- Use the equation $\bar{v} = \frac{d}{t}$ to calculate the average speed ($\bar{\mathbf{v}}$).



Measuring Instantaneous Speed (v)

- Measure the length of the vehicle or card attached to it (**d**) with a ruler / metre stick.
- Measure time (**t**) taken for the vehicle to pass a point with a light gate connected to a timer.
- Use the equation $v = \frac{d}{t}$ to calculate the instantaneous speed (**v**).



Example: Calculate the speed of a car as it passes through the traffic lights. The car is 4m long and takes 0.75s to pass the traffic lights.

List	**Equation**	$d = v\,t$
d= 4m	**Substitute**	$4 = v \times 0.75$
v = ?	**Answer & units**	$v = 5.33ms^{-1}$
t = 0.75s		

Vectors and Scalars

Classifying Vectors and Scalars

Physical quantities can be divided into two groups:

- a **scalar** quantity is completely described by stating its **magnitude** (size) only.
- a **vector** quantity is completely described by stating its **magnitude** and **direction**.

Which quantities are scalars and which are vectors?

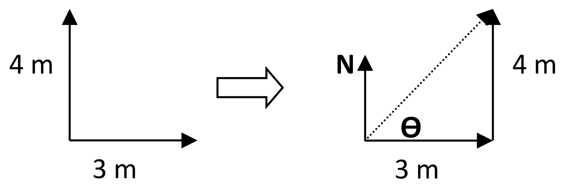
Scalars	Vectors
distance	displacement
speed	velocity
mass	force
time	acceleration
energy	weight

Vector Diagrams

In order to carry out any calculations we need to know how to calculate the resultant of two vector quantities. This is illustrated in the examples below.

Hints

- **Ensure all vectors are drawn tip to tail**
- **Draw a North line at the start point**
- **Draw the resultant vector from the start to the end point**
- **All bearings are measured clockwise from the North line to the resultant vector.**



Use Pythagoras to calculate the magnitude of the vector

$x^2 = 3^2 + 4^2$

$x = 5m$

Use Tan ϴ = opp / adj to find angle ϴ

Tan ϴ = 4 / 3

ϴ = 53.1° bearing = 90 – 53.1 = 36.9

Resultant vector = 5 m at 037 °

Vector Diagrams and Calculations (ctd)

Distance and Displacement

Distance is the total distance travelled regardless of the direction.
Displacement is the length measured from the start point to the end point in a straight line. Its direction must be stated.

Speed and Velocity

As stated previously, speed is defined as the distance travelled per second.
Velocity can be defined as the displacement (s) of an object per second (t) measured in ms^{-1}.

Speed and velocity are described by the equations below:

$$\text{speed} = \frac{\text{distance}}{\text{time}} \qquad \text{velocity} = \frac{\text{displacement}}{\text{time}}$$

Quantity	Symbol	SI Unit
velocity	v	m/s or ms^{-1}
displacement	s	m
time	t	s

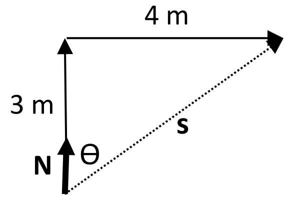
In symbol form the velocity equation is:

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

Velocity is a vector quantity and speed is scalar.
The direction of the velocity will be the same as the direction of the displacement.

Example: A woman walks 3 m due North and then 4 m due East. She takes 10 seconds.
a) Find the (i) distance she has walked and (ii) her displacement.
b) Calculate her (i) average speed and (ii) velocity.

Solution
We will represent her walk by drawing a vector diagram.



a) (i) The distance she has travelled is 3 + 4 = 7 m
(ii) Her displacement can be calculated using Pythagoras:

$$s^2 = 3^2 + 4^2$$
$$s = 5 \text{ m}$$

The angle Θ is calculated using

$$\tan \Theta = 4 / 3$$
$$\Theta = 53^o$$

s = 5 m at 053

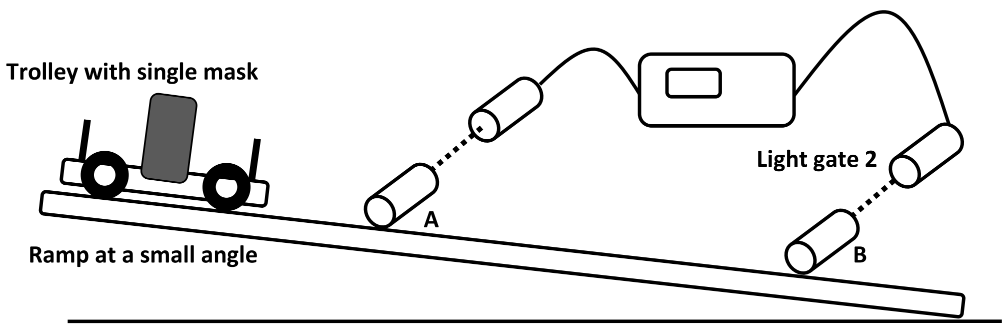
b) (i) d = 7 m   d= v t
v = ?   7 = v x 10
t = 10 s   v = 0.7 ms^{-1}

(ii) s = 5 m   s = vt
v = ?   5 = v x 10
t = 10 s   v = 0.5 ms^{-1} at 053   **Remember that velocity requires a bearing**

Acceleration

Measuring Acceleration

- Measure the length of the mask with a ruler. Set the electronic timer to measure instantaneous speed.
- Place the light gates at similar positions to A and B.
- Allow the trolley to run down the slope so that the mask will cut both light beams.
- Record initial speed (u), final speed (v), and time between light gates from electronic timer (t).



- Using the relationship a = (v-u)/t , calculate the value of the acceleration of the trolley on the slope.

  (An alternative method is also available to measure acceleration. This is done with a 'double' mask rather than a 'single' one, which is then used to calculate acceleration)

Acceleration

Acceleration is the **change in speed (or velocity)** every **second** and is measured in metres per second per second (ms^{-2}).

