National 5 Physics

Dynamics and Space

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Prefixes and Scientific Notation

Throughout the course, appropriate attention should be given to units, prefixes and scientific notation.

tera	T	10^{12}	x 1,000,000,000,000
giga	G	10^{9}	x 1,000,000,000
mega	M	10^{6}	x 1,000,000
kilo	k	10^{3}	x 1,000
centi	c	10^{-2}	/100
milli	m	10^{-3}	/1,000
micro	µ	10^{-6}	/1,000,000
nano	n	10^{-9}	/1,000,000,000
pico	p	10^{-12}	/1,000,000,000,000

In this section the prefixes you will use most often are centi(c) milli (m), micro (µ), kilo (k), mega (M) and giga (G). It is essential that you use these correctly in calculations.

In Physics, the standard unit for time is the **second (s)** and therefore if time is given in milliseconds (ms) or microseconds (µs) it must be converted to seconds.

Example 1

A car takes 2 ms to pass a point in the road. How many seconds is this?

2 ms = 2 milliseconds = 2 x 10^{-3} s = 2/1 000 = 0.002 seconds.

In Physics, the standard unit for distance is the **metre (m)** and therefore if distance is given in kilometres (km) it must be converted to metres.

Example 2

A car travels 15.6 km in ten minutes. How far in metres has it travelled?

15.6 km = 15.6 kilometres = 15.6 x 10^{3} m = 15.6 x 1 000 = 15 600 metres.

Example 3

An object experiences a force of 15 kN. How many Newton is this?

15 kN = 15 kiloNewtons = 15 x 10^{3} N = 15 x 1000 = 15 000 Newtons

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Contents

1. Velocity and Displacement - Vectors and Scalars

1.1 Vector and scalar quantities: force, speed, velocity, distance, displacement, acceleration, mass, time and energy.

1.2 Calculation of the resultant of two vector quantities in one dimension or at right angles.

1.3 Determination of displacement and/or distance using scale diagram or calculation. Use of appropriate relationships to calculate velocity in one dimension.

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

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

Velocity and displacement – 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**.

The following table lists some of the scalars and vectors quantities that will be encountered in this course.

Scalars	Vectors
Energy	Velocity
Temperature	Weight
Pressure	Acceleration
Time	Displacement
Mass	Momentum
Current	Force
Speed	
Volume	
Voltage	
Distance	
Area	
Resistance	
Frequency	

Vectors

A vector is often drawn with an arrow to indicate its size and direction. The starting point of the arrow is called the "tail" and the arrow end is called the "tip".

Adding Vectors

Example

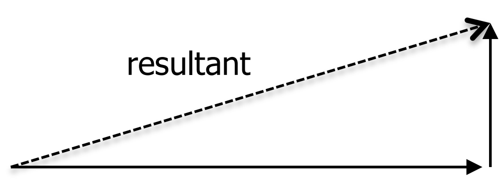
Two forces are applied to a box as shown below

Resultant = 12 – 8 = 4 N to the right

When adding more than one vector they must be added "tip to tail". That means that the tip of the first vector must point at the tail of the next vector.

In some cases that means that the two vectors have to be redrawn so that they are being added "nose/tip to tail". See example below.

Then join a line from the tail of the first vector to the nose/tip of the second vector. This is the **resultant** vector.

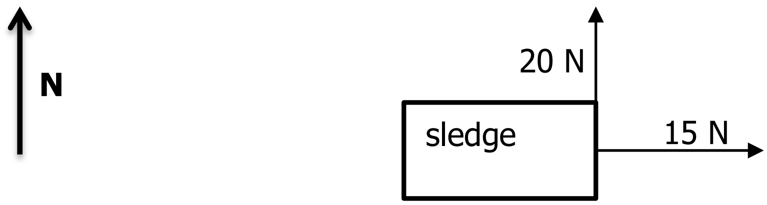


There are two possible methods for finding the size and direction of the resultant of two vectors acting at right angles to each other.

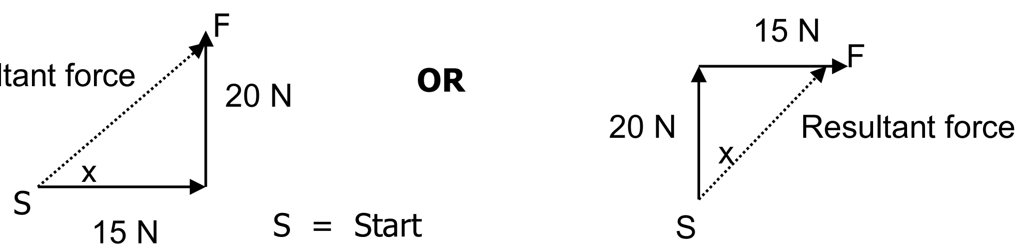
- Draw a scale diagram
- Use Pythagoras and trig functions.

Example 1

If there are two forces pulling a sledge (see diagram below) then calculate the resultant force acting on the sledge.



Step 1
Redraw the diagram with the vectors 'tip to tail'. The first way to do this is below.



S = Start
F = Finish

Step 2
Do the calculation using Pythagoras to find the resultant force.

Resultant = $\sqrt{(15^2 + 20^2)} = \sqrt{(225 + 400)} = 25$ N

Step 3
BUT resultant force must have a direction. This can be found by drawing a scale diagram.

Rules for Drawing A Scale Diagram
1. Select a scale which will allow you to draw a diagram that fits on about half a page.
2. Mark North and the starting point.
3. Draw the two vectors and the resultant.
4. Measure the angle between the first vector and the displacement.
   This is the direction.

Angle x = 53^0

(Trigonometry can also be used

$\tan x = 4/3 \Rightarrow x = \tan^{-1}(4/3) = 53.1^o$)

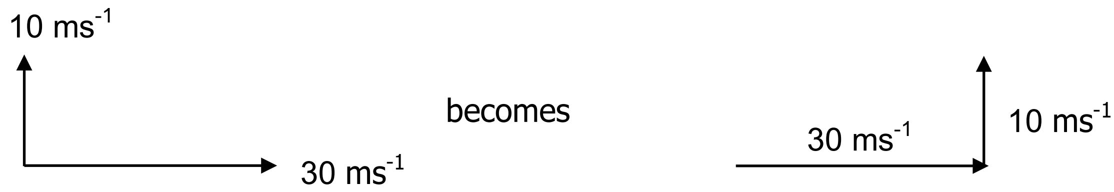
Displacement is 5 m in a direction of 53 ^{o} East of North or at a bearing of 053^o.

Step 4
Write down the full answer.

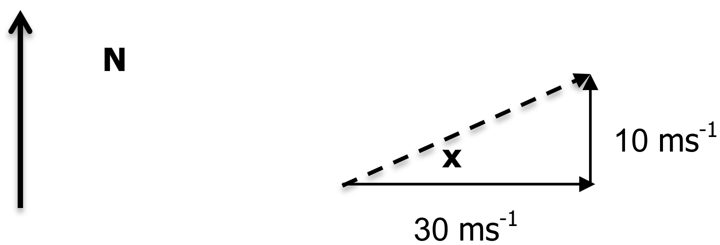
Resultant force is 25 N at 53^0 North of East or at a bearing of (037).

Example 2

A strong wind blows at 30 ms^{-1} Eastward. What is the resultant velocity of a plane flying due North at 10 ms^{-1}?



Scale Diagram



Velocity = 31.6 m/s 18^0 north of east or at bearing of (072).

Trigonometry

Velocity = $\sqrt{(30^2 + 10^2)}$ = 31.6 ms^{-1}

tan x = 10/30 => x = $\tan^{-1}(10/30) = 18^0$ => direction is 18^0 north of east or at a bearing = (072)

Velocity = 31.6 ms^{-1} at bearing of (072) or 18^0 north of east

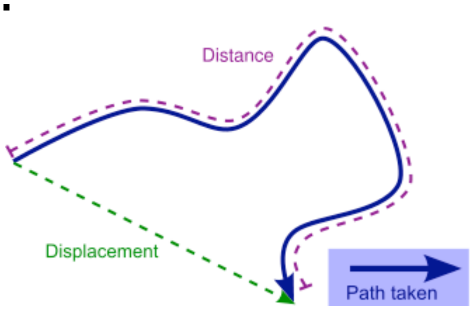
Distance and Displacement

Distance is a measure of how far a body has actually travelled in any direction.
Distance is a scalar as it only requires a magnitude

Displacement is the measurement of how far an object has travelled in a straight line from the start to the finish of its journey.
Displacement is a vector and so a magnitude and a direction is required.

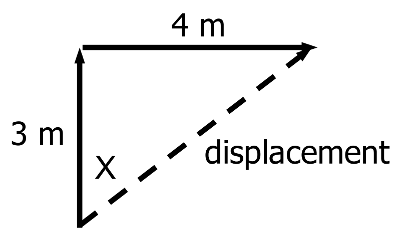
Example

1.



A walker has followed a path through a forest as shown. The distance travelled is much larger than their displacement from the starting position.

2.



A skateboarder travels 3 m due North, then turns and travels due East for 4 m.

They have travelled a distance of 3 + 4 = 7 m

The displacement is calculated as follows:

$(\text{Displacement})^2 = 3^2 + 4^2 = 25 \Rightarrow \text{displacement} = \sqrt{25} = 5$ m

BUT displacement must have a direction. This can be found by drawing a scale diagram.

Rules for Drawing A Scale Diagram

1. Select a scale which will allow you to draw a diagram that fits on about half a page.
2. Mark North and the starting point.
3. Draw the two vectors and the resultant.
4. Measure the angle between the first vector and the displacement.
   This is the direction.

Angle x = 53^0

Trigonometry can also be used

$\tan x = 4/3 \Rightarrow x = \tan^{-1}(4/3) = 53.1^o$

Displacement is 5 m in a direction of 53 ^{o} East of North or at a bearing of 053^o.

Speed

Speed is described by the equation below. Speed is a scalar quantity.

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

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

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

Velocity

Velocity is described by the equation below. Velocity is a vector quantity. The direction of the velocity will be the same as the direction of the displacement.

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

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

Symbol	Definition	Unit	Unit symbol
v	velocity	metre per second	ms^{-1}
s	displacement	metre	m
t	time	second	s

If the velocity is measured over the whole journey then it is known as **average velocity**, with the symbol $\bar{v}$**.**

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

Symbol	Definition	Unit	Unit symbol
$\bar{v}$	Average velocity	metre per second	ms^{-1}
s	total displacement	metre	m

Example

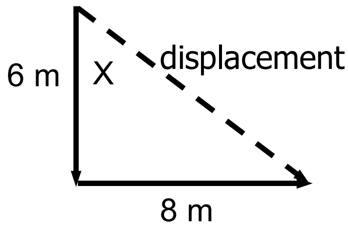
A remote control toy car goes 6 m due South and then 8 m due East. It takes two minutes to do this journey.

a) Find the distance it travelled and its displacement.

b) Calculate its average speed and velocity.

Solution

First draw a diagram to help.



a) Distance = 6 + 8 = 14 m

$(\text{Displacement})^2 = 6^2 + 8^2 = 100 \Rightarrow$ displacement = $\sqrt{100}$ = 10 m

Direction: Angle x can be calculated using trigonometry

tan x = 8/6 => x = $\tan^{-1}(8/6) = 53^0$

or by scale diagram

Displacement is 10 m in a direction of 53^o East of South or at a bearing of (127)

.

b) Average Speed

d = 14 m

t = 2 minutes = 2 x 60 = 120 s.

v = ?

v = d/t

v = 14/120

v = 0.1166

v = 0.12 ms^{-1}

Velocity

s = 10 m

t = 2 minutes = 2 x 60 = 120 s.

v = ?

v = s/t

v = 10/120

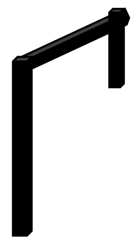
v = 0.083 ms^{-1}

Instantaneous Speed

The instantaneous speed of a vehicle at a given point can be measured by finding the average speed during a **very short time** as the vehicle passes that point. Average speed and instantaneous speed are often very different e.g. the average speed of a runner during a race will be less than the instantaneous speed as the winning line is crossed.

Measuring Instantaneous Speeds

To measure instantaneous speeds, it is necessary to be able to measure **very** short times. With an ordinary stopclock, human reaction time introduces large errors. These can be avoided by using electronic timers. The most usual is a light gate.



