Gleniffer High School

S3 Physics

Dynamics and Space

Summary Notes

Name: ______________________________

Mr Downie 2021

DYNAMICS

VECTORS and SCALARS

Physical quantities can be divided into two groups:

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

Distance is a **scalar** quantity. Distance is the total path length. It is fully described by magnitude (size) alone,
Displacement is a **vector** quantity. Displacement is the direct length from the starting point to the finishing point. To fully describe displacement both magnitude and direction must be given.

Speed is another example of a **scalar** quantity. **Velocity** is another example of a **vector** quantity. Speed and velocity are described by the equations below.

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

$$\text{velocity} = \frac{\text{displacement}}{\text{time}}$$

The direction of the velocity will be the same as the direction of the displacement.

A summary table of common scalars and vectors is shown below.

Vectors	Scalars
Displacement	Distance
Velocity	Speed
Acceleration	Time
Force	Mass
Impulse	Energy

AVERAGE SPEED

The **average speed** of a moving object can be found by measuring the **distance** it travels and the **time** it takes to travel that distance. Average speeds are usually measured over large distances or long times. **Metre-sticks** or **trundle wheels** would normally be used to measure the distance in an average speed experiment. The time would normally be measured using a handheld **stopwatch**.

The following equation is used to calculate average speed: -

average speed = distance / time

where,

average speed is measured in metres per second (ms^{-1})
distance is measured in metres (m)
time is measured in seconds (s)

Example
A marble takes 4 seconds to travel 50 cm across a desk. Calculate the average speed of the marble.

average speed = ?   distance = 50 cm = 0.5 m   time = 4.0 s

average speed = distance / time
average speed = 0.5 / 4.0
average speed = 0.125 ms^{-1}

When much larger distances or longer times are used it is often necessary to use a different set of units for average speed calculations. These are shown below: -

Average speed is measured in kilometres per hour (kmh^{-1})
Distance is measured in kilometres (km)
Time is measured in hours (h)

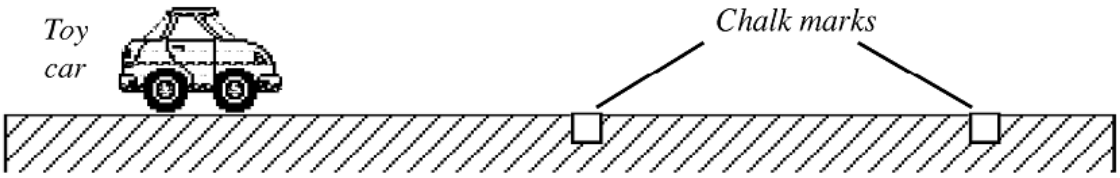
Example
A cyclist travels 7000 m in 30 minutes. Calculate the cyclist's average speed.

average speed = ?   distance = 7000 m = 7 km   time = 30 minutes = 0.5 h

average speed = distance / time
average speed = 7.0 / 0.5
average speed = 14 kmh^{-1}

Average Speed - Experiment

To measure the average speed of a toy car rolling across the floor of the laboratory carry out the following experiment.



Using a metre stick measure the distance between the chalk marks.
Using a stopwatch measure the time from when the toy car crosses the first chalk until it passes the second chalk mark.

The data can then be enetered into the following equation and the average speed can be calculated.

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

Where,

$\bar{v}$ represents the average speed (speed can also be represented with"v")
d represents the distance travelled
t represents the time taken

<u>Example</u>

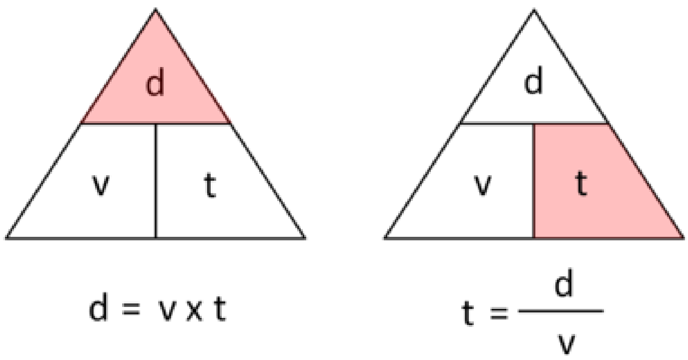
A hill walker has an average walking speed of 3.5 kmh^{-1}. Calculate their distance travelled if they walk for 2 hours.

$d = \bar{v}t$

d = 3.5 x 2

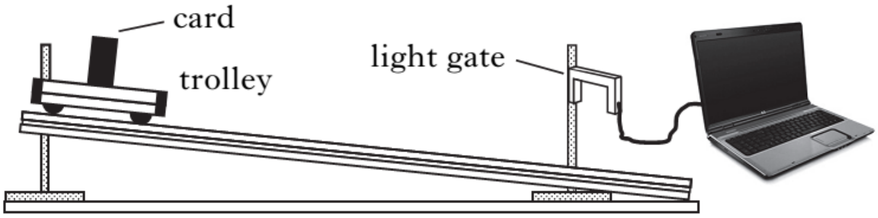
d = 7 km

The speed, disatance, time equation can also be represented as a triangle.



Instantaneous Speed

To measure the instantaneous speed of a trolley rolling down a slope carry out the following experiment.



Use a ruler to measure the length of the card.
Note the time on the timing app on the PC. This is the time for which the beam of light in the light gate is cut by the card.

The data can then be entered into the following equation and the instanteous speed can be calculated.

$$\text{Speed of vehicle} = \frac{\text{length of card or vehicle}}{\text{time to cut beam}}$$

In this equation the' speed of vehicle' represents an instantaneous speed because the time interval is so small.

<u>Example</u>

A trolley is fitted with a card 0.10 m in length. The trolley is set in motion and the card cuts a light gate. The time on the timer is 0.025 seconds. Calculate the speed of the trolley when it passes the light gate.