It can be calculated using the formula:

$$\text{acceleration} = \frac{\text{final velocity} - \text{initial velocity}}{\text{time}}$$

In symbol form:

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

Quantity	Symbol	SI Unit
acceleration	a	m/s^2 or ms^{-2}
final velocity	v	ms^{-1}
Initial velocity	u	ms^{-1}
time	t	s

A common form of the equation worth remembering is **$v = u + at$**

Example:

1. Calculate the acceleration of a vehicle travelling from rest to 12 ms^{-1} in 5 s.

a = ?
v = 12 ms^{-1}
u = 0 (at rest)
t = 5 s

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

$a = \frac{12 - 0}{5}$

a = 2.4 ms^{-2}

2. A car accelerates at 4 ms^{-2} for 10 s from rest. Calculate the sped of the car after 10 s.

a = 4 ms^{-2}
v = ?
u = 0 (at rest)
t = 10 s

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

v = u + at
v = 0 + (4 x 10)
v = 40 ms^{-1}

3. Calculate the deceleration of a train which travels from 30 ms^{-1} to 16 ms^{-1} in a time of 1 minute.

a = ?
v = 16 ms^{-1}
u = 30 ms^{-1}
t = 1 minute = 60 s

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

$a = \frac{16 - 30}{60}$

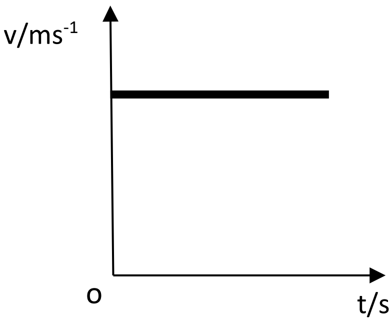
a = - 0.47 ms^{-2}

Graphs

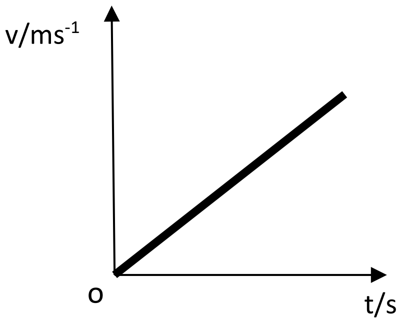
Speed – Time Graphs

A speed-time graph is a useful way of describing the motion of an object.
Since speed is a scalar quantity, a speed-time graph considers motion in one direction only.

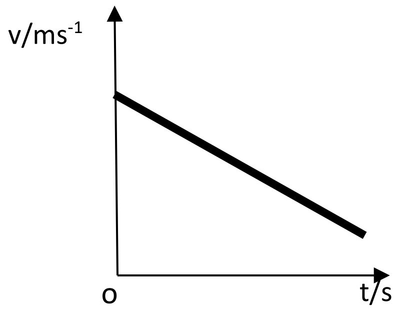
The graphs below illustrate the 3 types of motion you will study.



constant speed



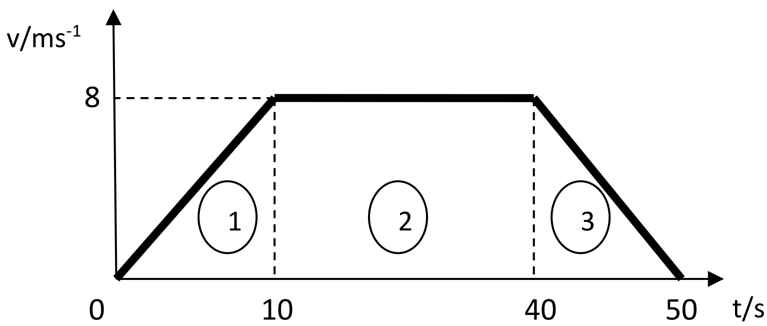
increasing speed
(constant acceleration)



decreasing speed
(constant deceleration)

The steeper the line (larger gradient) the greater the acceleration

Example: The motion of a car over 50 s is described in the speed-time graph below.



a) Calculate the acceleration of the car during the first 10 s.
b) Calculate the distance travelled by the car for the entire 50 s.

Solution

a) a = ?
$v = 8\ ms^{-1}$
u = 0 (at rest)
t = 10 s

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

$a = \frac{8 - 0}{10}$

$a = 0.8\ ms^{-2}$

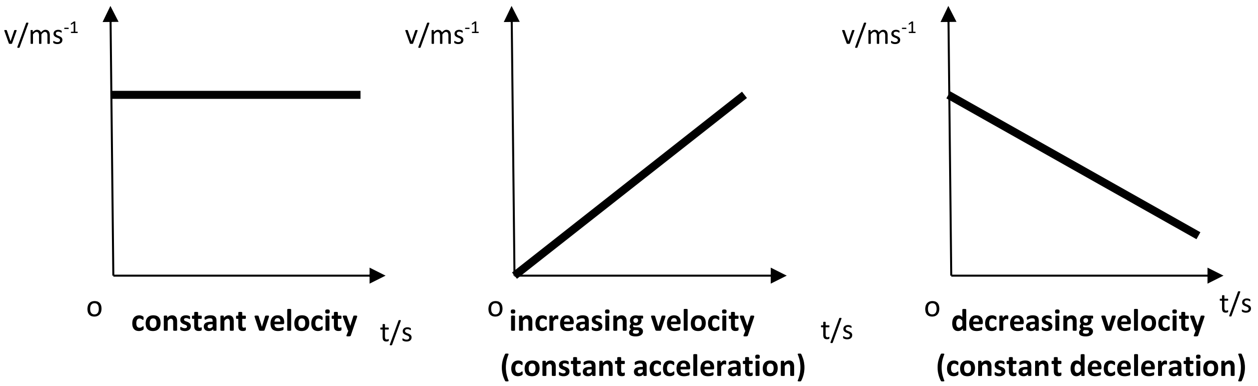
b) **To calculate the distance travelled we cannot use d = vt as the speed is not constant throughout the journey.**
The distance travelled = area under the speed-time graph
Area 1 = ½ (10 x 8) = 40 (area of right angled triangle)
Area 2 = 30 x 8 = 240 (area of rectangle)
Area 3 = ½ (10 x 8) = 40 (area of right angled triangle)
Total area = 40 + 240 + 40 = 320 so distance travelled = 320m

Velocity – Time Graphs

A velocity-time graph is a useful way of describing the motion of an object.

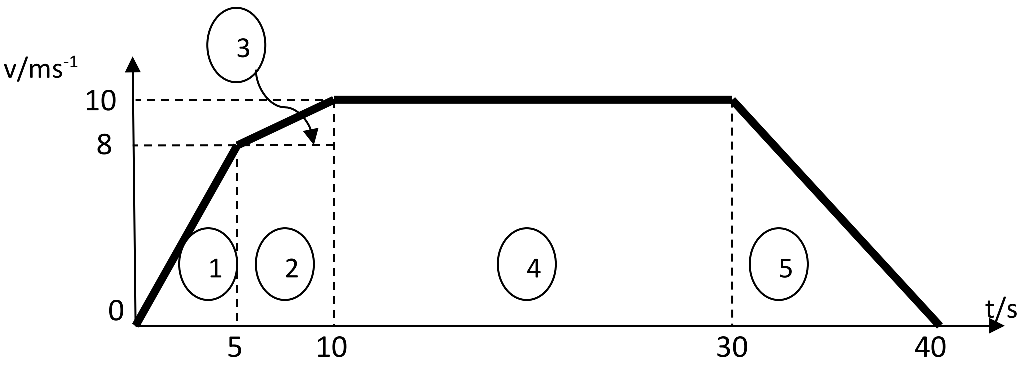
Since velocity is a vector quantity, a velocity-time graph can consider motion in two directions.

The graphs below illustrate the 3 types of motion you will study.