Light gate
used in class

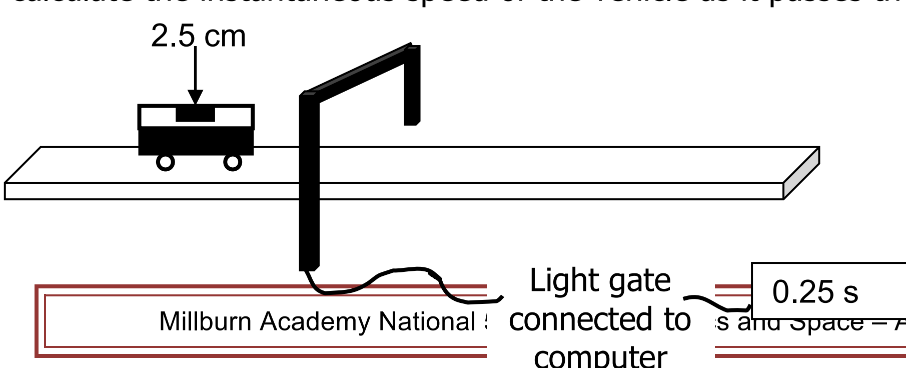
A light gate consists of a light source aimed at a photocell. The photocell is connected to an electronic timer or computer. The timer measures how long an object takes to cut the light beam. The distance travelled is the length of the object which passes through the beam. Often a card is attached so that the card passes through the beam. The length of the card is easy to measure. The instantaneous speed as the vehicle passes through the light gate is then calculated using:

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

Symbol	Definition	Unit	Unit symbol
v	Speed of vehicle	metre per second	ms^{-1}
d	length of card	metre	m
t	time	second	s

Example

A vehicle moves through a light gate as shown in the diagram. Using the data from the diagram, calculate the instantaneous speed of the vehicle as it passes the light gate.



Solution

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

$$v = \frac{0.025}{0.25}$$

$$v = 0.1\ ms^{-1}$$

2. Velocity – Time graphs

2.1 Velocity–time graphs for objects from recorded or experimental data.
2.2 Interpretation of velocity – time graph to describe the motion of an object.

$$\text{Displacement} = \text{area under v} - \text{t graph}$$

3. Acceleration

3.1 Acceleration of a vehicle between two points using appropriate relationships with initial and final velocity and time of change.
3.2 Acceleration from a velocity–time graph.

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

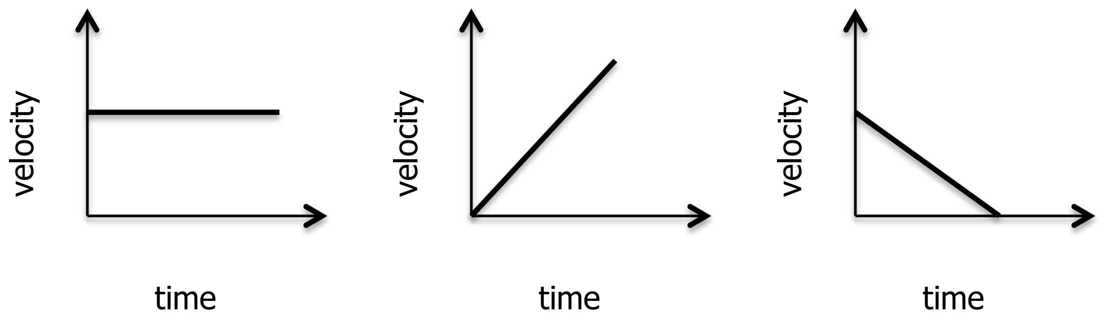
$$a = \frac{v - u}{t}$$

Velocity-Time Graphs

A velocity-time graph is a useful way to describe the motion of an object. Time is always plotted along the x-axis, and velocity is plotted along the y-axis.

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

Constant velocity | Increasing velocity (acceleration) | Decreasing velocity (deceleration)



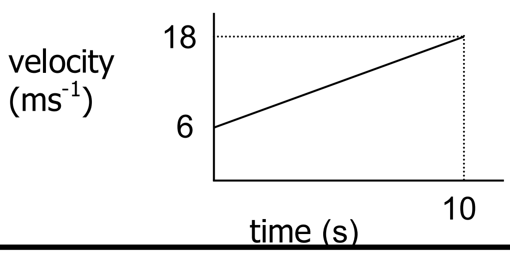
The slope (or gradient) of the line on a velocity-time graph indicates the acceleration.

While the slope is steady, the acceleration is constant.
If the line gets steeper, the acceleration (or deceleration) gets greater.
If the slope has zero gradient, and the line is flat, then the acceleration is zero and the velocity is constant.

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

Examples

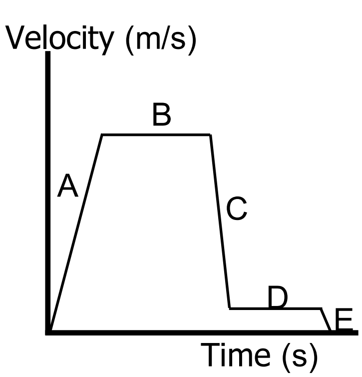
Calculate the acceleration shown in the graph below.



Answer
v=18; u=6; t=10

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

$$a = \frac{18 - 6}{10} = 1.2\ ms^{-2}$$



The graph opposite describes the motion of a vehicle. Explain in words the motion of the vehicle during each of the lettered stages.

A : Vehicle starts from rest and accelerates uniformly to its maximum velocity.

B : Vehicles travels at a constant velocity

C : Vehicle decelerates uniformly to its new lower velocity.

D : Vehicle travels at this new (lower) constant velocity.

Calculating Distance Travelled from a Velocity-Time Graph

If an object is accelerating it is often not possible to easily find its average speed. This in turn prevents the use of the equation distance = average speed x time to find the distance travelled.

Thankfully there is another way -
we can use a velocity time graph

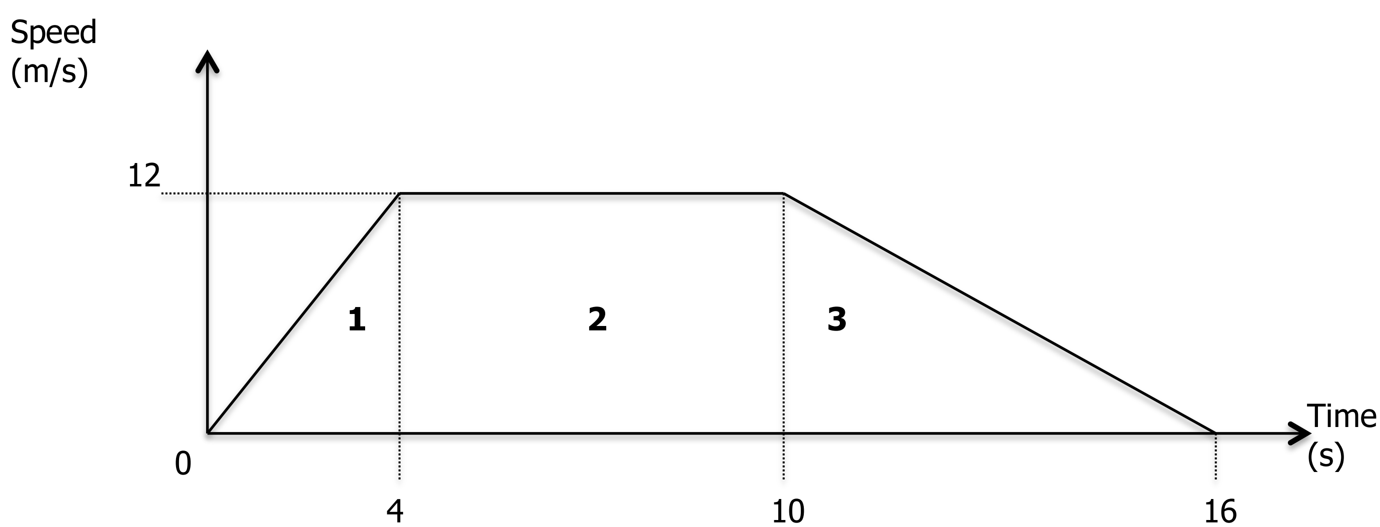
To find **displacement** travelled the **area under the velocity time graph is calculated.**

Distance gone = area under a speed-time graph

Displacement = area under a velocity-time graph

Remember that displacement and distance are not the same thing.
However, if the object is travelling in a straight line then they will be the same. This rule applies to any shape of graph.

Example



It is best to split the area under the graph into rectangles and triangles. Calculate the area of each and then add them together. [Area of a triangle is ½ base x height]

Distance gone = area 1 + area 2 + area 3

Distance gone = (½ x 12 x 4) + (12 x 6) + (½ x 6 x12)

Distance gone = 24 + 72 + 36 = 132 m

Acceleration

Most vehicles do not travel at the same velocity all the time. If their velocity increases, they are said to accelerate. If they slow down, they decelerate. Acceleration describes **how quickly** velocity changes. Acceleration is a **vector** quantity. Only the acceleration of vehicles travelling in straight lines will be considered in this course.

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

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

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

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

Units of Acceleration

The units of acceleration are the units of velocity (metres per second) divided by the units of time (seconds). The result is metres per second per second. This is usually called metres per second squared and is written **ms^{-2}**.

An acceleration of 2 ms^{-2} means that every second, the velocity increases by 2 ms^{-1}.

Note

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

Examples

A train accelerates from rest to 40 m/s in a time of 60 s. Calculate the acceleration.

$u = 0\ ms^{-1}$
$v = 40\ ms^{-1}$
$t = 60\ s$

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

$$a = \frac{40-0}{60}$$

$$a = 0.67\ ms^{-2}$$

A car is moving at 15 m/s, when it starts to accelerate at 2 m/s^2. What will be its speed after accelerating at this rate for 4 seconds?

$u = 15\ ms^{-1}$
$a = 2\ ms^{-2}$
$t = 4\ s$

$$2 = \frac{v - 15}{4}$$

$$v = 8 + 15$$

$$v = 23\ ms^{-1}$$

Newton's Laws

4.1 Applications of Newton's laws and balanced forces to explain constant velocity, making reference to frictional forces.
4.2 Calculations involving the relationship between unbalanced force, mass and acceleration for situations where more than one force is acting.
4.3 Calculations involving the relationship between work done, unbalanced force and distance/displacement.
4.4 Calculations involving the relationship between weight, mass and gravitational field strength during interplanetary rocket flight.
4.5 Newton's second law and its application to space travel, including rocket launch and landing.
4.6 Newton's third law and its application to explain motion resulting from a 'reaction' force.
4.7 Use of Newton's laws to explain free-fall and terminal velocity.

$$F = ma$$

$$W = mg$$

$$E_W = Fd$$

Newton's Laws

Forces

Effects 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

Forces are vectors
A force is a vector quantity because to describe it properly direction and size are required.

Measurement of Forces
Forces are measured in units called **newtons** (N). (See later for definition).
Forces can be measured with a **newton balance** or **spring balance**. This instrument uses the effect of a force on the shape (length) of a spring. The extension of the spring is directly proportional to the force applied to it.
The scale is calibrated to measure the size of the force in newtons.

The force to be measured is applied to the hook, which is attached to the spring inside the spring balance. The force causes the spring to stretch. The bigger the force the more the spring stretches and the marker moves across the scale.

The Force of Friction

Friction is a **resistive** force, which opposes the relative motion of two surfaces in contact. This means that it acts in the **opposite** direction to the relative movement of the two surfaces.

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

Friction is a very common force.

Friction between two solid surfaces depends on two factors:

- how **rough** the two surfaces are
- the size of the **force** between the two surfaces [how hard they are pressed together.]

Friction increases the rougher the two surfaces are and the bigger the force between them.

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

An example of this is air being used in an air puck.