Instantaneous speed = length of card / time on timer

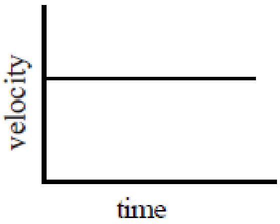
Instantaneous speed = 0.10 / 0.025

Instantaneous speed = 4 ms^{-1}

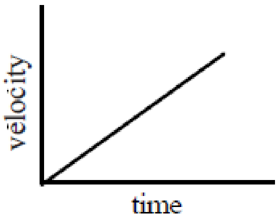
SPEED-TIME GRAPHS

A speed-time graph is a useful way to describe the movement of an object. The shape of the graph shows whether the object is…

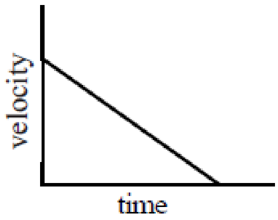
- accelerating/speeding up
- decelerating/slowing down
- moving with a constant (steady) speed



Constant speed



Accelerating/speeding up

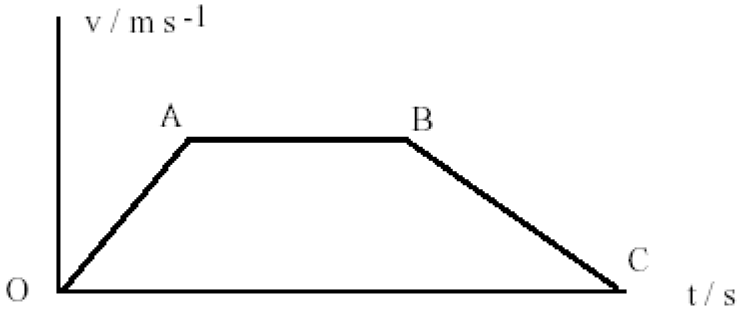


Decelerating/slowing down

The **distance travelled** by an object can be calculated from the **area under** a speed-time graph.

Example

An object starts from rest and reaches a speed of 4 ms^{-1} after 2 s. It continues at 4 ms^{-1} for a further 4 s, before decelerating to rest after another 4 s. Calculate the object's distance travelled from its starting point.



Distance travelled = Area under graph (Split the graph into two triangles and one rectangle)

Distance travelled = area under OA + area under AB + area under BC

Distance travelled = (½ x b x h) + (l x b) + (½ x b x h)

Distance travelled = (0.5 x 2 x 4) + (4 x 4) + (0.5 x 4 x 4)

Distance travelled = (4) + (16) + (8)

Distance travelled = 28 m

ACCELERATION

Most objects do not travel at the same speed all the time. If they speed up, they are said to accelerate. If they slow down, they decelerate.
Acceleration is the Physics quantity used to describe **the rate of change of speed**. An object with an acceleration of 3 ms^{-2}, will be increasing its speed by 3 ms^{-1} every second.

Acceleration Calculations

Acceleration can be calculated using the following equation: -

acceleration = change in speed / time taken for change

This equation can also be written as shown below: -

$$a = \frac{\Delta v}{t}$$

This equation shows that the unit for acceleration will be the unit of speed (ms^{-1}) divided by the unit for time (s). **This means the unit for acceleration is written as ms^{-2}**. This unit is a short way of writing metres per second per second.

Example

A car accelerates from rest to a speed of 8 ms^{-1}. If this takes 3.2 seconds, what is the acceleration of the car?

acceleration = ? change in speed = 8 – 0 = 8 ms^{-1} time = 3.2 s

acceleration = change in speed / time taken for change
acceleration = 8 / 3.2
acceleration = 2.5 ms^{-2}

The equation for acceleration can also be written as: -

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

where,
a is the acceleration in ms^{-2}
v is the final speed in ms^{-1}
u is the initial speed in ms^{-1}
t is the time taken for the speed to change in s

Example One

A car is moving at 15 ms^{-1}, before it accelerates to 23 ms^{-1}. Calculate the acceleration of the car if the change in speed takes 4 s.

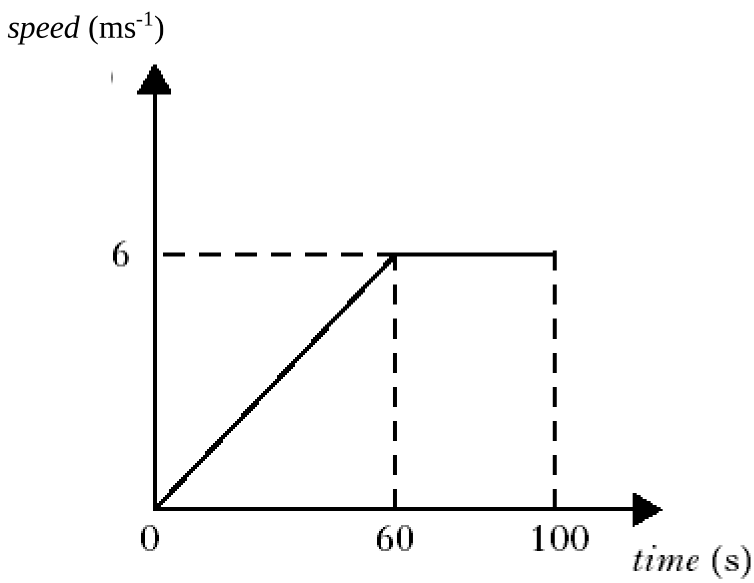
a = ?
v = 23 ms^{-1}
u = 15 ms^{-1}
t = 4 s

a = (v – u) / t
a = (23 – 15) / 4
a = (8) / 4
a = 2 ms^{-2}

Note
In examples where the final speed is smaller than the initial speed, the value for the acceleration will be a negative. A negative acceleration is called a deceleration.

Example Two

Calculate the acceleration for the motion graph shown below.



a = ?
v = 6 ms^{-1}
u = 0 ms^{-1}
t = 60 s

a = (v – u) / t
a = (6 – 0) / 60
a = (6) / 60
a = 0.1 ms^{-2}

Another useful way to display the acceleration equation is

$$v = u + at$$

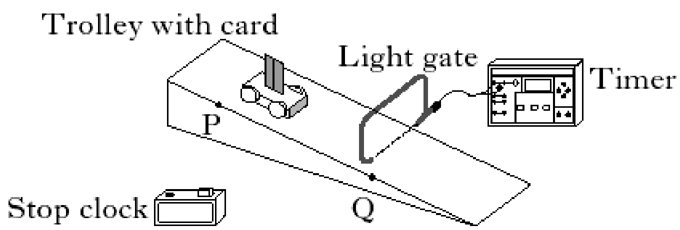
Example

A car is moving at 12 ms^{-1}, when it starts to accelerate at 1.5 ms^{-2}. Calculate the final speed of the car if it accelerates at this rate for 4 s.

v = ?
u = 12 ms^{-1}
a = 1.5 ms^{-2}
t = 4 s

v = u + at
v = 12 + (1.5 x 4)
v = 18 ms^{-1}

There are several experimental methods that can be used to measure the acceleration of a moving object.