The steeper the line (larger gradient) the greater the acceleration

Example: The motion of a car over 40 s is described in the velocity-time graph below.



a) During which stage of the journey is the acceleration of the car the greatest?
b) Calculate the deceleration of the car between 30 and 40 s.
c) Calculate the displacement of the car for the entire 40 s.

Solution

a) Between 0 and 5 s. **(the gradient of the line is greater than 5 s to 10 s)**

b) a = ?
v = 0
u = $10 ms^{-1}$
t = 10s

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

$$a = \frac{0 - 10}{10}$$

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

c) Displacement = area under the velocity-time graph

Area 1 = ½ (5 x 8) = 20
Area 2 = 5 x 8 = 40
Area 3 = ½ (5 x 2) = 5
Area 4 = 20 x 10 = 200
Area 5 = ½ (10 x 10) = 50

Forces

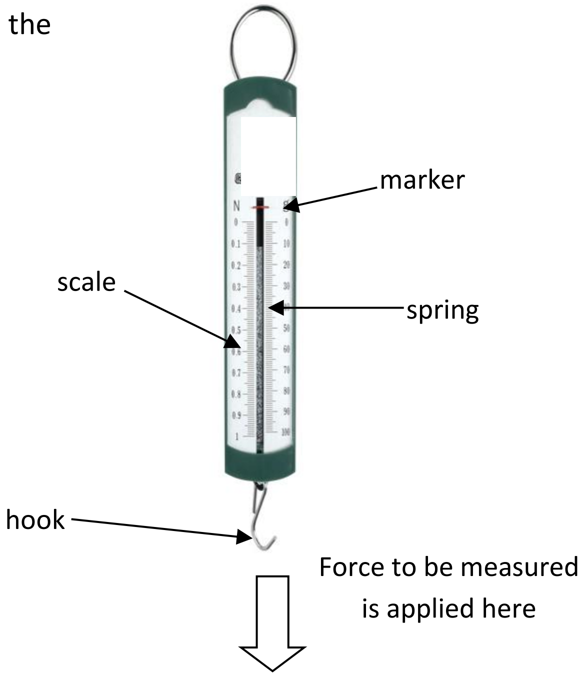
Effects of Forces

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

- the **shape** of an object e.g. squeezing plasticine
- the **speed** of an object e.g. kicking a football from rest
- the **direction of movement** of an object e.g. hitting a tennis ball with a racquet.

Measurement of Forces

Forces are measured in units called **Newtons** (N). Force is a **Vector** quantity.
Forces can be measured with a newton balance. This instrument depends on the effect of a force on the

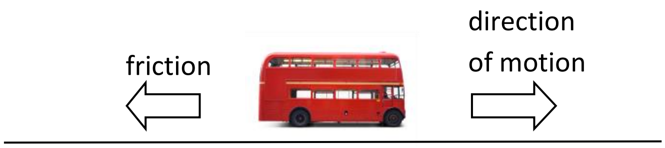


- The force to be measured is applied to the hook which is attached to the spring.
- The force causes the spring to stretch.
- The greater the force, the greater the stretch of the spring and the further the marker moves across the scale.

Friction

Introduction to Friction

Friction is a **resistive** force, which **opposes** the direction of 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.

Air friction is usually 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** (as the object accelerates).

Increasing Friction

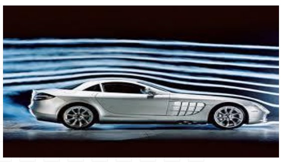
Where friction is used to **slow** an object down, it should be **increased**.
This can be achieved by:

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

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 the shape of the object to reduce air friction (aerodynamic teardrop shape).

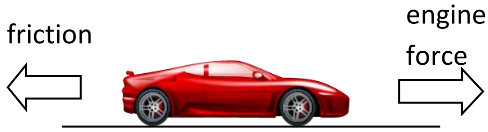


Newton’s Laws of Motion (1 and 2)

Balanced Forces

A force is a vector quantity because to describe it properly requires a direction as well as size.

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

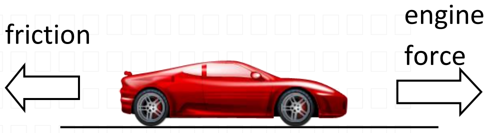


When the engine force = friction on the car the forces are balanced.

Balanced forces have the same effect as having **no** forces acting at all.

Newton’s 1st Law of Motion

An object will remain at rest or travel in a straight line at a constant velocity (or speed) if the forces are balanced.



- If we consider the car moving in a straight line. If the engine force = friction, it will continue to move at a constant velocity (or speed) in the same direction.
- If the same car is stationary (not moving) and all forces acting on it are balanced (same as no force at all) the car will not move.

Free Body Diagrams

We can use free body diagrams to analyse the forces on an object. This allows us to determine the motion of the object.

Example: If the bus is travelling with an engine thrust of 12kN and all forces acting on the bus are balanced

a) calculate the size of the frictional force acting

b) determine the motion of the bus.

Solution a) Draw the free body diagram

Since the forces are balanced
friction = 12kN

b) constant velocity (or speed) since the forces are balanced.

Newton's 2nd Law of Motion

This law deals with situations when there is an unbalanced force acting on the object.
The velocity cannot remain constant and the acceleration produced will depend on:

- the mass (**m**) of the object **($a \propto 1/m$) - if m increases a decreases and vice versa**
- the unbalanced force **(F)** **($a \propto F$) - if F increases a increases and vice versa**

This law can be summarised by the equation **F = ma**

Force, Mass and Acceleration Equation

A newton is defined as the force which makes a 1 kg mass accelerate at $1ms^{-2}$

From the definition: $\text{acceleration} = \dfrac{\text{unbalanced force}}{\text{mass}}$

In symbol form: $a = \dfrac{F}{m}$ $F = ma$ $m = \dfrac{F}{a}$

Quantity	Symbol	SI Unit
unbalanced force	F	N
mass	m	kg
acceleration	a	ms^{-2}

Example: Calculate the unbalanced force acting on a 10000 kg bus accelerating at 3.5 ms^{-2}.

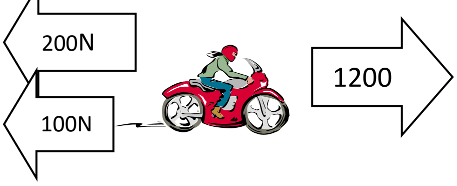
F = ? F = ma
m = 10000 kg F = 10000 x 3.5
a = $3.5ms^{-2}$ F = 35000 N

Resultant Forces (1)

When several forces act on one object, they can be replaced by one force which has the same effect. This single force is called the **resultant** or **unbalanced** force.