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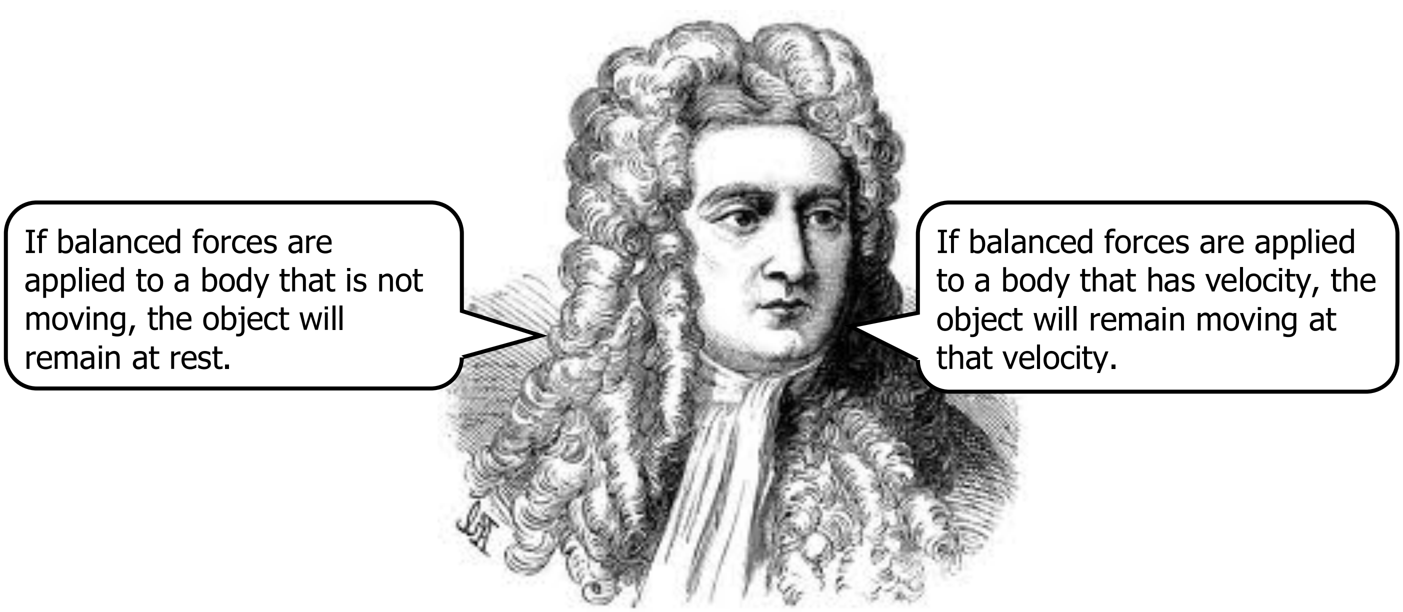
Newton's First Law

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

Balanced forces have the same effect as **no force** at all. When the forces on an object are balanced (or when there are no forces at all), then neither the speed nor direction of movement will change.

Newton said :



philvaz.com

Newton’s First Law of Motion

If there are **no forces acting** on an **object or the forces are balanced** then the **object** will **remain at rest or travel at a constant speed in a straight line.**

This is why a passenger in a bus (not wearing a seat belt) will continue to move forward after the bus has applied its brakes. The force was applied to the bus and not to the passenger. Therefore the passenger will continue moving forwards until a force stops them (usually the backrest from the seat in front of them).

In everyday life it is unusual to have balanced forces.
If a pencil is pushed along a desk. Once the pushing force is removed, the pencil will come to a stop, as the force of friction acts against the motion.

Examples of balanced forces

www.photosearch.com

Citycigarblogspot.com

wallconvert.co

Force, Mass and Acceleration

Newton followed up his first law about balanced forces with a second law that describes how an object will accelerate if there is an unbalanced or resultant force acting on it. When the forces are balanced an object will remain at rest or travel at a constant speed in a straight line. But when the forces are not balanced the velocity cannot remain constant. It will change. The acceleration tells you how quickly the velocity is changing.

The acceleration of an object (produced by an unbalanced force) is:

- *directly proportional to the magnitude of the unbalanced force,*
- *in the same direction as the unbalanced force*
- *inversely proportional to the mass of the object.*

$$\mathbf{F = m\,a}$$

Symbol	Definition	Unit	Unit symbol
F	force	newton	N
m	mass	kilograms	kg
a	acceleration	metres per second squared	m/s^2

This formula defines the newton.

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

Example

A car of mass 1 000 kg has an unbalanced force of 1 600 N acting on it. What will be its acceleration?

F = 1 600 N
m = 1 000 kg

$$F = ma$$
$$1600 = 1000 \times a$$
$$a = \frac{1600}{1000}$$
$$a = 1.6\ ms^{-2}$$

Mass and Weight

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

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

The **strength of gravity** in a particular place is called **the gravitational field strength.**
This tells you the weight of 1 kilogram.
Its symbol is **g** and its unit is newtons per kilogram, **N/kg.** On Earth g is rounded to **10 N/kg.**

Mass and weight are connected by the following formula:-

$$W = mg$$

Symbol	Definition	Unit	Unit symbol
W	weight	newton	N
m	mass	kilograms	kg
g	gravitational field strength	newtons per kilogram	N/kg

The gravitational field strength is different for different planets within our solar system. Consequently, a 1 kg bag of sugar will have a mass of 1 kg everywhere, but its weight varies on different planets.

Example

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

Gravitational field strength on Mars is 3.8 N/kg

m = 5.6 kg
g = 3.8 N/kg

W = mg
W = 5.6 x 3.8
W = 21.28
W = 21 N

Resultant Forces

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.**

Combining forces in a straight line

To combine forces acting in one direction:

- draw a diagram of the object
- mark in all the forces acting - use an arrow to represent each force's direction.
  Do not forget weight, which is often not specifically mentioned in the question.

Use arithmetic to find the resultant by:

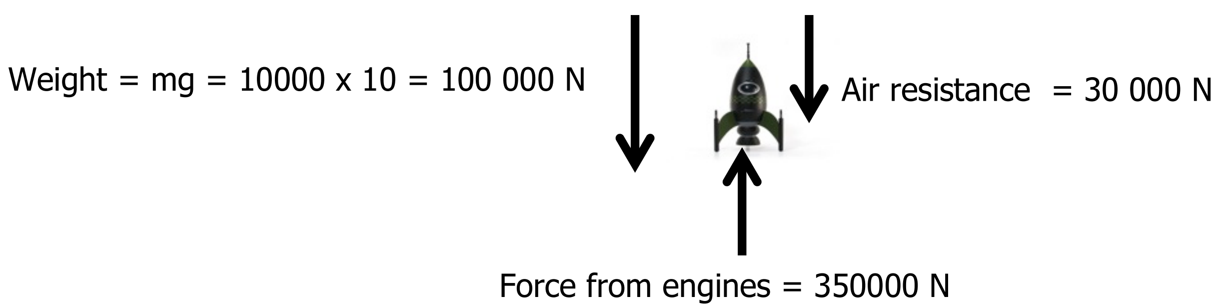
- **adding** together forces which act in the **same** direction
- **subtracting** forces which act in the **opposite** direction.

A diagram like this is called a **free body diagram**.

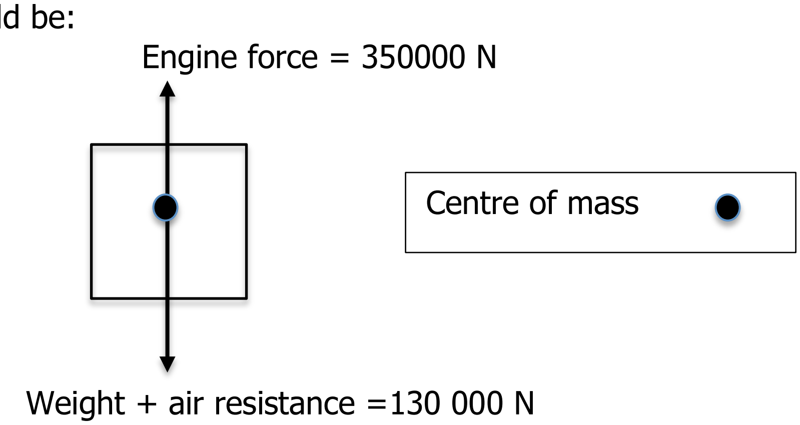
Example

A short time after take off, a rocket of mass 10 000 kg has a thrust of 350 000 N and experiences air resistance of 30 000 N. Draw a free body diagram and find the resultant force acting on the rocket.

This can be illustrated as follows



The free body diagram would be:



Resultant force = force from engine – (air resistance + weight)

Resultant force = 350 000 – (100 000 + 30 000) = 220 000 N upwards

Real Life Situation

Engineers working in the space industry use this type of calculation to find out the size of the engine force that is required to launch a spacecraft.

They also calculate the size of the engine force which would be required to slow the spacecraft down so that it can land in a safe, controlled manner.

Example

A landing specialist working at NASA is given the following information about a space craft landing on to Mars. He does some initial calculations and knows how to ensure that the space craft approaches the surface of the planet at the correct velocity.

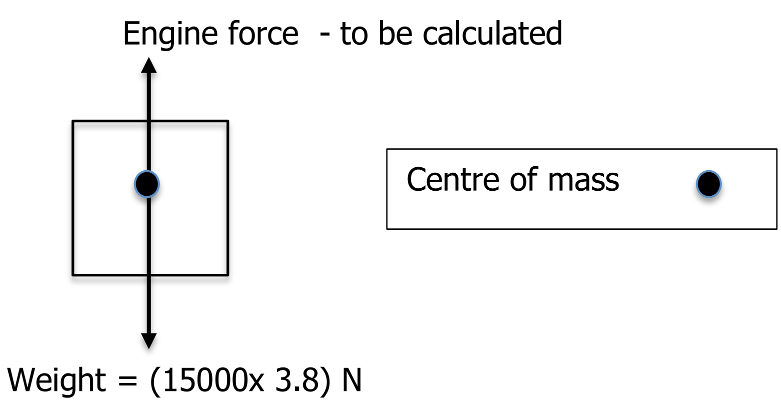
However he must now calculate the size of the force that the rocket engines must apply in order to maintain the constant velocity.
He uses the following information:

Mass of rocket 15 000 kg.
Gravitational field strength = 3.8 N/kg

Draw a free body diagram and calculate the size of the force that the rocket engines must produce.

Constant velocity means that there are **no unbalanced forces** acting on the space craft.

Free Body Diagram



Total downward force = weight

m = 15000 kg
g = 3.8 N/kg

W = mg
W = 15 000 x 3.8
W = 57 000 N

Upwards force = weight

Force applied by rocket engines = 57 000 N upwards

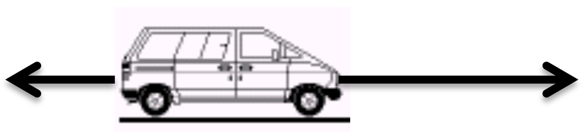
Calculations Using F = ma For More Than One Force

If there is more than one applied force in a problem then draw a free body diagram and mark on all the known forces.
Use this to calculate the resultant force (F in the equation) before using the equation F = ma.

Examples

1. A car of mass 1 000 kg experiences friction equal to 500 N. If the engine force is 1 300 N, what will be the car's acceleration?

Friction = 500 N



Engine force = 1300 N

Resultant force = 1300 – 500 = 800 N

F = 800 N
m = 1 000 kg

$$F = ma$$
$$800 = 1000 \times a$$
$$a = \frac{800}{1000}$$
$$a = 0.8\ ms^{-2}$$

2. Given that the tank below has a mass of 6000 kg, calculate its acceleration.

Resultant force = 2000 – 1200 = 800 N

F = 800 N
m = 6 000 kg

$$F = ma$$
$$800 = 6000 \times a$$
$$a = \frac{800}{6000}$$
$$a = 0.8\ ms^{-2}$$

Acceleration Due To Gravity And Gravitational Field Strength

Weight is the force which causes an object to accelerate downwards.
W = mg where g is the gravitational field strength.

The value of the acceleration caused by weight can be calculated from Newton's second law, using the equation F = ma where F is now the weight W, and W = mg. (This assumes that friction is negligible).

$$\text{Acceleration due to gravity } = \text{a}$$

Using Newton's Second Law:

$$\text{a} = \frac{\text{F}}{\text{m}}$$

In this case the force is weight so:

$$\text{a} = \frac{\text{W}}{\text{m}}$$

W = mg giving:

$$\text{a} = \frac{\text{mg}}{\text{m}} = \text{g where g is in m s}^{-2}$$

The numerical values of the acceleration due to gravity and gravitational field strength are equal. Their units, **N/kg** and **m/s²** are also equivalent.