In the experiment shown above the length of the card would be measured before the trolley was released from point, P.
At the same time as the trolley is released from rest the stop clock would be started. The stop clock would be stopped when the trolley reaches point, Q.
At point, Q, the card breaks the beam of light in the light gate and the timer records how long the beam is broken.
When the experimental data has been collected it can be used in the following equation to calculate the acceleration.

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

v is calculated by dividing the length of the card by the time shown on the timer
u is zero as the trolley started from rest
t is the time taken to travel from P to Q shown on the stop clock
a can now be calculated by inserting the data into the equation.

NEWTON'S LAWS

Forces

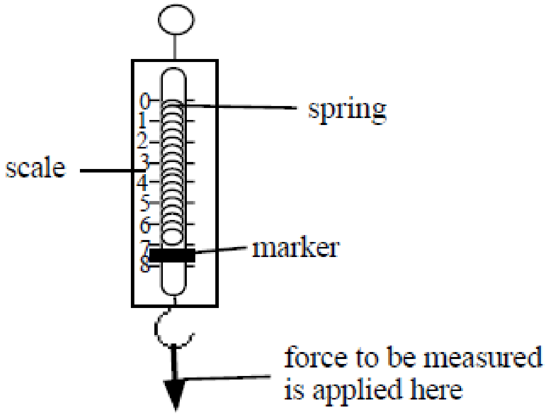
Effect of forces
Forces can only be detected by their effects.

They can change:
• the shape of an object (stretch it, squeeze it etc)
• the speed of an object
• the direction of movement of an object

Measurement of Forces

Forces are measured in units called **Newtons (N).**

Forces can be measured with a **Newton balance**. This instrument depends on the effect of a force on the shape (length) of a spring.



A Newton balance has a spring inside. 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.

In this unit the names of some of the common forces covered are:

- Weight
- Friction
- Engine force
- Air resistance

Friction

Friction causes a force that opposes the motion of a body. The force of friction can stop a moving object or slow it down. The force of friction can also keep objects from starting to move. Friction is caused by the contact of two surfaces. If objects do not slide across each other easily, the force of friction between the surfaces of two objects is high. If objects slide easily, the force of friction is low.

High Friction Low Friction

High friction – it is difficult to slide the bristles of two brushes across each other.

Low friction – it is not difficult to slide the back of two brushes across each other.

Changing Friction

The force of friction can be increased by making the surfaces rougher or by pressing the surfaces harder together e.g. the brakes on a bicycle.

The force of friction can be reduced by making the surfaces smoother or lifting the surfaces away from each other. Lubrication, for example, uses oil which lifts two surfaces apart and reduces the force of friction. Air can also be used to lift surfaces apart, e.g. a hovercraft or air hockey.

Changing Friction – Streamlining

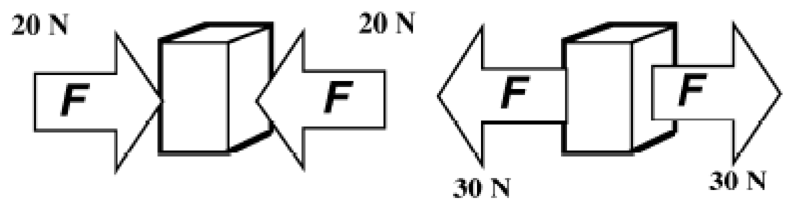
When an object moves through the air, the air ribs against the object causing friction. This air friction is called air resistance. Streamlining is when you change the shape of an object to reduce the air resistance.

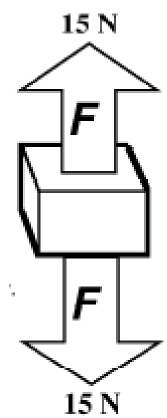
The shape of a vehicle can be made more curved, ideally like a teardrop or an aeroplane wing, to reduce air resistance. Sometimes a spoiler can be fitted to the back of a vehicle to make it more streamlined. Another way to reduce air resistance is to make the vehicle closer to the ground.

Newton’s First Law of Motion

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

Examples of Balanced Forces



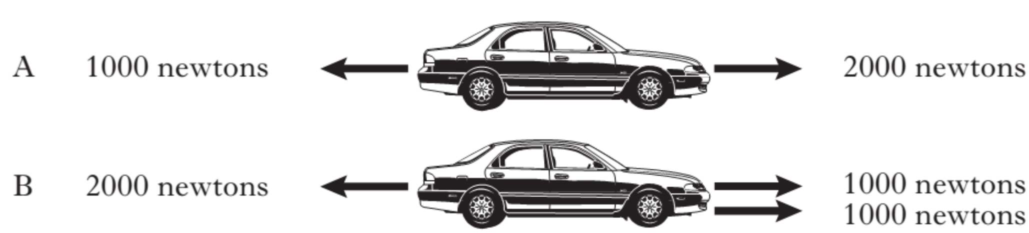


Newton’s first law of motion can be written as,

“When forces on an object are balanced it will remain stationary or move with a constant velocity.”

Example

Which car, A or B, will be moving to the right with a constant speed?



Solution

Car B – it has balanced forces (2000 N to the right and 2000 N to the left) acting on it.

Newton's Second Law of Motion

This law deals with situations when there is an unbalanced force acting on an object.

In this situation the speed (velocity) of the car cannot remain constant. This will result in the car having an acceleration.
As the unbalanced force is increased, assuming mass remains constant, the acceleration of the car will increase.
If the mass of the car if increased, assuming the unbalanced force remains constant, the acceleration will decrease.

These statements can be summarized in the following equation which is a statement of Newton's Second Law of Motion.

Unbalanced force = mass x acceleration

F = m x a

where,

F is the unbalanced force measured in Newtons(N)
m is the mass measured in kilograms(kg)
a is the acceleration measured in metres per second per second(ms^{-2})

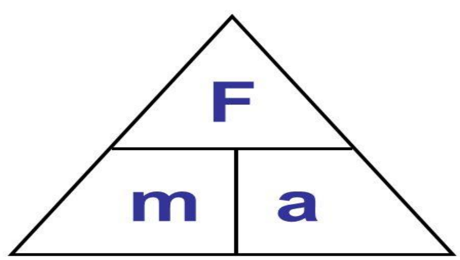
This equation also allows the Newton to be defined as the force which makes a 1 kg mass accelerate at 1 ms^{-2}.

also:

$$\text{acceleration} = \frac{\text{force}}{\text{mass}}$$

and:

$$\text{mass} = \frac{\text{force}}{\text{acceleration}}$$



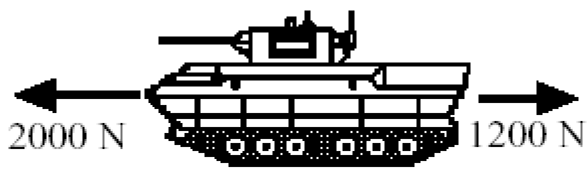
Example One

A car of mass 1000 kg has an unbalanced force of 1600 N acting on it. Calculate the acceleration of the car.