Example: Horizontal
A motorcycle and rider of combined mass 650 kg provide an engine force of 1200 N. The friction between the road and motorcycle is 100N and the drag value = 200N.
Calculate:

a) **the unbalanced force acting on the motorcycle**
b) **the acceleration of the motorcycle**



Solution

a) Draw a free body diagram

F = 1200 - (200 + 100)
F = 900 N This 900 N force is the resultant of the 3 forces

b) F = 900 N F = ma
a = ? 900 = 650 x a
m = 650 kg a = 1.38 ms^{-2}

Resultant Forces (2) in the vertical direction will be considered in the Space Exploration section

Motion During Free Fall and Terminal Velocity

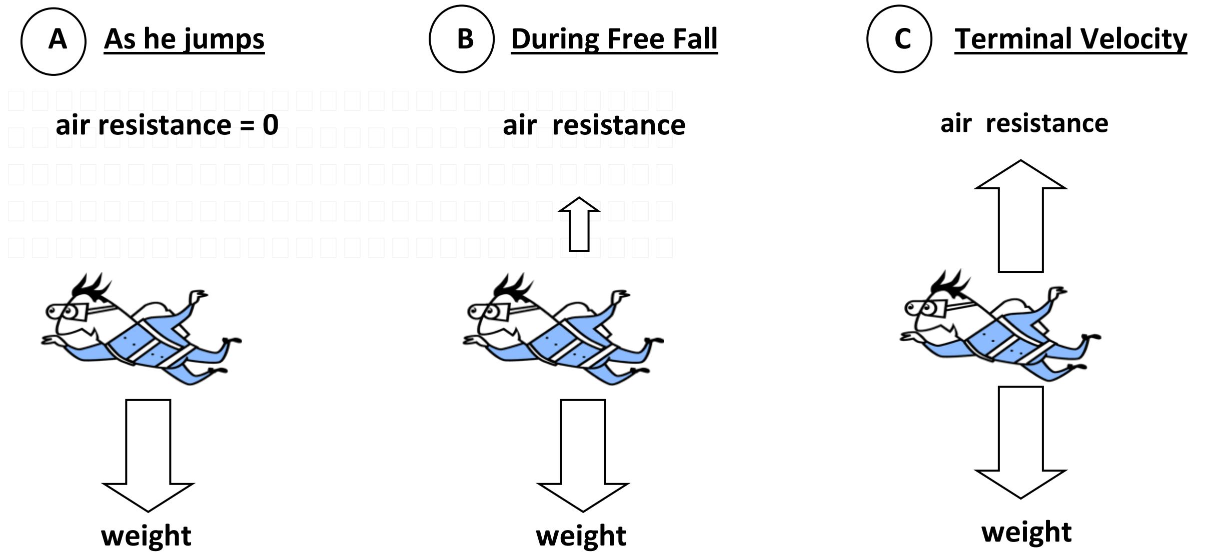
Free fall is the term used when an object is being acted upon only by the force of gravity (weight).

However, free fall will cause the object to accelerate and from the section Introduction to Friction, it states that:

air resistance will increase as an object accelerates

so we have to look at air resistance as well as weight to study motion during free fall.

Example: If we consider a sky diver jumping out of an aeroplane



A – As he jumps

one force acting down

Unbalanced Force downwards (Newton's 2nd law)

maximum acceleration

B – During Free Fall

weight > air resistance

Unbalanced Force downwards (Newton's 2nd law)

decreasing acceleration

C – Terminal Velocity

weight = air resistance

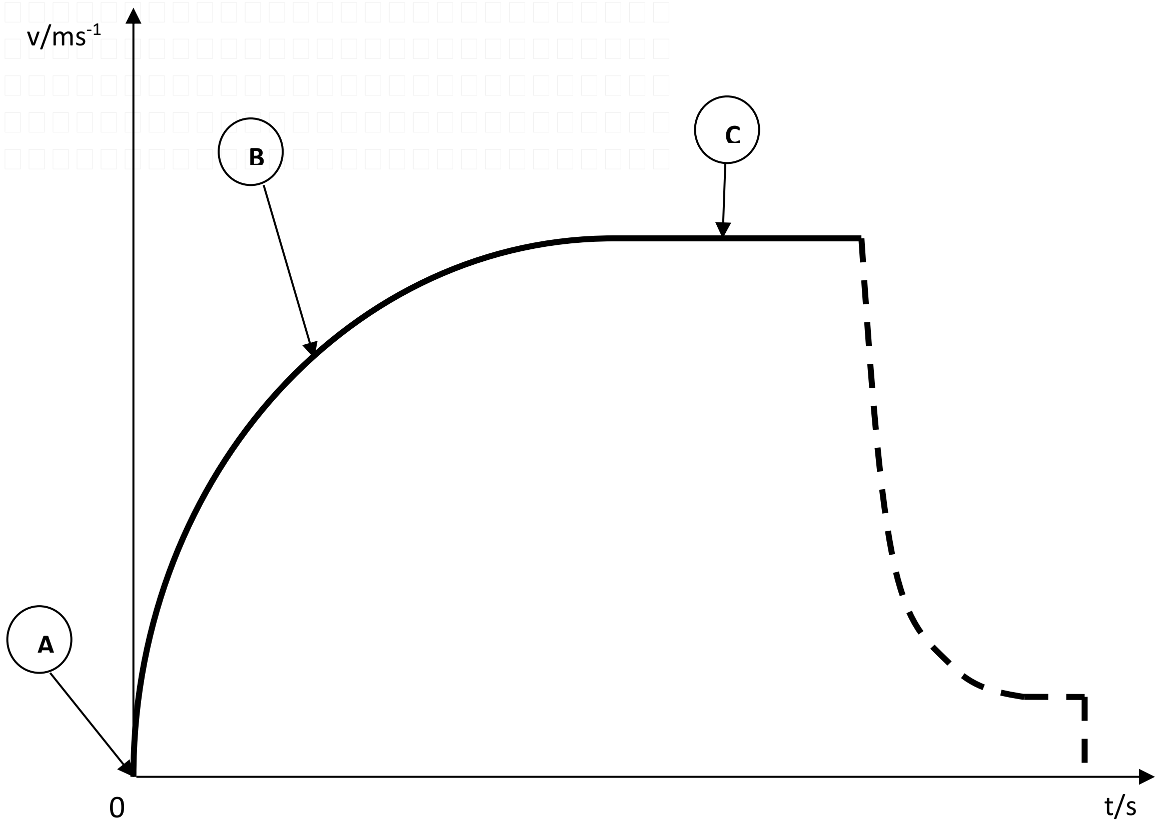
Balanced Forces (Newton's 1st Law)

acceleration = o (constant velocity)

As the skydiver accelerates downwards, air resistance increases upwards until the value of air resistance = the skydiver's weight. This results in the two forces having the same value acting in opposite directions. According to Newton's 1st Law of Motion the skydiver will now travel at a constant velocity. This velocity is known as **Terminal Velocity**.

Motion During Free Fall and Terminal Velocity (ctd)

The motion of the skydiver in the example is best illustrated in a velocity – time graph. Refer to the previous page to fully understand what happens at points A, B and C.