Example

On the moon, where the gravitational field strength is 1.6 N/kg, a stone falls and takes 1.5 s to reach the surface. What is its velocity as it hits the surface of the moon?
(There is no atmosphere to cause any air resistance on the moon).

u = 0 m/s
g = 1.6 N/kg (=1.6 m/s^2)

t = 1.5 s

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

$$1.6 = \frac{v - 0}{1.5}$$

$$v = 1.6 \times 1.5$$

$$v = 2.4 \text{ ms}^{-1}$$

Free Fall

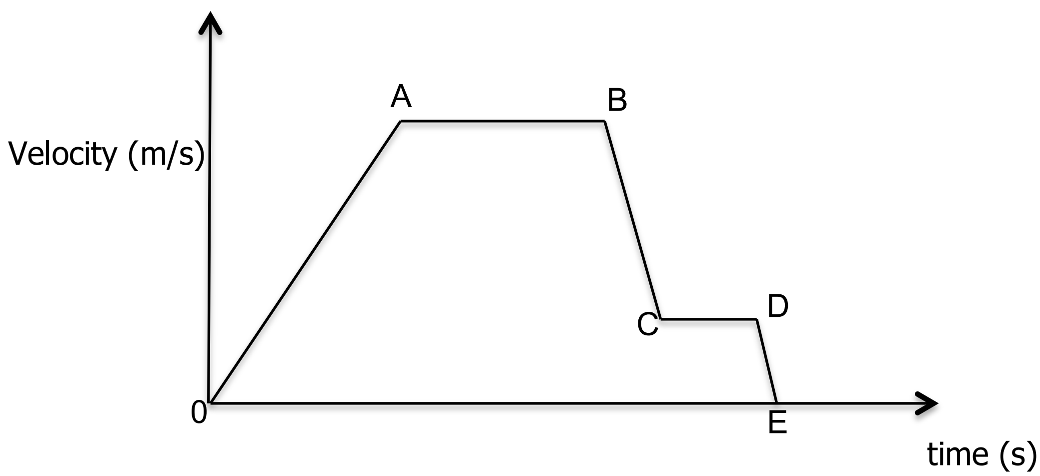
When an object is released from a height and allowed to fall vertically down under the influence of gravity then:

- the object's initial vertical velocity is zero.
- the vertical velocity increases as the object accelerates at 10 m/s^2

The object will continue to accelerate until the force acting downwards (weight) and the force acting upwards (air resistance) on the object are balanced.
When this happens the object will fall at a constant vertical velocity. This vertical velocity is known as the **terminal velocity.**

If an object is falling as described above and the only two forces acting on it are weight and air resistance then the object is said to be in **free fall.**

When a parachutist first jumps out of an aircraft they are in free fall until they open their parachute. This is best illustrated using a velocity time graph.



At O
The parachutist leaves the aircraft

OA
The parachutist accelerates towards the earth.
As their velocity increases, their air resistance also increases.
Air resistance will increase until the air resistance acting upwards is equal in size to the weight of the parachutist acting downwards.
When these two forces are balanced the parachutist has reached their **terminal velocity**.
(Point A on graph above)

AB
Parachutist falls at a constant velocity.

BC
At B, parachutist opens their parachute and they rapidly decelerate due to increased air resistance.
Once the upward and downward forces are balanced again the parachutist will fall at their (new) **lower terminal velocity.** (Point C on graph above).

DE
Rapid deceleration as parachutist (safely) lands.

Weight, Mass, and Space

An object's mass does not change from place to place, but an object's weight does change because of the gravitational field strength.

As you already know W = mg.

For the space shuttle in low earth orbit, the weight is **not zero.** This is because at this orbit height there is still a gravitational force acting on the shuttle.

The "weightlessness" experienced by astronauts on board the Shuttle is caused by the free fall of all objects in orbit. The Shuttle is pulled towards the Earth because of gravity. The shuttle’s high orbital speed causes the fall towards the surface to be exactly matched by the curvature of the Earth away from the shuttle. In essence, the shuttle is constantly falling around the Earth.

The gravitational field strength at the surface of the Earth (9.8 N/kg) is due to the mass of the Earth and the radius of the Earth. There are **different** gravitational field strengths for every planet in the solar system.

Example

Of particular interest for future Space Exploration is the gravitational acceleration of the moon which is 1/6 of the value on earth. This means that the engine thrust required to launch from the moon is much less than the thrust required to launch from the earth.

For more information please use:
http://exploration.grc.nasa.

Work Done and Energy

Energy

Energy cannot be created or destroyed, but it can be changed from one form into another. All forms of energy are measured in the same unit: the **joule (J).** When a force causes movement, some energy is changed from one form to another (it is **transformed**) and we say that **work is done**. For example, the force of friction causes kinetic energy to be transformed into heat.

Work Done

The work done is a measure of the energy transformed. 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 is measured in the same units as energy: joules. The symbol for work is E_W.

$$E_W = F\,d$$

Symbol	Definition	Unit	Unit symbol
E_W	energy	joules	J
F	force	newtons	N
d	distance	metres	m

Example

Calculate the work done by a gardener who uses a wheelbarrow to move 15 kg of soil a distance of 500 m.

m = 15 kg
g = 10 N/kg

W = mg
W = 15 x 10
W = 150 N

The weight is equivalent to the force the gardener has to apply to move the wheelbarrow of soil.

F = W = 150 N
d = 500 m

E_W = Fd
E_W = 150 x 500
E_W = 75 000 J

Newton's Third Law

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. 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.**

Examples

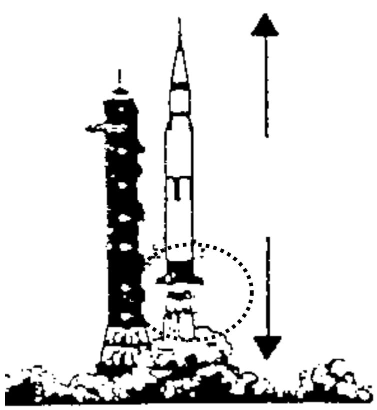
A footballer heading a ball.

Object A is the head. Object B is the ball. When the player heads the ball, the head exerts a force to the right on the ball. The ball exerts a force on the head that is equal in size and opposite in direction.

Please note the deformation of the shape of the ball

Watch
http://www.youtube.com/watch?v=seg7eLmw5pY
for slow motion kicking of a rugby ball

http://www.youtube.com/watch?v=lBMA2wWuqh8
for slow motion kicking of a football



Object A is the rocket. Object B is the exhaust gases from the fuel. When the rocket takes off, the rocket exerts a force downwards on the exhaust gases. The exhaust gases exerts a force on the rocket that is equal in size and opposite in direction.

Tutorial Problems on Speed, Distance and Time

1. A runner completes a 200 m race in 25 s. What is his average speed in m/s?

2. A friend asks you to measure his average cycling speed along a flat road. Describe which measurements you would take and the measuring instruments you would use.

3. An athlete takes 4 minutes 20 s to complete a 1500 m race. What is the average speed?

4. On a fun run, a competitor runs 10 km in 1 hour. What is her average speed in:
   a) km/h
   b) m/s?

5. Describe how you could measure the average speed of a car as it passes along the road outside your school.

6. Concorde can travel at 680 m/s (twice the speed of sound). How far will it travel in 25 s at this speed?

7. A girl can walk at an average speed of 2 m/s. How far will she walk in 20 minutes?

8. How long will it take a cyclist to travel 40 km at an average speed of 5 m/s?

9. How long (to the nearest minute) will the Glasgow to London shuttle take if it flies at an average speed of 220 m/s for the 750 km flight?

10. How long, to the nearest minute, will a car take to travel 50 km if its average speed is 20 m/s?

11. Look at this timetable for a train between Edinburgh and Glasgow:

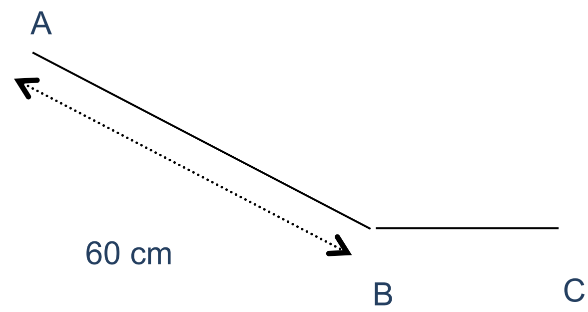
Station	**Time**	**Distance from Glasgow**
Glasgow	0800	0 km
Falkirk	0820	34 km
Linlithgow	0828	46 km
Edinburgh	0850	73 km

   a) What was the average speed for the whole journey in m/s?
   b) What was the average speed in m/s between Glasgow and Falkirk?
   c) Explain the difference in average speeds in a) and b).

12. Describe how you would measure the instantaneous speed of a vehicle as it reached the bottom of a slope.

13. In an experiment to measure instantaneous speed, these measurements were obtained:
Reading on timer = 0.125 s Length of car = 5 cm
Calculate the instantaneous speed of the vehicle in m/s.

14. A trolley with a 10 cm card attached to it is released from A and runs down the slope, passing through a light gate at B, and stopping at C.
Time from A to B = 0.8 s.



Time on light gate timer = 0.067 s

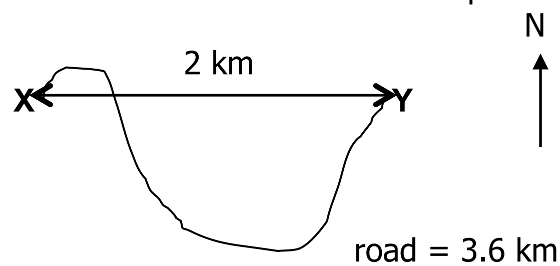
a) What is the average speed between A and B?
b) What is the instantaneous speed at B?

Tutorial Problems on Scalars and Vectors

1. What is the difference between a vector quantity and a scalar quantity?

2. Use your answer to question 1 to explain the difference between distance and displacement.

3. A man walks from X to Y along a winding road.

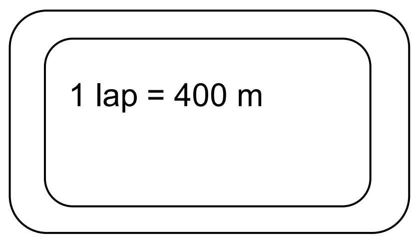


   a) What is his displacement at the end of his walk?
   b) What distance has he walked?

4. If the walker in question 3 took 40 minutes for his walk, what was
   a) his average speed
   b) his average velocity?

5. One complete lap of a running track is 400m. An athlete completes one lap in 48 s in the 400 m race. What is his

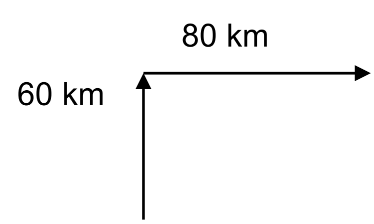
   a) distance travelled
   b) displacement
   c) average speed
   d) average velocity.



6. Repeat Q 5 for a runner in the 800 m race whose winning time was 1 min 54 s.

7. A car travels 40 km north, then turns back south for 10 km. The journey takes 1 hour. What is
   a) the displacement of the car
   b) the distance the car has travelled
   c) the average velocity of the car
   d) the average speed of the car?

8. A car drives 60 km north, then 80 km east, as shown in the diagram. The journey takes 2 hours. Calculate the
   a) distance travelled
   b) displacement
   c) average speed
   d) average velocity.



Tutorial Problems on Acceleration

1. A Jaguar can reach 27 m/s from rest in 9.0 s. What is its acceleration?

2. The space shuttle reaches 1000 m/s, 45 s after launch. What is its acceleration?

3. A car reaches 30 m/s from a speed of 18 m/s in 6 s. What is its acceleration?

4. A train moving at 10 m/s increases its speed to 45 m/s in 10 s. What is its acceleration?

5. A bullet travelling at 240 m/s hits a wall and stops in 0.2 s. What is its acceleration?

6. A car travelling at 20 m/s brakes and slows to a halt in 8 s. What is the deceleration?

7. Describe how you would measure the acceleration of a small vehicle as it runs down a slope in the laboratory.

8. On approaching the speed limit signs, a car slows from 30 m/s to 12 m/s in 5 s. What is its deceleration?

9. A bowling ball is accelerated from rest at 3 m/s^2 for 1.2 s. What final speed will it reach?

10. How long will it take a car to increase its speed from 8 m/s to 20 m/s if it accelerates at 3 m/s^2?

11. A cyclist can accelerate at 0.5 m/s^2 when cycling at 4 m/s. How long will she take to reach 5.5 m/s?

12. The maximum deceleration a car's brakes can safely produce is 8 m/s^2. What will be the minimum stopping time if the driver applies the brakes when travelling at 60 mph (27 m/s)?