F = 1600 N	F = m x a
m = 1000 kg	1600 = 1000 x a
a = ?	a = 1600 / 1000
	a = 1.6 ms^{-2}

Example Two

Calculate the mass of the vehicle shown, if the engine force is 2000 N and the force of friction is 1200 N. The acceleration of the vehicle is 0.04 ms^{-2}.



This is a typical assessment calculation question that would be worth 4 marks. This should tell you that the solution needs a calculation and an extra step.

In this example the extra step needs you to find the unbalanced force before you attempt the calculation.

Solution

$F = F_{engine} - F_{friction}$	F = m x a
F = 2000 – 1200	800 = m x 0.04
F = 800 N	m = 800 / 0.04
a = 0.04 ms^{-2}	m = 20,000 kg
m = ?	

Example Three
The forces acting on a parachutist at a point during their jump are shown below. If the mass of the parachutist is 50 kg, calculate their acceleration.

This is a typical assessment calculation question that would be worth 4 marks. This should tell you that the solution needs a calculation and an extra step.

In this example the extra step needs you to find the unbalanced force before you attempt the calculation.

Solution
$F = F_{downward} – F_{upward}$
F = 700 – 600
F = 100 N
m = 50 kg
a = ?

F = m x a
100 = 50 x a
a = 100 / 50
a = 2 ms^{-2}

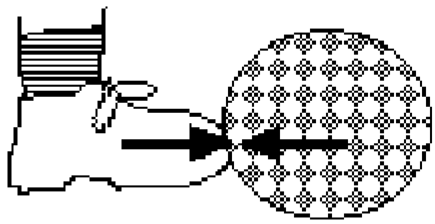
Newton's Third Law of Motion

Newton's Third Law of Motion can be written as,

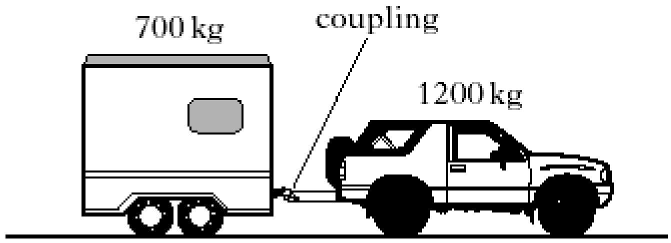
"For every action force there is an equal and opposite reaction force."

This means that forces will occur in **Newton Pairs**. Some examples are shown below.

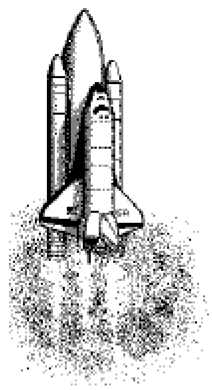
When the player strikes the ball, his foot exerts a force to the right on the ball. At the same time, the ball exerts a force to the left on the player's foot.



When the car exerts a force on the coupling, the coupling exerts a force on the car in the opposite direction.



At take-off for a space shuttle, when the launch rocket pushes the gases backwards, the gases push the launch rocket forwards.



WEIGHT

Mass measures how much matter there is in an object. Mass is measured in **kilograms**. The mass of an object stays the same at all places.

Weight is a force. The weight of an object always acts downwards. Weight is measured in **Newtons**. The weight of an object can change.

Weight to mass ratio is usually called gravity. Gravity is the shortened version of gravitational field strength. **Gravity is measured in Newtons per kilogram (Nkg^{-1})**. Gravity can vary but is quoted as 9.8 Newtons per kilogram (9.8 Nkg^{-1}) on planet Earth.

Weight = mass x gravity
W = m x g

where,

W is weight measured in Newtons (N)
m is mass measured in kilograms (kg)
g is measured in Newtons per kilogram (Nkg^{-1})

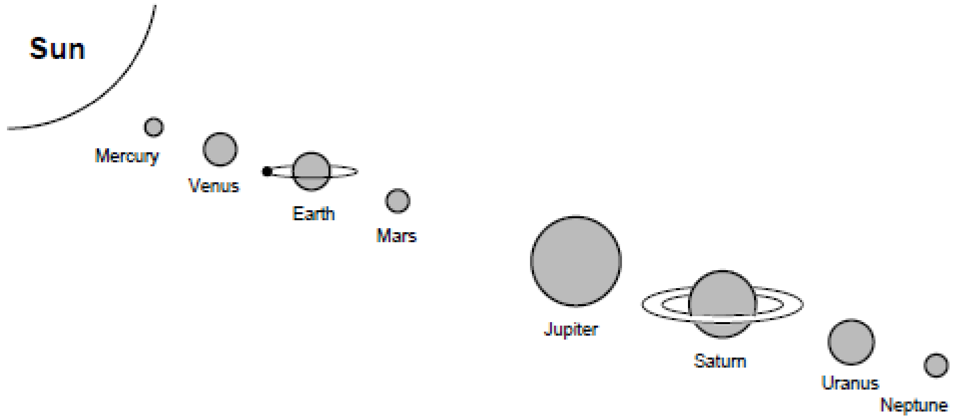
Example
A pupil has a mass of 60 kg. Calculate their weight on planet Earth.

W = ?
m = 60 kg
g = 9.8 Nkg^{-1}

W = m x g
W = 60 x 9.8
W = 588 N

This means an object's weight, which depends on gravity, will depend on where it is in our solar system. The table below shows how gravity can vary in our solar system.

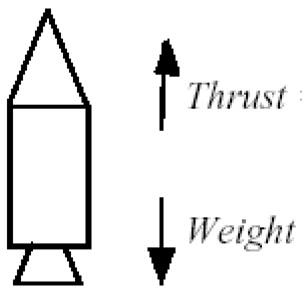
Celestial Body	g value at surface of Celestial Body (Nkg^{-1})
Moon	1.6
Venus	8.8
Mars	3.7
Sun	274



Example

A space probe, mass 800 kg, takes off on its return flight from Venus by using a thrust (upward force) of 20,000 N. Calculate the following:

a) weight of probe when leaving Venus
b) mass of probe when it lands on planet Earth
c) weight of probe when it lands on planet Earth



a)
W = m x g
W = 800 x 8.8
W = 7040 N

b) 800 kg (mass does not change – assuming no parts fall off the probe!)

c)
W = m x g
W = 800 x 9.8
W = 7840 N

SATELLITES

Although Newton's theory (from 1666) on satellite motion was correct, the technology to put an artificial satellite into orbit outside Earth's atmosphere did not exist until the late 1950s.