What do you think has happened to cause the motion represented by the dotted lines? (Hint: How does the sky diver land on the ground safely?)

Weight and Mass

Weight

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 **newtons (N)**.

Mass

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, Mass and Gravitational Field Strength Equation

Weight always acts vertically downwards. Its size does not just depend on the mass of the object, but on the strength of gravity at that place.
The strength of gravity in a particular place is called the **gravitational field strength (g)** and is defined as **the weight per unit mass**. It is measured in **Nkg^{-1}. On Earth, g = 9.8 Nkg^{-1}.**

From the definition:

$$\text{gravitational field strength} = \frac{\text{weight}}{\text{mass}}$$

In symbol form: $g = \frac{W}{m}$ $W = mg$ $m = \frac{W}{g}$

Quantity	Symbol	SI Unit
weight	W	N
mass	m	kg
gravitational field strength	g	Nkg^{-1}

Example: A girl has a mass of 70 kg on Earth (g = 9.8 Nkg^{-1})

a) Calculate her weight on i) Earth and ii) the moon where g = 1.6 Nkg^{-1}.

b) What is her mass on the moon?

Solution

a) i) W = ? W = mg
m = 70 kg W = 70 x 9.8
g = 9.8 Nkg^{-1} W = 686 N

ii) W = ? W = mg
m = 70 kg W = 70 x 1.6
g = 1.6 Nkg^{-1} W = 112 N

b) m = 70 kg (mass does not change)

W = m g Calculations - During Interplanetary Flight

The value for g is not always constant. It changes as you travel:

- further away from the centre of the earth;
- to a different planet, moon or star.

Every planet, moon and star has their own gravitational field strength.

Planet, Moon or Star	Value for g / Nkg^{-1}
Mercury	3.7
Venus	8.9
Earth	9.8
Earth's Moon	1.6
Mars	3.7
Jupiter	23
Saturn	9
Uranus	8.7
Neptune	11
Sun	270

Example: A satellite of mass 20000 kg travels from Earth to Mars, Jupiter, Saturn and Mercury.

a) Calculate the rocket's weight on Mars.

b) What is the mass of the rocket on Jupiter?

c) Of the 4 planets (including Earth) visited by the rockets, on which planets would the weight of the rocket be the same? Explain your answer.

Solution

a)) W = ?
m = 20000 kg
g = 3.7 Nkg^{-1}

W = mg
W = 20000 x 3.7
W = 74000 N

b) m = 20000 kg

c) Mercury and Mars. The values for g on both planets are the same with the mass of the rocket remaining constant.

During interplanetary flight there is no need for the engines to be kept on. Since space is a vacuum there is almost no friction acting on the space vehicle. With no unbalanced forces acting on the vehicle it will continue to move at a steady velocity (Newton's First Law of Motion).

Newton's Laws of Motion (3)

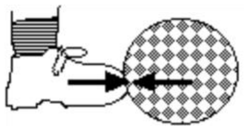
Newton's 3rd law of Motion

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 (do not confuse this with balanced forces).

Newton's Third Law can be stated as:
If an 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.

For example:

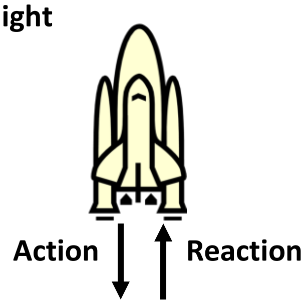
a) Kicking a ball



Action: **The foot exerts a force on the ball**

Reaction: **The ball exerts an equal force on the foot**

b) Rocket flight



Action: **The rocket pushes gases out the back**

Reaction: **The gases push the rocket in the opposite direction.**

Satellites and Projectiles

Satellites

Satellites - Introduction

A **satellite** is an object which **orbits another object**.
The Moon is a natural satellite which orbits earth and Sputnik is a man-made satellite as it was put into an orbit of the earth.

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.

Geostationary Satellite

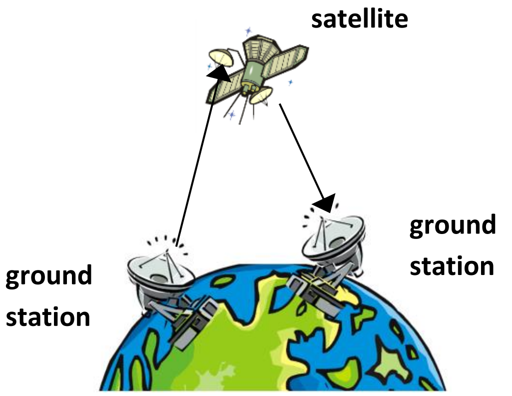
A **geostationary satellite** is a satellite which:

- 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

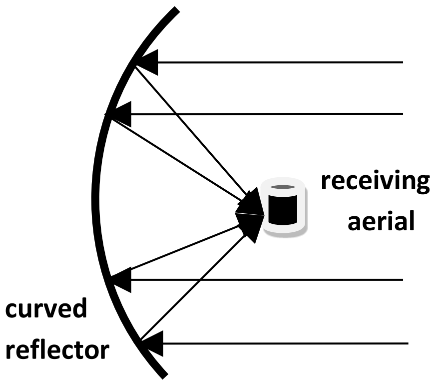
Ground stations send microwave signals to the satellite using a curved dish transmitter to transmit a strong signal. At the satellite the signal is **collected** by a curved dish receiver, then **amplified** and finally **retransmitted** (at a different frequency) back to the ground using another curved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



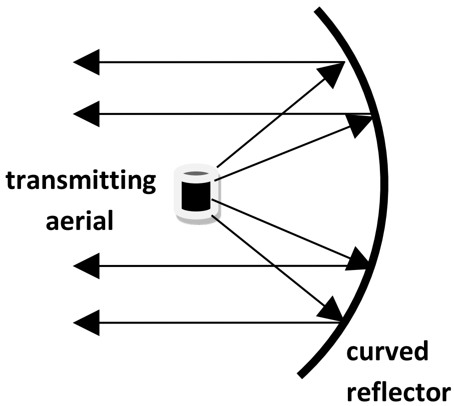
Satellite Communication – Parabolic (Curved) Reflectors

Receiving the signal



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.

Transmitting the 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.

Applications of Satellites

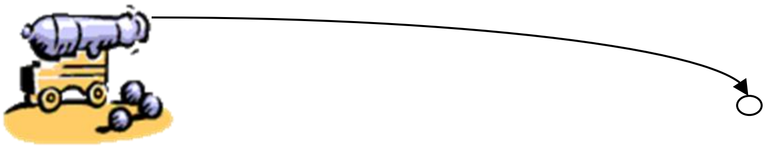
Satellites are being used by many countries in different ways. For example:

- **Sending a television or radio signal across the country or to another country**
  The Olympic Games can be beamed around the world using satellite communication. 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.