13. The table below gives some performance figures for cars.

Car	Time for 0 - 60 mph	max. speed in mph
Mondeo 1.8 LX	10.2 s	122
Peugeot 106 XN 1.1	12.5 s	103
Renalt Clio RL	14.3 s	95
Nissan Micra 1.0 S	15.2 s	89
Porsche Boxster	6.5 s	139

a) Which car has the smallest acceleration?

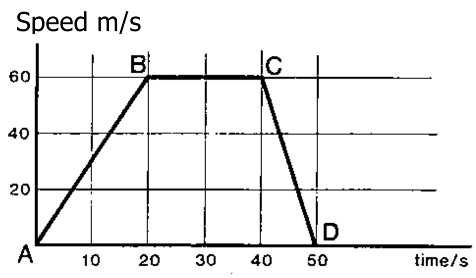
b) Which car has the largest acceleration?

Velocity-time Graphs

1. The graph shows how the speed of the car changes during a short journey.

   (a) What is the acceleration during AB?

   (b) What is the deceleration during CD?



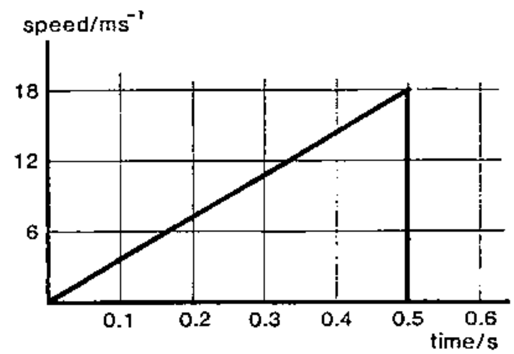
2. To test the strength of a nuclear waste container, it is fired along a track towards a concrete wall. The speed-time graph is shown opposite.

   (a) At what time did the container hit the wall?

   (b) How fast did it hit the wall?

   (c) How long was the test track?

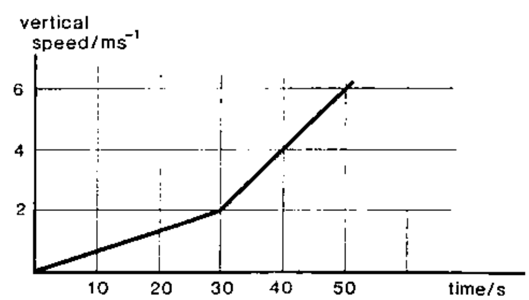
   (d) What was its acceleration?



3. A hot air balloon is released and accelerates upwards. During the lift, some of the sandbags are released and the acceleration increases. The graph shows its vertical motion during the first 50 seconds of its flight.

   (a) Calculate both accelerations.

   (b) At what height were the sandbags released?



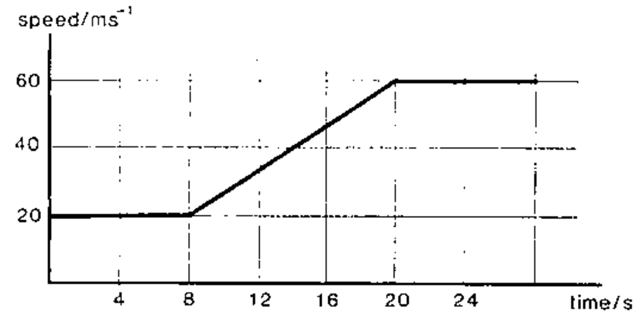
4. A glider, cruising at 20 m/s, goes into a shallow dive and increases its speed. The graph shows its motion starting a few seconds before its dive.

   (a) At what time did it start the dive?

   (b) What was the time taken during the dive?

   (c) What was the acceleration during the dive?

   (d) How far did it travel during the dive?



5. During a test run of a hovertrain its speed was recorded as shown in the table below.

Time (s)	0	20	40	60	80	100	120	140
Speed (m/s)	0	10	40	70	100	100	50	0

   (a) Draw a graph of the train's motion during the test run.

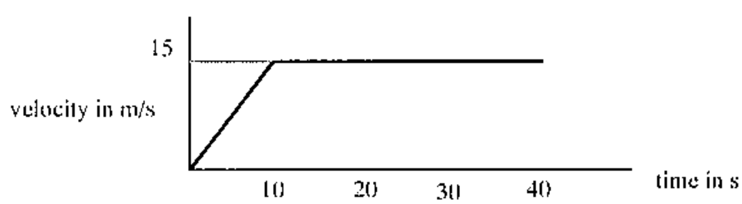
   (b) Calculate the two accelerations during the test run.

   (c) Calculate the deceleration of the train.

   (d) Calculate the total distance travelled during the test run.

   (e) Calculate the **average** speed during the run.

6. The graph below shows how the velocity of a car varies over a 40 s period.



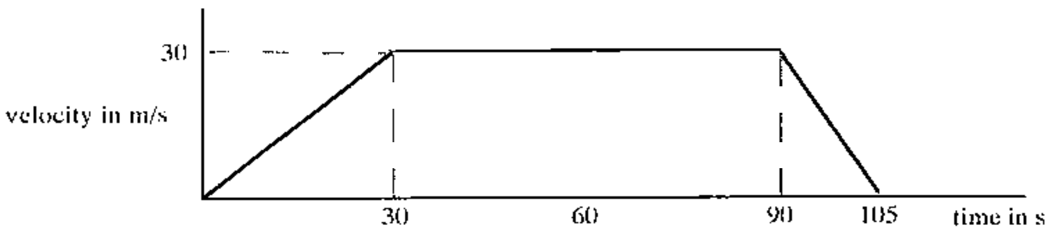
   a) Describe the motion of the car during this 40 s period.

   b) Calculate the acceleration of the vehicle.

   c) How far does the car travel while accelerating?

   d) What is the total distance travelled by the car?

7. Use the graph below to answer the following questions.



a) During which time period is the vehicle travelling at a constant velocity?

b) Calculate the values of i) the initial acceleration ii) the final deceleration

c) What is the braking distance of the car?

d) What is the total distance travelled?

e) What is the average velocity of the car?

8. Draw a velocity-time graph to describe the following motion:-A car accelerates from rest to 2 m/s in 8 s, then travels at a constant velocity for 12 s, finally slowing steadily to a halt in 4 s.

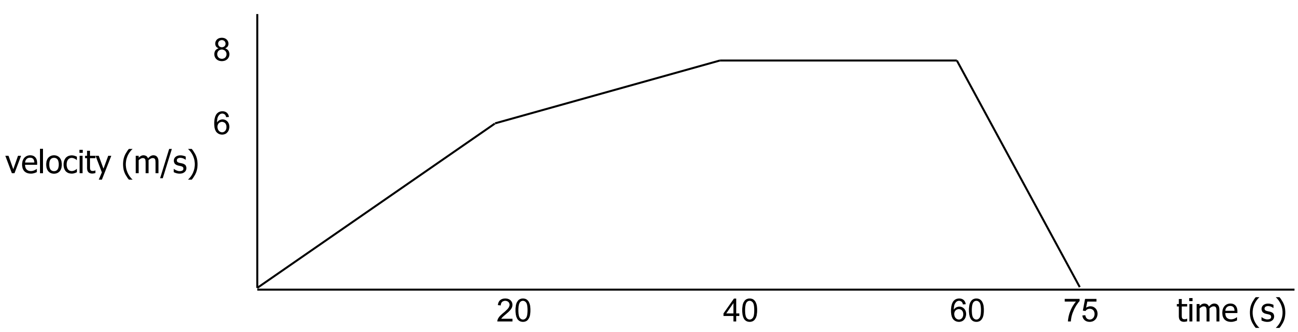
9. For the vehicle in the previous question, what are the values of

a) the maximum velocity

b) the distance travelled

c) the average velocity?

10. The graph below describes the motion of a cyclist.



a) What is the value of the maximum positive acceleration?

b) Show by calculation whether the cyclist travels farther while accelerating, or while cycling at the maximum velocity.

Mass and Weight

1. Define mass.

2. Define weight.

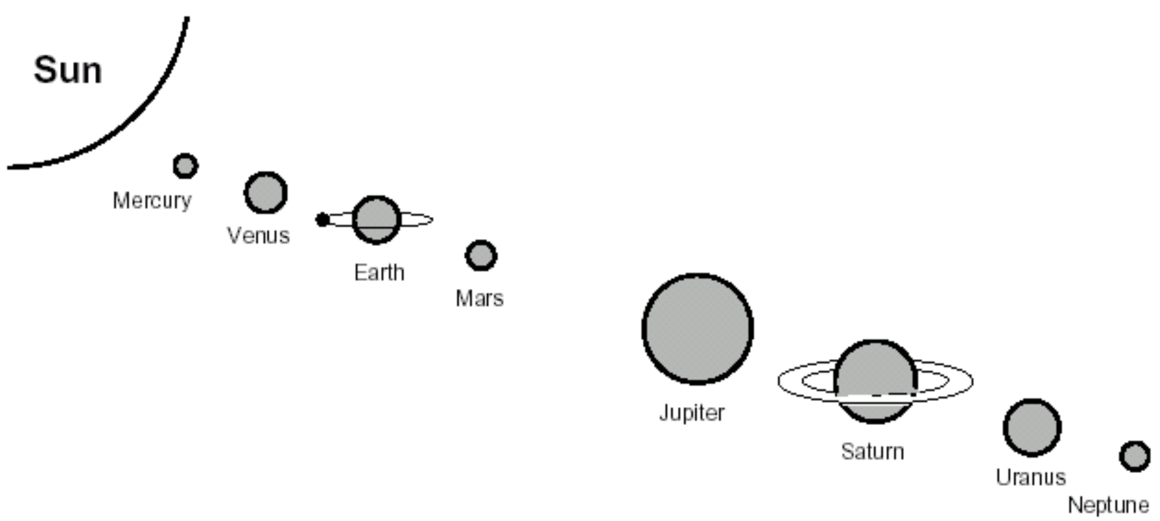
3. a. What is name given to the ratio of $\frac{\text{weight}}{\text{mass}}$?

4. Does mass or weight change depending on how far away you are from a planet and on what planet you are on?

Read the information below on 'g' for other bodies in the Solar System.

Planet	**g (N/kg)**
Mercury	3.7
Venus	8.8
Earth	10
(Moon)	1.6
Mars	3.8
Jupiter	26.4
Saturn	11.5
Uranus	11.7
Neptune	11.8
Pluto	4.2

5. Calculate your mystery friend's weight on each of the planets, assuming your mystery friend's mass is 56 kg.



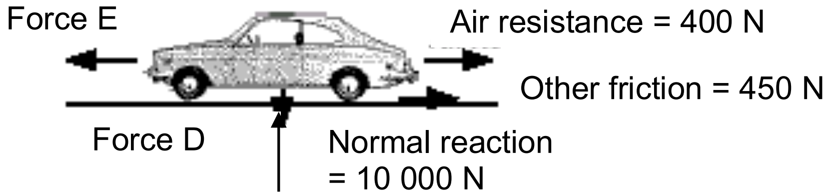
6. What is the weight of a 10 kg bag of potatoes on Earth?
7. What is the weight of a 250 g bag of sweets on Earth?
8. What is the mass of a girl if her weight on Earth is 450 N?
9. What is the weight of a 10,000 kg spacecraft on
   a)Earth
   b) Mars
   c) Venus?
10. What would a 60 kg man weigh on Jupiter?
11. Which planet's gravity is closest to our own?
12. An astronaut who weighs 700 N on Earth goes to a planet where he weighs 266 N. Calculate his mass and state which planet he was on.
13. What would an astronaut weigh on Earth, if his weight on Venus was 528 N?

Friction

1. Define what friction is.
2. Give two examples where friction slows things down.
3. Give two examples of where friction helps things move.
4. Describe two methods of increasing friction.
5. Describe three methods of decreasing friction.
6. Where in a bicycle is friction deliberately
   a) increased
   b) decreased?
7. What is friction commonly called when the one of the surfaces involved is air?
8. What is friction commonly called when the one of the surfaces involved is water?

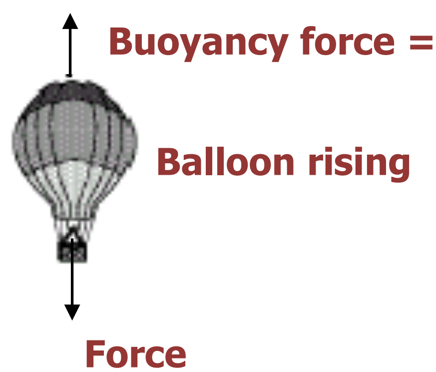
Balanced Forces and Newton's First Law

1. The diagram below shows the forces acting on a car moving at constant velocity.



a) What can you say about the forces acting on this car?
b) How big is the engine force E?
c) What is the weight of the car ?