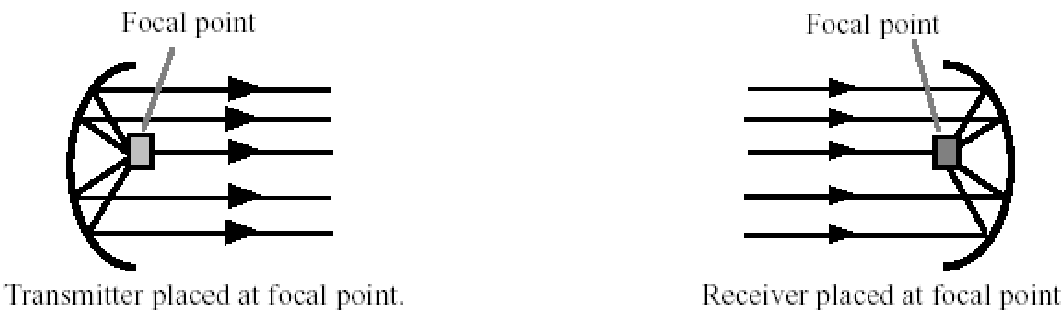
When satellites are launched into space they are used for specific jobs. Communications and weather satellites are amongst the most common uses of approximately 1000 satellites that are orbiting the Earth. Communication satellites are an example of **geo-stationary satellites**. This means they remain above a fixed point on the Earth's surface giving them an orbital period of **24 hours**. Most communication satellites are located **36000 km** above their fixed point on the earth's surface.

Each satellite will carry its own set of instruments which might detect long wavelength radio waves, microwaves, infra-red, visible light, UV, X-rays or high energy gamma rays. Every satellite does have some items in common with every other satellite.

Item	Use
Aerials and Receivers	To send and receive signals (usually radio waves or microwaves) from the Earth or other satellites.
Solar Panels	To convert energy from the Sun into electricity.
Batteries	To store electrical energy that is generated by the solar panels.
On-board Processors	To allow the satellite to interpret the signals received.
Rocket Motors	To alter the satellite position in space.
Fuel Tanks	To store fuel for the rocket motors.

Satellites are controlled from ground stations. The ground stations use large dish aerials to send and receive signals from satellites.

To send signals a dish aerial would have a transmitter placed at its focal point. To receive signals an aerial would be placed at the focal point.



A benefit to society from the use of satellite technology has been the thousands of lives saved as a result of information from weather satellites. These low orbiting satellites provide data on tropical storms as well as monitoring the progress of other phenomena such as volcanic eruptions and forest fires.

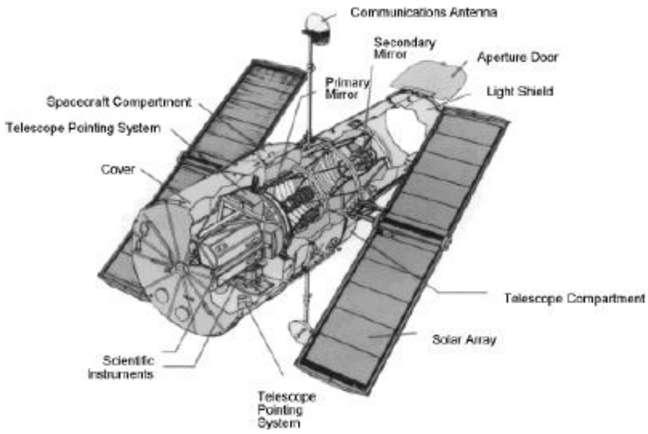
Global Positioning System (GPS) is another satellite based technology that is now in common use. This US government owned system uses 24 satellites to give complete worldwide coverage. Each GPS satellite continually broadcasts a navigation message consisting of two parts:

1. the satellite's trajectory (its path in space)
2. the exact time of the broadcast

Combining these two pieces of information reveals the location of the satellite in space. A GPS receiver on Earth listens to these messages, usually from 3 or 4 satellites, and calculates the receiver's position on Earth.

SPACE EXPLORATION

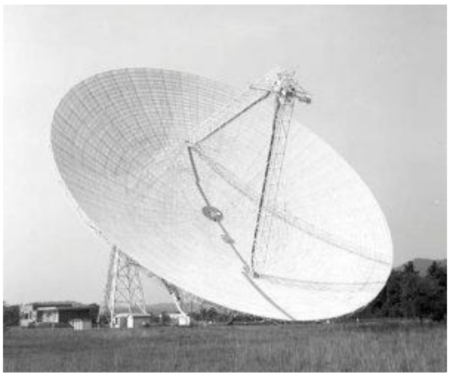
Astronomers have been studying space almost from the dawn of civilisation. The human eye provided the first observations and by the 17^{th} century simple optical telescopes were widely used by those who studied the sky at night. Nowadays telescopes are much more complicated. The world's largest reflecting telescope – the Hubble Space Telescope - can provide data on distant galaxies.



The Hubble Space Telescope (HST) is a reflecting telescope and is currently the largest space telescope there is. It is 43 feet long (13.1 meters) and weighs 24,250 pounds (11,000kg). Its reflector is 94.8 inches in diameter (240cm). The Hubble Space Telescope was launched into space on April 24, 1990, from the Space Shuttle Discovery. It is still operational. It has had some work performed on it from time to time, such as installing new state-of-the-art cameras. This wonderful telescope has brought a wealth of information to researchers here on Earth. It has taken numerous spectacular pictures of faraway galaxies, nebulae, a green space blob, beautiful dying stars (one that looks like a butterfly), and amazing infrared and ultraviolet pictures that show an incredible amount of detail. These pictures have allowed researchers to greatly expand our knowledge of the universe.

The HST is not the only telescope used by astronomers to explore space…

Radio
Radio telescopes detect noise from radio wavelengths in space. It turns out that objects in space give off radio noise. These telescopes are able to listen to all this noise and process it into information for researchers to study. A radio telescope can produce a picture from an object it is listening to from the noise is picks up from that object.



X-Ray
X-ray telescopes are used to study mainly the Sun, stars and supernovas. X-ray telescopes work better at very high altitudes on the Earth's surface, like on top of a very tall mountain where the atmosphere is thinner. They work even better in space. This is because the Earth's atmosphere interferes with the x-ray signals they receive.