Projectiles

Projectile Motion

A **projectile** is an object which has been given a constant horizontal velocity through the air, but which is also accelerating towards the ground at 9.8ms^{-2} due to gravity.
This results in the trajectory (path) of the projectile being curved.
For example, a cannon firing a cannonball will result in the cannonball following a curved trajectory as shown below.



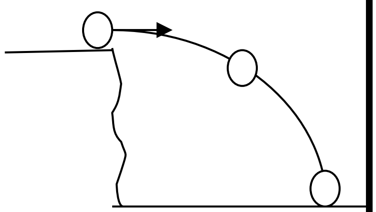
A projectile has two **separate** motions at right angles to each other - **horizontal and vertical**. Each motion is **independent** of the other.

Points to note:

- The **horizontal** motion is at a **constant velocity** since there are no forces acting horizontally if air resistance can be ignored (Newton's first law of motion).
  Horizontal displacement = horizontal velocity x time in the air (**s = v t**)
- The **vertical** motion is one of **constant acceleration**, equal to the value of **g**.
  For projectiles which are projected horizontally, the initial vertical velocity is zero.
  For vertical calculations, use **v = u + at**, where **u = 0 and a = g (= 9.8ms^{-2} on Earth).**

Example: Using formulae
A ball is kicked horizontally at 5 ms^{-1} from a cliff top as shown below. It takes 2 seconds to reach the ground.

a) How far does the ball travel horizontally in 2 seconds?
b) What was its vertical velocity just before it hit the ground?



Solution

a) Horizontal
s =?
v = 5ms^{-1}
t = 2 s

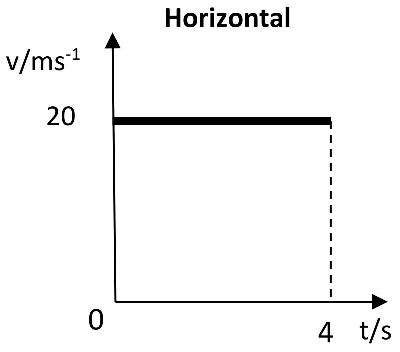
s = v t
s = 5 x 2
s = 10 m

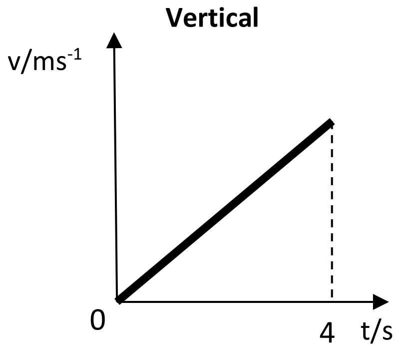
b) Vertical
v = ?
u = 0
a = 9.8 ms^{-2} (= g on Earth)
t = 2s (time is the same for vertical and horizontal motion)

v = u + at
v = 0 + (9.8 x 2)
v = 19.6 ms^{-1}

Projectile Motion (ctd)

Example: Using Graphs
A bird flying horizontally at a constant velocity drops a fish it is carrying into a lake.
The velocity - time graphs for both the horizontal and vertical motion of the fish from when it is dropped until it hits the water are shown below.





Calculate

a) **The horizontal velocity when it hits the water.**
b) **The vertical velocity when it hits the water.**
c) **The horizontal displacement of the fish travelled after it was dropped.**
d) **The height the osprey was flying when it dropped the fish.**

Solution

a) Horizontal velocity = 20 ms^{-1} (horizontal velocity remains constant throughout).

b) Vertical

v = ?	v = u + at
u = 0	v = 0 + (9.8 x 4)
a = 10 ms^{-2}	v = 39.2 ms^{-1}
t = 4 s	

c) Horizontal displacement = area under the horizontal velocity - time graph
= area of rectangle
= 20 x 4
= 80 m.

d) Height = area under the vertical velocity - time graph
= area of triangle
= ½ x 40 x 4
= 80 m.

Satellites – An Application of Projectile Motion

Satellite motion is an application of projectile motion. A satellite is continually accelerating (due to its weight) vertically towards the ground just like any other projectile. However, the satellite is moving so fast horizontally that the Earth curves away from it as quickly as it falls. This means that the satellite never reaches the earth but continues to move in orbit.

Cosmology

The Universe

Cosmic Definitions

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:

- **Asteriod** An asteroid is like a very tiny planet which orbits a star. The vast majority of asteroids in the solar system are found between Mars & Jupiter.
- **Star** A hot ball of matter which is undergoing nuclear fusion emitting 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.
- **Dwarf Planet** Just like a planet, but smaller. An example is Pluto.
- **Moon** A lump of matter which orbits a planet. Our moon orbits Earth. Deimos which orbits Mars is another example of a moon.
- **Solar System** A solar system consists of a star and all the objects orbiting it as well as all the material in that system. Our Solar System includes the Sun together with the eight planets and their moons as well as all other celestial bodies that orbit the sun.
- **Galaxy** A large cluster of stars, some of which have planets orbiting them. The Milky Way is an example of a galaxy.
- **Exo Planet** (or Extrasolar Planet) A planet outside our Solar System. Many thousands of exoplanets have now been discovered.
- **The Universe** Consists of many Galaxies separated by empty space.

Light Year

Contrary to the name, a light year is a measure of **distance** and **not** time.

1 light year is the distance light travels in 1 year.

Light is an electromagnetic wave which travels at a speed of 300 000 000 ms^{-1}.

Question
How far does light travel in one year?

d = ?
v = 300 000 000 ms^{-1}
t = 1 x 365.25 x 24 x 60 x 60 = 31 557 600 s

d = v t
d = 300 000000 x 31 557 600
d = 9 467 280 000 000 000 m

one light year = 9.47×10^{15} m

As the distances in the universe are very large we need to use the term light year instead of metres or even miles. Below are distances you will be required to know.

Approximate distance from **Earth** to:

- **The Sun** 0.000016 light years (or 8.3 light minutes)
- **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.

The Big Bang Theory (The Theory of the Origin of the Universe)

Most astronomers believe the Universe began in a Big Bang about 13.75 billion years ago. Time, space and matter all began with the Big Bang. In a fraction of a second, the Universe grew from smaller than a single atom to bigger than a galaxy and it kept on growing at a fantastic rate. It is still expanding today.

Scientists are reasonably certain that the universe had a beginning. This is the basis of the Big Bang Theory. To support this argument scientists have discovered that:

- Galaxies appear to be moving away from us at speeds proportional to their distance. This observation supports the expansion of the universe and suggests that the universe was once compacted.
- If the universe was initially very, very hot as the Big Bang suggests, we should be able to find some small remains of this heat. In 1965, Radio astronomers discovered Cosmic Microwave Background radiation (CMB) which spread throughout parts of the observable universe. This is thought to be the small remains which scientists were looking for.
- Finally, the abundance of the "light elements" Hydrogen and Helium found in the observable universe are thought to support the Big Bang model of origins.