1. The diagram shows the forces acting on a balloon as it rises.



a) What will be the size of force A?
b) If the balloon was falling at a constant velocity, what would be the size of force A?

2. State Newton's First Law.

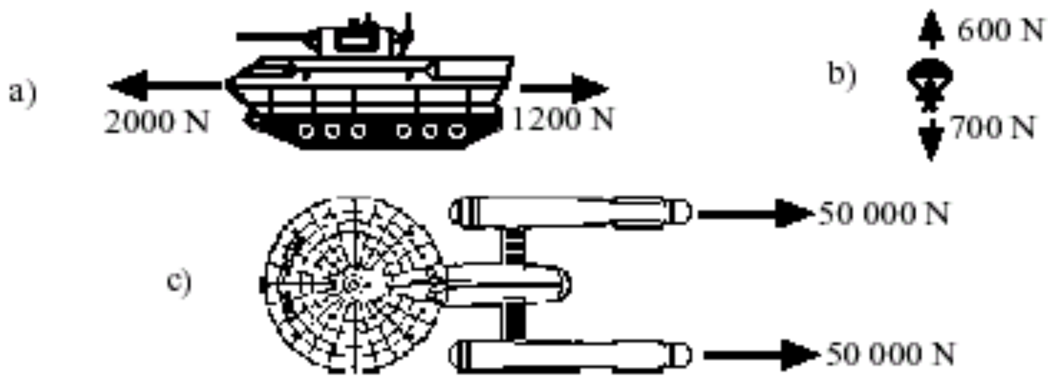
4. Explain, using Newton's First Law, why passengers without seat belts in a moving car appear to be "thrown forwards" in the car, when the car stops suddenly.

5. Explain how a parachutist reaches a terminal velocity.

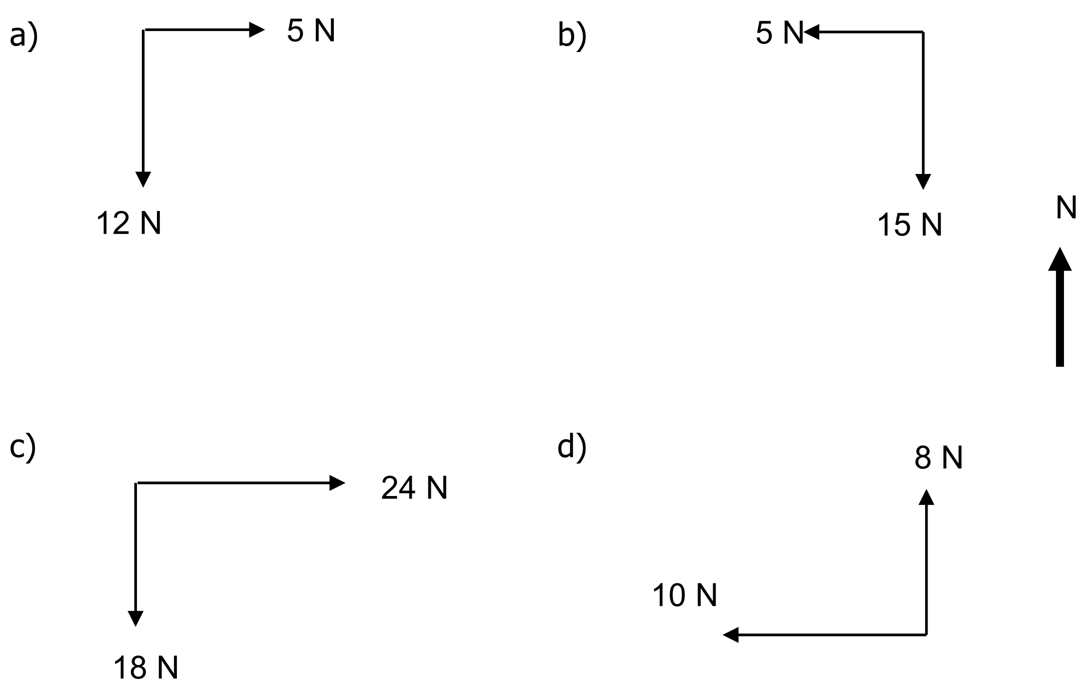
Resultant Forces

1. What is meant by the resultant force on an object?

2. What are the resultants of the following forces?



3. By using a scale diagram or otherwise, find the resultant of the following pairs of forces. Remember to draw the vectors "tip to tail".



Newton's Second Law

1. What force is needed to accelerate a 5 kg mass at 3 m/s^2?
2. What will be the acceleration of a 12 kg mass acted on by a force of 30 N?
3. What mass would accelerate at 2 m/s^2 when acted on by a 12 N force?
4. What force will accelerate 250 g at 2 m/s^2?
5. What force would be needed to accelerate a 10 tonne lorry at 1.5 m/s^2?
   (1 tonne = 1000 kg)
6. Give two reasons why a car will have a smaller acceleration in similar conditions when a roof rack is added.
7. Describe an experiment to investigate the effect of varying the unbalanced force acting on a fixed mass.
8. A car of mass 1200 kg experiences friction equal to 500 N when travelling at a certain speed. If the engine force is 1400 N, what will be the car's acceleration?
9. A car of mass 2000 kg has a total engine force of 4500 N. The frictional drag force acting against the car is 1700 N. What is the acceleration of the car?
10. Two girls push a car of mass 1000 kg. Each pushes with a force of 100 N and the force of friction is 120 N. Calculate the acceleration of the car.
11. A boat engine produces a force of 10000 N and the friction and water resistance total 3500 N. If the mass of the boat is 2000 kg, what will be its acceleration?
12. A careless driver tries to start his car with the hand brake still on. The engine exerts a force of 2500 N and the hand brake exerts a force of 1300 N. The car moves off with an acceleration of 1.2 m/s^2. What is the mass of the car?
13. A car of mass 1200 kg can accelerate at 2 m/s^2 with an engine force of 3000 N. What must be the total friction force acting on the car?
14. A helicopter winches an injured climber up from a mountainside. The climber's mass is 65 kg.
    a) What is the weight of the climber?
    b) If he is accelerated upwards at 1.0 m/s^2, what unbalanced force is required?
    c) What total upwards force must be produced by the helicopter?
15. An 800 kg car is accelerated from 0 to 18 m/s in 12 seconds.
    a) What is the resultant force acting on the car?

Answers to numerical problems

Speed, distance and Time

1. 8 m/s
2. –
3. 5.77 m/s
4. a) 10 km/h
   b) 2.7 m/s
5. –
6. 17 000m
7. 2 400m
8. 8000s
9. 57 min (3 409s)
10. 42 min (2 500s)
11. a) 24.3 m/s
    b) 28.3 m/s
12. –
13. 0.4 m/s
14. a) 0.75 m/s
    b) 1.49 m/s

Scalars and Vectors

1. –
2. –
3. a) 2 km E
   b) 3.6 km
4. a) 1.5 m/s
   b) 0.83 m/s E
5. a) 400 m b) 0 c) 8.3 m/s d) 0
6. a) 800 m b) 0 c) 7.02 m/s d) 0
7. a) 30km N b) 50 km c) 30 km/h d) 50 km/h
8. a) 140 km b) 100km on a bearing of 053^0 c) 70 km/h d) 50 km/h on a bearing of 053^0

Acceleration

1. 3 m/s^2
2. 22.2 m/s^2
3. 2 m/s^2
4. 3.5 m/s^2
5. -1 200 m/s^2
6. -2.5 m/s^2
7. –
8. 3.6 m/s^2
9. 3.6 m/s
10. 4 s
11. 3 s
12. 3.4 s
13. a) Micra b) Porsche c) i) 20.7s d) ii) 15.1 s

Velocity-time graphs

1. a) 3 m/s^2 b) 6 m/s^2
2. a) 0.5 s b) 18 m/s c) 4.5 m d) 36 m/s^2
3. a) i) 0.067 m/s^2 ii) 0.2 m/s^2
   b) 30 m
4. a) 8 s b) 12 s c) 3.33 m/s^2 d) 480m
5. a) - b) 0.5 m/s^2 1.5 m/s^2 c) 2.5 m/s^2 d) 7 400 m e) 52.9 m/s
6. a) - b) 1.5 m/s^2 c) 75m d) 525 m
7. a) 30 -> 90 b) -2 m/s^2 c) 225 m d) 2 475 m e) 23.6 m/s
8. -
9. a) 2 m/s b) 36 m c) 1.5 m/s
10. a) 0.3 m/s^2 b) Max vel – 160m Accelerating 200 m

Mass and Weight
1. –
2. –
3. –
4. –
5. –
6. --
7. Mercury – 207 N, Venus – 493 N, Earth 560 N, Mars 213 N, Jupiter 1 480 N, Saturn 644 N, Uranus 655 N, Neptune 661 N.
8. 100 N
9. 2.5 N
10. 45 kg
11. a) 100 000 N
    b) 38 000 N
    c) 88 000 N
12. 1 580 N
13. Venus
14. Mass 70 kg on planet Mars (g=3.8 N/kg)
15. Mass 60 kg, Weight = 600 N

Problems on Friction
No numerical problems

Balanced Forces and Newton's First Law
1. a) They are balanced b) 850 N c) 10 000 N
2. a) 2000 N b) 2000N
3. –
4. –
5. –

Resultant Forces
1. –
2. a) 800 N Left b) 100 N Down c) 100 000 N Right
3. a) 13 N Bearing 157^o b) 15.8 N Bearing 198^o c) 30 N Bearing 127^o d) 12.8 N Bearing 309^o

Newton's Second Law

1. 15 N
2. 2.5 m/s^2
3. 6 kg
4. 0.5 N
5. 15 000 N
6. –
7. –
8. 0.75 m/s^2
9. 1.4 m/s^2
10. 0.08 m/s^2
11. 3.25 m/s^2
12. 1 000 kg
13. 600 N
14. a) 650 N b) 65 N c) 715 N
15. a) 1 200 N b) 2 880 N

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1. **Projectile Motion**
    1.1. Explanation of projectile motion Effect of electric field on a charge.
    1.2. Calculations of projectile motion from a horizontal launch using appropriate relationships and graphs.
    1.3. Explanation of satellite orbits in terms of projectile motion.

$$Horizontal\ range = area\ under\ v_H - t\ graph$$

$$Vertical\ range = area\ under\ v_v - t\ graph$$

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

$$v_v = u + at$$

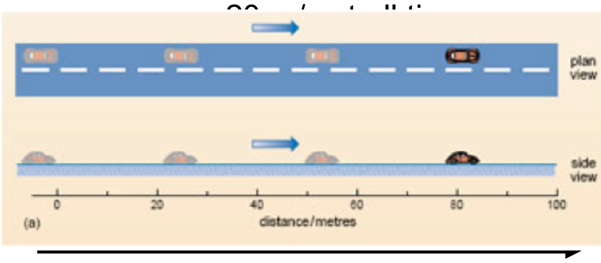
Projectile Motion

A **projectile** is an object that is only being acted upon by the downward force of gravity. In this course will be study objects being dropped **vertically** and objects being fired **horizontally**. A projectile has two **separate** motions at right angles to each other. Each motion is **independent** of the other. A projectile will have a **constant horizontal velocity** and a **constant vertical acceleration**, this results in a curved path of motion.

A projectile can be viewed as having two discrete components of motion:

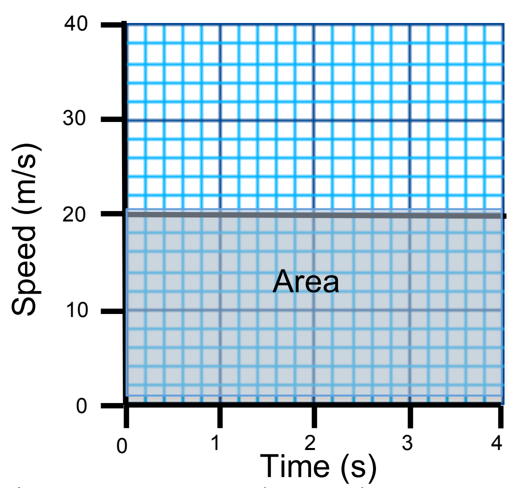
HORIZONTAL

A constant horizontal velocity.