Gamma Ray
Gamma ray telescopes are best used at high altitudes like the x-ray telescopes. This is also because gamma ray signals are disrupted and become weaker when they enter the Earth's atmosphere. Gamma ray telescopes detect bursts of gamma rays. They help astronomers confirm events in outer space like supernovas, pulsars and black holes.

Optical Telescopes
An optical telescope gathers and focuses light mainly from the visible part of the electromagnetic spectrum in order to directly view a magnified image for producing a photograph or collecting data via electronic image sensors.
The light gathering power of a telescope and its ability to resolve minute detail is directly related to the diameter of the objective lens. The larger the objective lens then a brighter image is obtained and it can resolve finer detail.

Our knowledge of space is growing thanks to our use of satellites, telescopes and space probes which orbit or land on other objects in our Solar System.

The most recent data that has been received from space exploration supports a theory proposed by a Belgian, George Lemaitre, in the early 1900s. He proposed that the Universe was expanding. This theory was built on by Edwin Hubble who discovered that distant galaxies were moving away from us more quickly than those closer to us. Hubble's research has also allowed us to work out that the Universe is approximately 13.8 billion years old

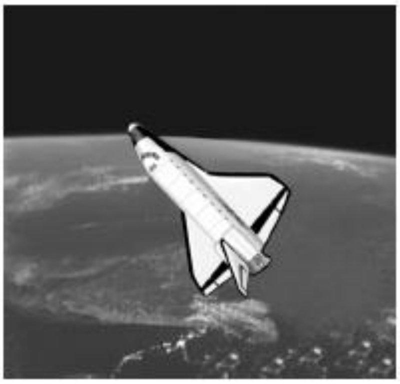
Lemaitre and Hubble's work could be explained if the origin of the Universe came from an explosion that blasted matter in all directions. This is the basis of the Big Bang theory. However, there are many ideas that are still being explored by astro-physicists including the existence of dark matter and exoplanets that could sustain life.

Space Travel
There are many challenges to overcome to achieve space travel including**:**

- travelling large distances with the possible solution of attaining high velocity by using ion drive (producing a small unbalanced force over an extended period of time
- travelling large distances using a ‘catapult’ from a fast moving asteroid, moon or planet
- manoeuvring a spacecraft in a zero friction environment, possibly to dock with the ISS
- maintaining sufficient energy to operate life support systems in a spacecraft, with the possible solution of using solar cells with area that varies with distance from the Sun

When objects that have been exploring space return to our atmosphere they will encounter air resistance (friction). This will cause the object to slow down and in some cases “burn up” in the atmosphere.

This happens because moving objects have kinetic energy and when they are slowed down the kinetic energy has to be changed into some other form of energy. In this case the other energy is heat, and due to the air resistance there can be so much heat that the object will disintegrate in the Earth’s atmosphere. This is a major problem for manned space missions!



For manned space missions it is necessary to cover the front and underside of the space craft with special tiles which have a high melting point. This will allow the tiles to withstand the high temperatures generated during re-entry. The tiles reflect and absorb the heat energy, providing a heat-shield which protects the occupants inside the space craft. Other risks associated with manned space flight include:

- fuel load on take-off
- potential exposure to radiation
- pressure differential

COSMOLOGY

Measurements in Space

The distance from the Sun to the Earth is approx. 150,000,000 km.

Astronomers call the distance from the Sun to the Earth one astronomical unit.

So,
1 au = 150,000,000 km
3 au = 3 x 150,000,000 = 450,000,000 km
6 au = 6 x 150,000,000 = 900,000,000 km

The astronomical unit is useful when dealing with distances in our Solar System but another unit is needed when measuring distances throughout the rest of the Universe.

A light year is a distance unit. A light year is the distance light travels in one year and can be calculated as shown…

distance = speed x time
distance = (speed of light) x (number of seconds in a year)
distance = $(3 \times 10^8) \times (365 \times 24 \times 60 \times 60)$
distance = 9.46×10^{15} m

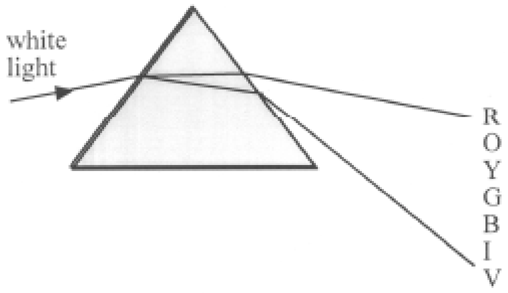
In other words, one light year = 9.46×10^{15} m

Example
The star Proxima Centauri is 4.3 light years from planet Earth. Calculate the distance to Proxima Centauri in metres.

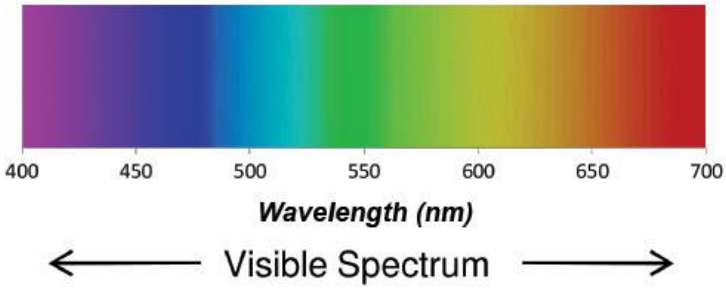
Solution
one light year = 9.46×10^{15} m
4.3 light years = $4.3 \times 9.46 \times 10^{15}$
= 4.1×10^{16} m
The distance to Proxima Centauri is 4.1×10^{16} m.

Spectroscopy
A useful technique used in the study of space is spectroscopy. Spectroscopy involves the measurement of frequencies of **light** that are emitted, absorbed or scattered by materials. These measurements can be used to identify the materials.