The Electromagnetic Spectrum

Detectors of Electromagnetic Radiations

Humans can detect some of the electromagnetic radiations e.g. the eyes can detect visible light, infra-red can be detected by skin and sun burn is a consequence of the skin being over exposed to ultra violet radiation from the sun.

However, energy is given out by objects in space (e.g. stars or galaxies) over the whole range of the electro-magnetic spectrum so to fully understand the universe we must collect information at all these wavelengths. Different kinds of telescope are therefore required to detect different wavelengths of radiation as one as alone cannot detect them all.

Below is a list of detectors for each radiation in the spectrum.

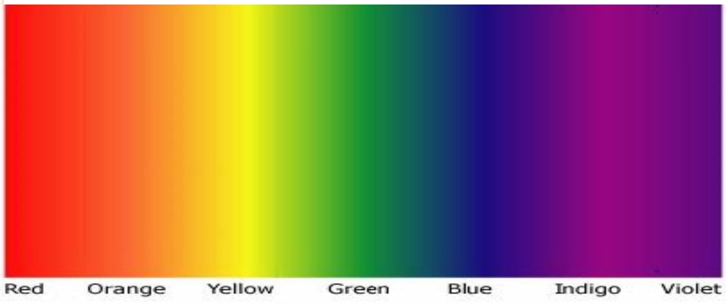
Radiation	Detector	Use
Radio and T.V	Aerial	Gives information on different planets e.g. distance from the Earth
Micro waves	Diode probe	The detection of Cosmic Microwave Background consolidated the belief the Big Bang occurred
Infra Red	Photodiode	Infra red is used to detect objects just outside the visible spectrum
Visible Light	Photographic film	Gives information on planets and stars including temperature and size
Ultra Violet	Fluorescent paint	Used to study star formation – most “young” stars emit ultra violet radiation
X-Rays	Photographic film	Used to detect the presence of black holes
Gamma rays	Geiger-Muller tube	Used to detect the presence of black holes and supernova

Spectroscopy

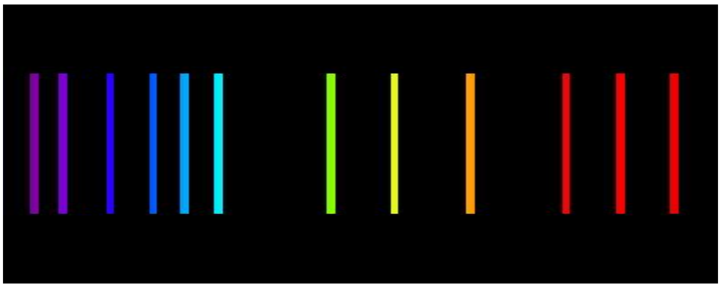
Continuous and Line Spectra

Astronomers can find out information about stars from the light the star emits using an instrument called a **spectroscope**.
The spectroscope splits up the light to produce a spectrum.
There are two types of spectra:

- **Continuous** – produced by light from solids, liquids and gases at high pressure and at high temperature. Each colour in the spectrum has a different frequency and wavelength



- **Line** – produced by hot gases at low pressure and gases which have an electric current passed through them. Each line in the spectrum corresponds to a particular frequency and wavelength.

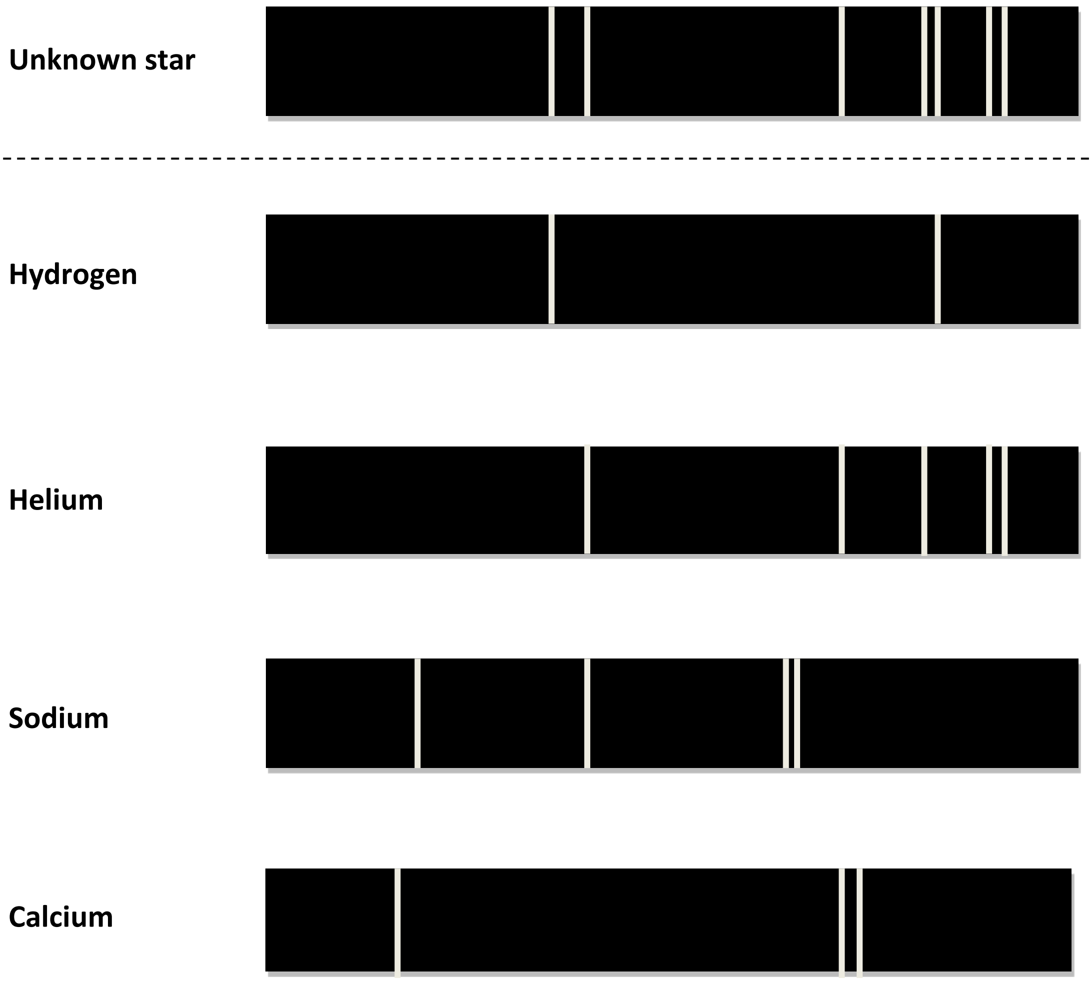


Line spectra are extremely useful for astronomers because every chemical element has its own unique spectrum (like D.N.A or fingerprints). This allows astronomers to identify elements present in distant stars.

You may find this easier to understand after looking at the example on the next page.