Time

The horizontal range can be found by plotting a velocity – time graph of the motion.

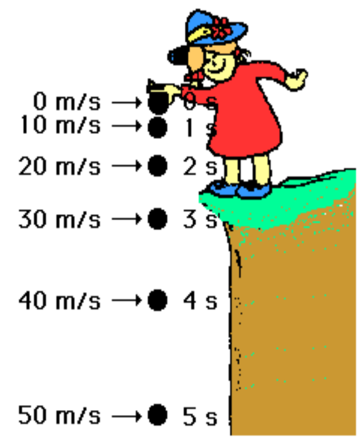


Distance = Area under graph
= b x h
= 4 x 20
= 80 m

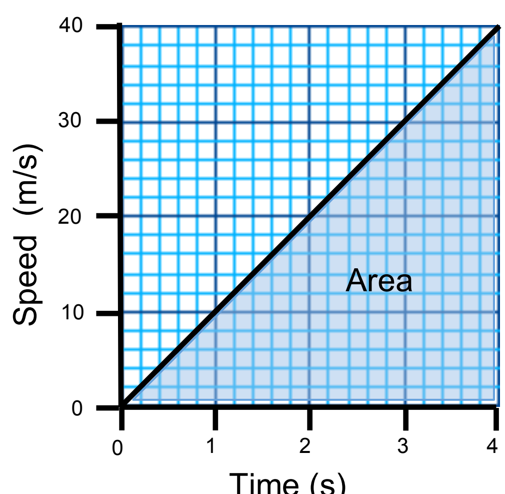
VERTICAL

A constant vertical acceleration

$a = 10\ m/s^2$ at all times



The vertical range can be found by plotting a velocity – time graph of the motion.



Distance = Area under graph
= ½ x b x h
= 0.5 x 4 x 40
= 80 m

Horizontal

The **horizontal** motion is at a **constant velocity** since there are no unbalanced forces acting horizontally (air resistance can be ignored).

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

Symbol	Name	Unit	Unit Symbol
s	Displacement	metre	m
v_H	Horizontal velocity	metres per second	ms^{-1}
t	Time	second	s

Horizontal distance travelled = horizontal velocity x time in the air. ($s = v_H \times t$)

Vertical

The **vertical** motion is one of **constant acceleration** due to gravity. ($a = 10\ ms^{-2}$).

$$v = u + at$$

Symbol	Name	Unit	Unit Symbol
u	Initial Speed	metre	m
v	Final speed	metres per second	ms^{-1}
a	Acceleration	metres per second per second	ms^{-2}
t	Time	second	s

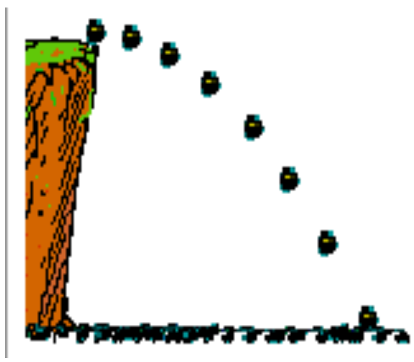
The **vertical** motion is one of **constant acceleration** due to gravity, equal to a_g.

For projectiles which are projected **horizontally, the initial vertical velocity is zero.**

For vertical calculations, use $a = (v-u)/t$, where **$u = 0$** and **$a = g = 10\ ms^{-2}$.**

Worked Example

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. What horizontal distance did it travel in the 2 seconds?

$S_H = ?$

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

$t = 2\ s$

$S_H = v_H \times t$

$S_H = 5 \times 2$

$S_H = 10\ m$

b. What was its vertical speed just before it hit the ground ?

$u_v = 0\ m/s$

$v_H = ?$

$t = 2\ s$

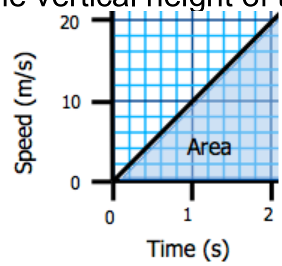
$a = 10\ ms^{-2}$

$a = (v-u)/t$

$10 = v/2$

$v_v = 20\ ms^{-1}$

c. What was the vertical height of the hill? (use a speed time graph)

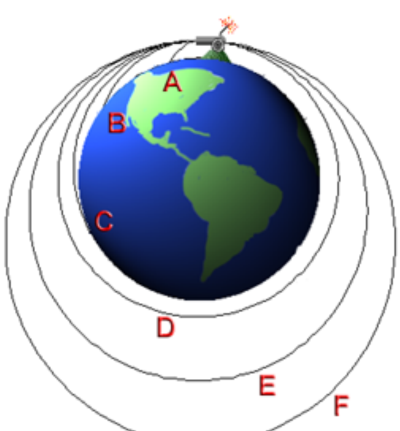


distance = area

$= 0.5 \times 2 \times 20$

$= 20\ m$

Projectiles at a height - Satellites



http://astro.unl.edu/naap/atmosphere/graphics/OrbitingCannonBalls.

When considering gravity, Isaac Newton conducted a thought experiment. He reasoned that if an object was fired from a high enough height, with enough horizontal velocity, it would fall back towards earth at the same rate as the Earth curved away from the object.

Newton was trying to explain that the **moon's orbit** was just an example of projectile motion.

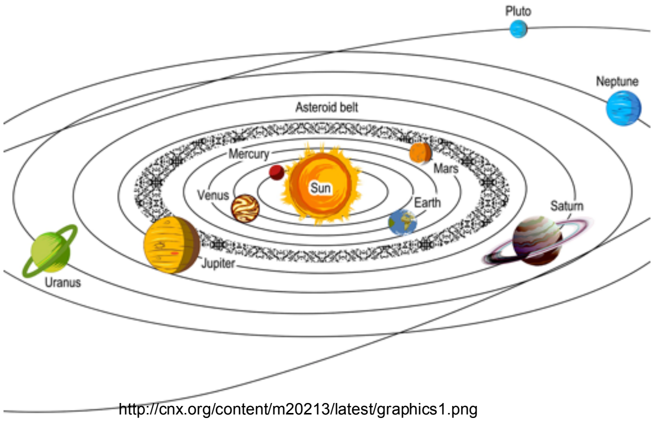
This same principle used for communications satellites **Geostationary orbits.**

Problems with Newton's Experiment.

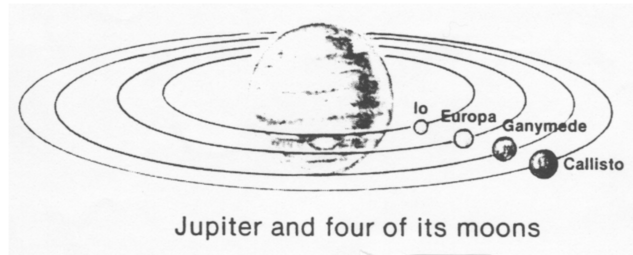
1. Newton did not allow for air resistance.
2. To stay in orbit, Newton calculated that a ball would have to be fired from 150 km above the Earth's surface (this would take it out of the Earth's atmosphere thus reducing the air resistance problem). However 300 years ago there was no conceivable way of getting anything that high up!

Natural Satellites

Planets are satellites of the star they orbit and moons are satellites of the planet they orbit.



http://cnx.org/content/m20213/latest/graphics1.png



http://www.is.wayne.edu/mnissani/a&s/Jupiter.gif

Artificial Satellites

The first artificial satellite (Sputnik 1) was launched by the Soviet Union on 4 October 1957. Many 1000's of satellites have been launched since then and there are currently approximately 3 500 in use (plus many thousands of bits of "space junk") orbiting the Earth.

The largest man made satellite is the International Space Station.

These satellites help make our lives safer, more convenient, provide entertainment and supply vast quantities of climate and meteorological data.

There are two types of artificial satellite orbit:-

Geostationary

A geostationary satellite remains above the same point of the earth's surface. It has a period of rotation of 24 hours. They maintain an orbit height of approximately 36,000 km above the surface of the Earth.

Polar Orbiting

These satellites have a low altitude and orbit around both the North and South Pole regions of Earth. These satellites are good for collecting climate data as information can be obtained at regular intervals throughout the day but not very appropriate for telecommunications as communication cannot be maintained for 24 hours a day from the same point on the earth's surface.

2. **Space Exploration**
    2.1. Evidence to support current understanding of the universe from telescopes and space exploration.
    2.2. Impact of space exploration on our understanding of planet Earth, including use of satellites.
    2.3. The potential benefits of space exploration including associated technologies and the impact on everyday life.
    2.4. Risks and benefits associated with space exploration, including challenges of re-entry to a planet's atmosphere.

$$E_h = Cm\Delta T$$

$$E_h = mL_v$$

Our Universe

Planets

Stars

Solar Systems

Galaxies

According to current estimates, the universe is approximately 13.8 billion (13.8×10^9) years old and consists of approximately 100 billion galaxies, each containing approximately 100 – 1000 million stars!!

How do we know this? Why are the numbers so approximate? How has the world benefitted from Space Exploration? Why are we still exploring Space?

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

Space Exploration

We have launched satellites, sent Man to the Moon and probes beyond the furthest planet in our solar system, built a Space Station that is visible from the ground, landed a "rover" on Mars; and launched the Hubble Space telescope, which has arguably produced the greatest pictures ever taken.

Although no manned missions to the Moon are currently planned, there are still thousands of people employed researching and developing the next generation of satellites, space station modules, probes, space telescopes and many other devices to aid our understanding of the universe.

Looking Up

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

http://icc.ub.edu/images/vla2.jpg

Understanding our planet

Weather Forecasting

Over 200 weather satellites carry equipment that allow real time detection of visible, infrared and microwave radiation. Weather satellites are either “Geostationary” or “polar orbiting”. The Geostationary satellites are used to photograph cloud cover, these images are then animated and used in weather forecasts on TV. The earth turns underneath the Polar orbiting satellites allowing full global data collection. Often these satellites are “sun-synchronous”, allowing data measurements to be recorded twice a day at the same point on the Earth’s surface at the same time each day.

Three polar-orbiting satellites working together can observe the entire planet every six hours. This allows a closer look at the Earth, producing images and measurements with a high resolution. These satellites are however always on the move and therefore do not allow continuous observation of a particular geographical area. Temperature, wind speed and direction, chemical content of the atmosphere, water vapour, cloud cover, precipitation, storms, and tropical cyclones can all be observed.

Environmental Monitoring

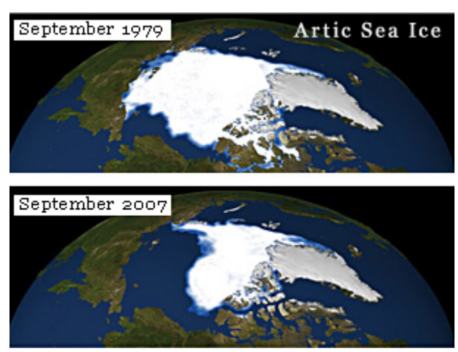
Satellites are ideal for observing the global environment, as they are capable of revealing and monitoring remote environments, hidden features, and even events that the human eye cannot detect. They provide reliable data 24 hours a day, seven days a week. Satellites can also monitor how winds disperse smoke from wildfires or ash from volcanic eruptions. Information on land surface temperature, winds, vegetation cover, bodies of water, human settlements, soil moisture, depth and extent of snow and ice can all be recorded.

Detail of the Oceans

Sea surface temperature, sea level height, ocean currents, and ocean winds are all monitored. It is also possible to monitor accidents, such as large oil spills, and periodic changes in the sea that affect global weather patterns, such as El Niño in the Pacific Ocean.