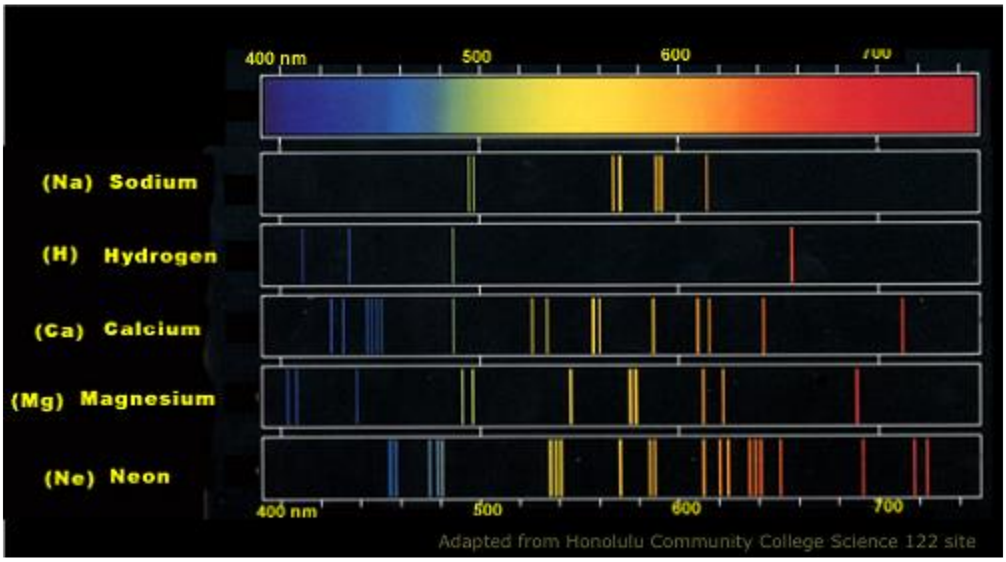
In you separate white light into its component parts you get a **continuous** visible spectrum, all frequencies of visible light are present. This can be done using a triangular prism as shown in the next diagram.



The continuous spectrum is normally displayed from the "blue" end to the "red" end as shown below where "n" is the prefix for nano or x10^{-9}



Each element in the periodic table has a unique **line emission** spectrum.

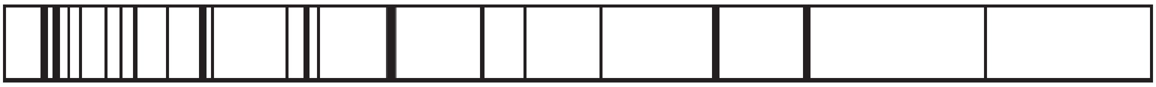


As each element has a unique set of lines in its spectrum, astronomers can collect light from a star and identify which elements are present in the star.

They identify the elements by matching the lines from the known spectrum to the lines in the star.

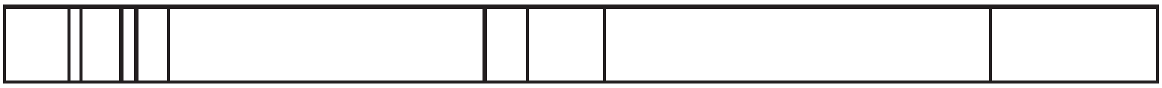
Example

The line spectrum form a distant star is shown below.

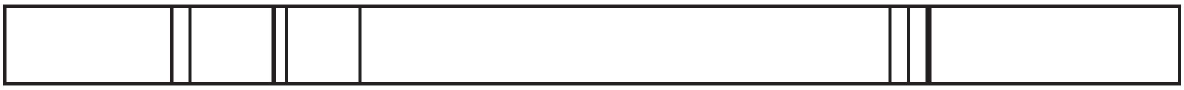


By studying the line spectra shown below, identify which of these elements are present in the distant star.

Cadmium

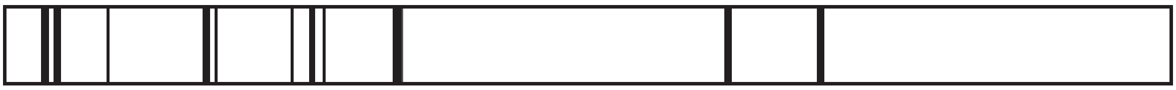


Calcium



Krypton

Mercury



Answer

Cadmium and Mercury

(All the lines for each element can be found in the spectrum of the star.)

Space Exploration Glossary

Star – a massive ball of gas that emits light through the release of energy produced by nuclear reactions at its core

Sun – the star at the centre of our Solar System

Planet – an object that orbits a star

Dwarf planet – a small object orbiting a star that has enough gravity to form an almost round shape

Asteroid – a small rocky object that orbits the Sun

Solar System – a star and all the planets that orbit it

Moon – a natural satellite of a planet

Satellite – an object that orbits a planet

Galaxy – a collection of stars

Universe – the whole of space

Exo-planet – a planet outside our Solar System

Black Hole – an area of space from which no light can escape

Cosmology Glossary

Astronomical unit – the standard unit for measuring distance within our Solar System

Light Year – the distance light travels in a year

Big Bang – a possible theory to explain the beginning of the Universe which states that the Universe began from a singularity (single point) and is continually expanding

Spectroscopy – a scientific measuring technique used on light

Continuous spectrum – an unbroken band of coloured light from violet to red

Line spectrum – a spectrum that consists of discrete coloured lines

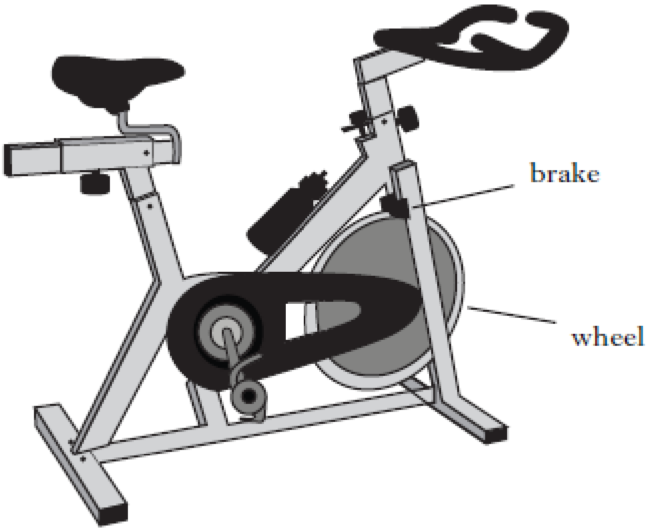
Absorption spectrum – a continuous spectrum that has dark lines due to the absorption of certain frequencies of light

ENERGY

Principle of Conservation of Energy

Energy cannot be created or destroyed, but it can be changed from one type into another type. All forms of energy are measured in the same unit –the **Joule (J)**.

Machines can be used to change one type of energy into another type of energy. For example, an electrical motor will change electrical energy into kinetic energy. However, not all the electrical energy that is supplied to the motor will be changed into the final useful form of energy. Some electrical energy will be changed into heat energy due to friction and some electrical energy will be changed into sound energy. This makes the machine inefficient.
In this machine there will be friction between the wheel and the brake.