Stellar Detectives

Example: Identify the elements that make up the unknown star from the line spectra below. The line spectra for hydrogen, helium, sodium and calcium are given below to help you.



Answer : Hydrogen and Helium.

All spectral lines present in Hydrogen and Helium are present in the unknown star.

Space Exploration

Space Technology

Made in Space for Us – The Benefits of Space Exploration

Space technology is not limited to be used in space. There are many items that benefit us in our day to day lives which have evolved from equipment used and created for use in space.

We have mainly benefited by the use of satellites.

- **Development of weather forecasting systems.**
- **Telecommunications via satellites.**
- **Analysis of our environment through environmental monitoring satellites.**
- **GPS & Sat Nav systems.**
- **National security through spy satellites.**

We have also benefited by the development of:

- **Artificial limbs** - Innovations in robotics and shock-absorption/comfort materials are inspiring and enable the private sector to create new and better solutions for animal and human artificial limbs.
- **Water purification** - This system, makes use of available resources by turning wastewater from respiration, sweat, and urine into drinkable water. Commercially, this system is benefiting people all over the world who need affordable, clean water.
- **Heat resistant paints** - The spacecraft Apollo's heat shield was coated with a material whose purpose was to burn and thus dissipate energy during re-entry while charring, to form a protective coating to block heat penetration. This led to the development of other applications of the heat shield, such as fire-retardant paints and foams for aircraft.
- **Memory foam mattresses**

Risks of Space Exploration

Risks of Manned Space Exploration

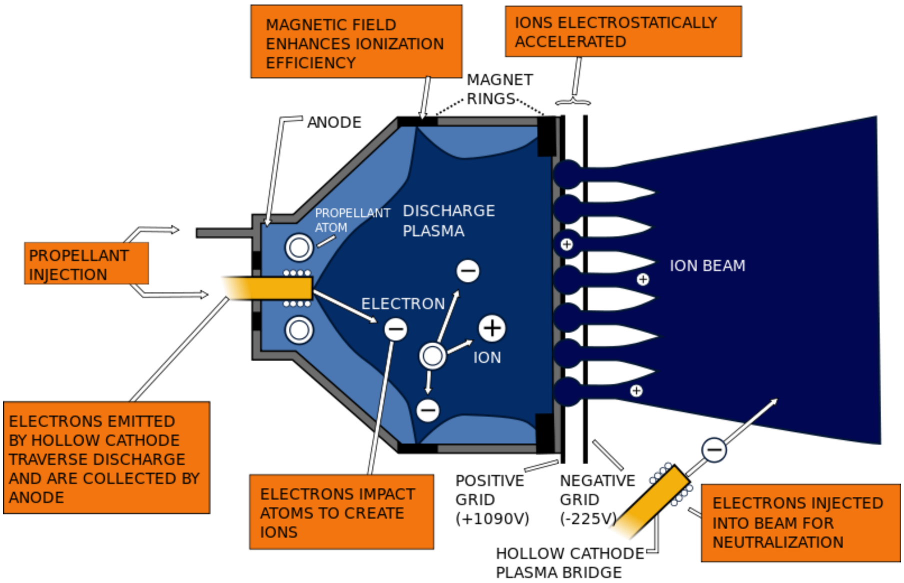
When a space craft returns from space it re-enters the Earth's atmosphere.
There are many challenges associated with re-entry and two are listed below:

- **Rise in temperature due to friction**
  The craft is travelling at around 8000ms^{-1} so a large frictional force acts on it due to the air in the atmosphere. The frictional force causes a rise in temperature which is a problem for the craft. The space craft uses special silica tiles to protect it and the bottom and leading edge are covered with black reinforced carbon.
  In other words, they have a high specific heat capacity.
  The peak skin temperature, on the underside of the wings close to the leading edges, is around 1600°C.

- **The angle of re-entry**
  If the angle of approach is too steep, frictional heating will be too fast and burn the spacecraft up. If the angle of approach is too shallow the spacecraft will skip off the atmosphere into a highly elliptical orbit which will take it far from the Earth (think about skipping a stone across a pond). There is thus an optimum angle for re-entry.
- **Huge mass of fuel on take-off presents risk of explosion.**
- **Exposure to dangerous radiations whilst in space.**
- **Pressure differences and breathing apparatus requirements.**

Challenges with Space Exploration in General

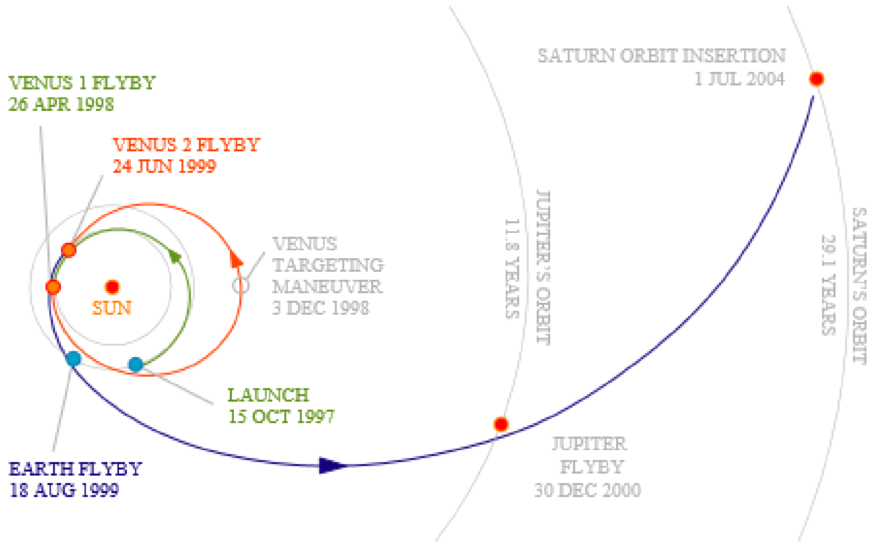
Travelling very large distances in space is very challenging. One solution is using Ion Drive, which creates thrust by interaction of ions rather than combustion of rocket fuel. Ion drive produces a small unbalanced force over an extended period of time.



Risks of Space Exploration

Challenges with Space Exploration

In order to travel beyond Venus & Jupiter in our solar system, we can use a 'catapult' from a fast moving asteroid, moon or planet. This is sometimes called **'gravity assist'** or the **'slingshot effect'**. By manoeuvring close to a celestial body (e.g. sun, moon, asteroid) we can use its gravitational field strength to supply a space craft with additional kinetic energy and accelerate it to a higher speed.



Manoeuvring a spacecraft in a zero friction environment can be challenging. An example is trying to 'dock' with the International Space Station. When a spacecraft fires a rocket to dock with the ISS, it is very difficult to stop once moving in a zero friction environment.

Maintaining sufficient energy to operate life support systems in a spacecraft is also challenging. It is possible to use solar cells with areas that vary with distance from sun.