Efficiency is measured by expressing the useful energy output as a percentage of the total energy input.

Formula for efficiency

$$\% \text{ Efficiency} = \frac{\text{useful energy output}}{\text{total energy input}} \times \frac{100}{1}$$

Power is the rate of energy transfer. This means the above equation can also be applied to power rather than energy.

Work done or Energy transferred

The work done is a measure of the energy transferred. It is equal to the force multiplied by the distance the force moves. The force and distance must be measured in the same direction. Work done is measured in the same units as energy: joules. The symbol for work is E_w.

The equation for calculating work done (or energy transferred) is…

$$E_w = F \times d$$

where,
E_w is the work done (or energy transferred) measured in Joules (J)
F is the force measured in Newtons (N)
d is the distance in metres (m)

Example One
A dog pulls a 4 kg sledge for a distance of 15 m using a force of 30 N.
Calculate the work done by the dog when pulling the sledge.

F = 30 N	$E_w = F \times d$
d = 15 m	$E_w = 30 \times 15$
E_w = ?	E_w = 450 J

Example Two
A book is pushed 60 cm across a desk, by a force of 50 N.
Calculate the energy transferred to the book.

F = 50 N	$E_w = F \times d$
d = 60 cm = 0.6 m	$E_w = 50 \times 0.6$
E_w = ?	E_w = 30 J

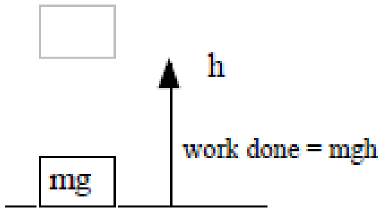
Example Three
During braking a van loses 21 000 J of energy. The brakes supply a force 1200 N.
Calculate the distance the van moves during braking.

F = 1200 N	$E_w = F \times d$
d = ?	$21\,000 = 1200 \times d$
E_w = 21 000	d = 17.5 m

Gravitational Potential Energy

An object which is raised up to a high position is said to have gravitational potential energy. The work done against gravity to raise it equals the energy transferred into potential energy.

Imagine a mass of m kg lifted through a height of h metres.



The **force, F,** needed to lift the mass has to be equal to the weight of the mass… W = **m x g**

The vertical distance moved by the mass is its height. This means **"d" = "h"**

The work done equation, $E_w = F \times d$, can be rewritten as…$E_w = m \times g \times h$…OR…

$$E_p = mgh$$

where,
E_p is gravitational potential energy measured in Joules (J)
m is mass measured in kilograms (kg)
g is gravitational field strength, which has a value of 9.8 Nkg^{-1} on planet Earth
h is the height measured in metres (m)

<u>Example One</u>
A student lifts a 0.35 kg textbook, 0.9 m from the floor to her desk.
Calculate the gravitational potential energy gained by the textbook.

E_p = ?
m = 0.35 kg
g = 9.8 Nkg^{-1}
h = 0.9 m

E_p =mgh
E_p = 0.35 x 9.8 x 0.9
E_p = 3.087
E_p = 3.1 J

<u>Example Two</u>
A ball drops 7.2 m on to the ground, losing 141 J of gravitational potential energy.
Calculate the mass of the ball.

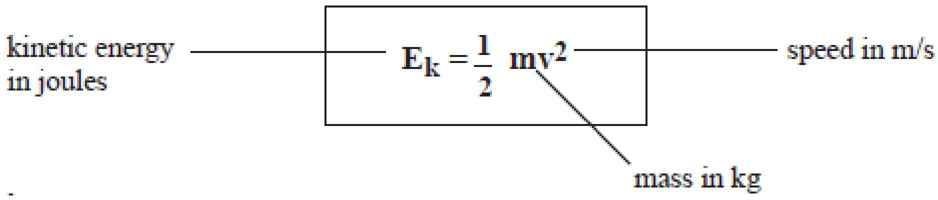
E_p = 141 J
m = ?
g = 9.8 Nkg^{-1}
h = 7.2 m

E_p =mgh
141 = m x 9.8 x 7.2
m = 141 / (9.8 x 7.2)
m = 2.0 kg

Kinetic Energy

Kinetic energy is the energy associated with a moving object. It is measured in joules and has the symbol E_k.
The kinetic energy of a moving object depends on the mass of the object and its speed.
The greater the mass the greater the kinetic energy.
The greater the speed the greater the kinetic energy.
So a large, fast moving object will have a lot of kinetic energy.

The equation for calculating kinetic energy is:



Notes
The unit of kinetic energy is the **Joule** which is normally written as a **J.**
The unit for speed is **metres per second** which is normally written as **ms^{-1}**.

Example One

A pupil, mass 55 kg, is running at 2.5 ms^{-1}. Calculate the pupil's kinetic energy.

E_k = ?
m = 55 kg
v = 2.5 ms^{-1}

$E_k = ½ \times m \times v^2$
$E_k = ½ \times 55 \times (2.5)^2$
E_k = 172 J

Example Two

A car of mass 1200 kg has 29 400 J of kinetic energy. Calculate the speed of the car.

E_k = 29 400 J
m = 1200 kg
v = ?

$E_k = ½ \times m \times v^2$
$29\,400 = ½ \times 1200 \times (v)^2$
$29\,400 = 600 \times (v)^2$
$(v)^2 = 29\,400 / 600$
$(v)^2 = 49$
$v = \sqrt{49}$
v = 7.0 ms^{-1}

$E_p = mgh$

$E_k = \frac{1}{2}mv^2$

$Q = It$

$V = IR$

$R_T = R_1 + R_2 + \ldots$

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$

$V_2 = \left(\frac{R_2}{R_1 + R_2}\right)V_s$

$\frac{V_1}{V_2} = \frac{R_1}{R_2}$

$P = \frac{E}{t}$

$P = IV$

$P = I^2 R$

$P = \frac{V^2}{R}$

$E_h = cm\Delta T$

$p = \frac{F}{A}$

$\frac{pV}{T} = \text{constant}$

$p_1V_1 = p_2V_2$

$\frac{p_1}{T_1} = \frac{p_2}{T_2}$

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$

$d = vt$

$v = f\lambda$

$T = \frac{1}{f}$

$A = \frac{N}{t}$

$D = \frac{E}{m}$

$H = Dw_R$

$\dot{H} = \frac{H}{t}$

$s = vt$

$d = \bar{v}t$

$s = \bar{v}t$

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

$W = mg$

$F = ma$

$E_w = Fd$

$E_h = ml$