Climate Monitoring

Satellites are ideal for monitoring climate change because they can monitor the concentration of greenhouse gases in the atmosphere, such as aerosols, water vapor, carbon monoxide (CO), carbon-dioxide (CO2) and methane.



http://serc.carleton.edu/images/eyesinthesky2/week3/arctic_sea_ice_september_1263888610.jpg

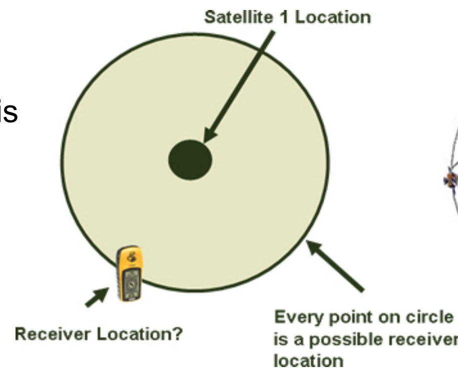
Satellite Imaging/Sensing

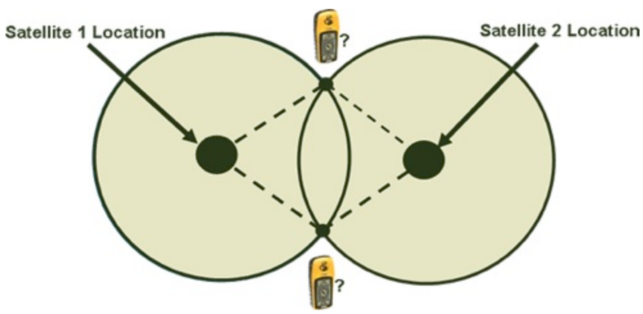
The IKONOS satellite has been used to obtain detailed imagery of military sites and nuclear facilities across the world. Coastal management, ground quality, irrigation, and many more applications can be found here http://www.satimagingcorp.com/services.html.

GPS

The GPS system uses 24 geostationary satellites transmitting microwaves to allow accurate determination of the position of an object. This includes a time stamp signal so by comparing multiple distance measurements, an object's velocity can be calculated.

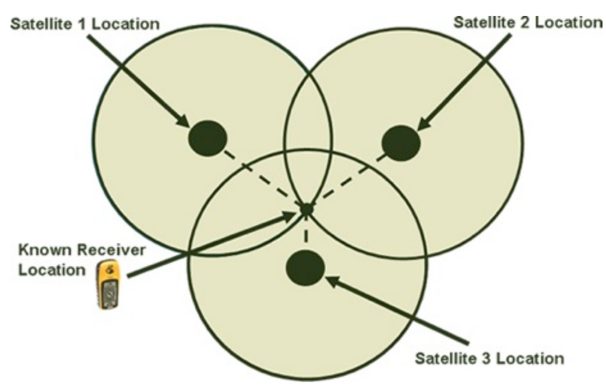
A GPS receiver finds its position by measuring the distance between itself and three or more GPS satellites (called trilateration). A microwave signal is sent out from one satellite to the GPS receiver, the receiver measures how long it took for the signal to reach it. The signal travels at a known speed, the receiver then uses the length of travel time for the signal to calculate a circular range of possible locations.





Using the signal from a second satellite, possible locations of the receiver on the ground are narrowed to the two points where the circles intersect as shown.

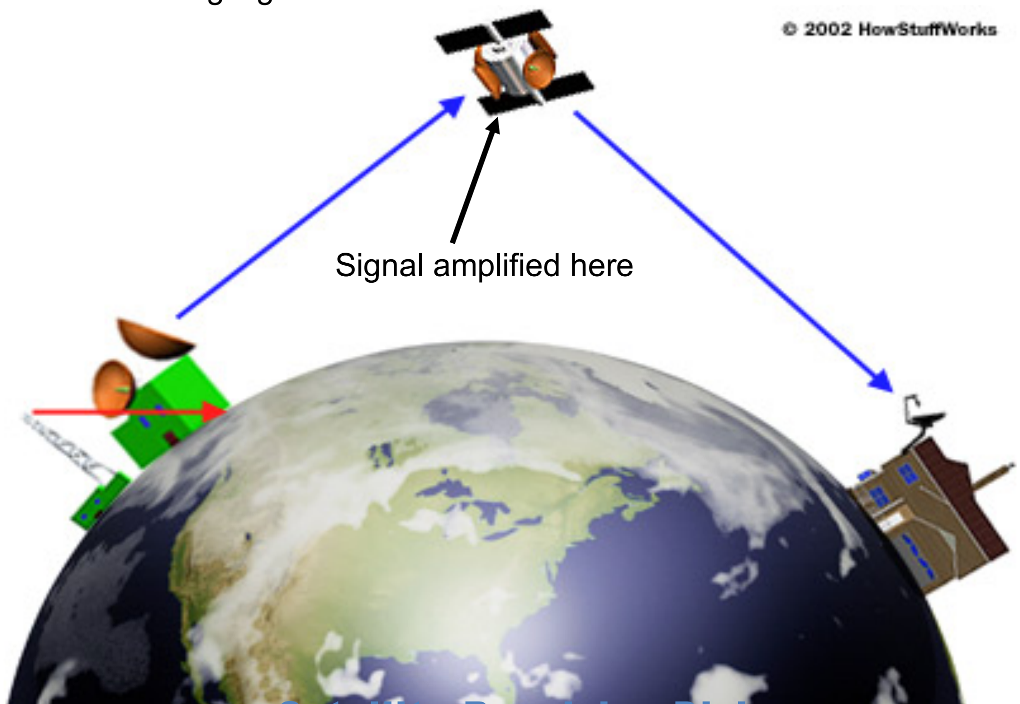
When a third satellite locates the receiver, an approximate location can be determined. Most GPS receivers give a location to within 100 metres using three satellites, but additional satellites will increase this accuracy. If four or more satellites are in range, the receiver can determine the user's position and elevation.



http://ibis.colostate.edu/DH.php?WC=/WS/CitSci/Tutorials_Wisconsin/Tutorial2_Static.html

Satellite Communications – Curved Reflectors In Action

Satellite dishes are designed to receive microwave signals from satellites. A satellite will have several receiving and several transmitting curved reflectors. Signals are **not** "bounced" off satellites. They are taken in (received), amplified and then retransmitted on a different frequency to avoid interference with the incoming signal.



Satellite Receiving Dish

The dish connected to a house is a curved reflector with a receiver placed at the focus of the curved dish. This dish reflects the signal transmitted from the orbiting satellite to the receiver located at the focus of the dish.

Radio Telescopes

http://www.vla.nrao.edu/images/tightcenter.small.jpg

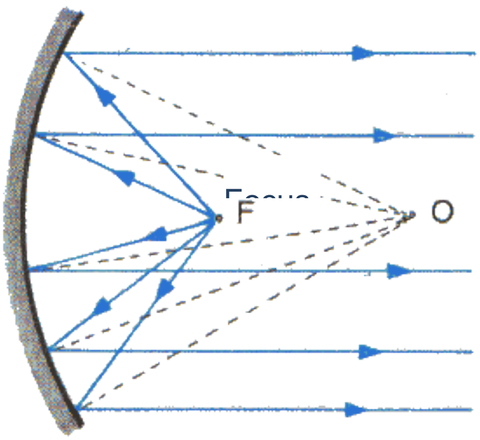
Radio astronomy is the study of celestial objects that emit radio waves. Astronomical phenomena that are invisible to the eye can be observed. Phenomena such as the Cosmic Microwave Background Radiation, which is the remnant signal of the birth of our Universe, the "Dark Ages" before the onset of the first stars and even the earliest generation of galaxies are observable using radio waves. Radio waves penetrate dust, so regions of space that cannot be seen in visible light can be investigated. Using radio telescopes astronomers analyse and explore the black holes that live at the hearts of most galaxies. These telescopes are huge curved reflectors designed to capture many radio waves. These are arranged in Very Large Arrays of many individual telescopes to allow improved resolution of data capture.

Curved Reflectors – In Detail

These can be used in transmitters and receivers of waves, e.g. sound, infrared, visible light, microwaves, TV signals and satellite communication.

The curved reflectors have a special parabolic shape that makes any waves that strike it reflect to the same point. This point is called the focus.

Transmitters



In a transmitter the transmitting device is placed at the focus of the parabolic reflector. The waves are emitted from the transmitter and are reflected off the curved reflector.

The special shape means that all the reflected waves come out in parallel straight lines. This makes it very good for sending the waves in a particular direction.

Outgoing waves are reflected out in a parallel beam

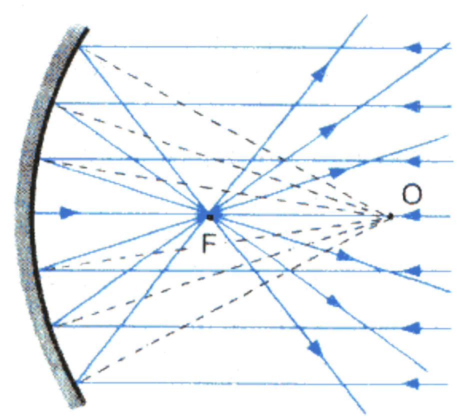
This is what happens in searchlights, torches and in microwave transmitters sending messages up to satellites.

Receivers

In a receiver the receiving device, such as an aerial, is placed at the focus of the parabolic reflector. The waves that strike the curved reflected are all reflected to the focus.

This makes the signal at the focus much stronger.
The curved "dish" can **gather more energy** from the wave and focus it onto the receiver.

Incoming waves are reflected to the focus.



Images from http://library.thinkquest.org/22915/reflection.html

Curved reflectors are used in satellite receivers, radio telescopes, solar cookers and in many other applications.

Technological Benefits of Space exploration

Many technological advances have been made in the pursuit of space travel. Some as a result of a requirement for new technology/materials, others due to a need to improve existing devices. These advances can then be applied to everyday life. Examples include in the fields of health and medicine, transportation, public safety, consumer goods, environmental and agricultural resources, computer technology and industrial productivity.

Technology	Use
Teflon-coated fiberglass	Developed for spacesuits now used worldwide as permanent roofing material in stadiums.
Liquid cooled spacesuits	Now used in portable cooling systems.
Lightweight breathing apparatus	Technology now employed by firefighters across the world
Stronger/safer school bus chassis	As a result of NASA technology from the space shuttle.
Robotic surgery	Originally developed for servicing spacecraft, robotics is now widely used in surgery and manufacturing.
Adaptation of the design of the fuel pump from the space shuttle.	Led to the LVAD - a device for maintaining the human heart's blood pumping capability during transplanting or while waiting for a donor organ.
Atomic Oxygen can gradually destroy materials used in satellites and spacecraft.	NASA developed a testing system to bombard items with atomic Oxygen, it was discovered that in a controlled manner this oxygen can clean microscopic dust from objects without damaging them. This technique is now used in non-contact ancient art restoration.
Multispectral imaging methods	Developed for investigating the surface of Mars. This is now used to analyse burnt objects to reveal writing that is not visible to the human eye.
Others include :- Developing power output of LEDs, infrared ear thermometers, Improvements in Artificial limbs, Invisible braces, scratch resistant lenses, development of the "Dustbuster" handheld vacuum cleaner, high performance silicon crystal solar cells, freeze drying, temper foam mattresses and many more.	

Technology is advancing rapidly, the sensors in satellite recording systems are significantly better than the equivalent technology available on the high street, however over time the research undertaken to produce the best equipment for a satellite can then be used to improve everyday items such as digital recording equipment.

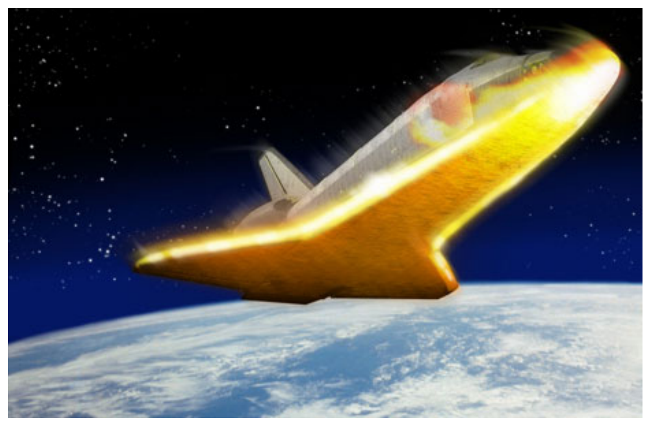
Risks of Space exploration

Space travel is not easy and there are many problems that can occur. Three astronauts were killed on the Apollo 1 mission when a space craft caught fire during testing. The first inflight disaster was the 1986 Challlenger disaster. A failure in the rings holding the solid rocket boosters allowed hot gases to escape leading to the break up of the external fuel tank. This caused the entire space craft to tilt towards the air stream and subsequently break up killing the crew of 7. The most recent U.S. disaster was the 2003 Columbia disaster. Due to a piece of insulation breaking off and damaging the leading edge of one of its wings the Columbia broke up in the atmosphere during re-entry.

Re-entry In Detail

As an aircraft moves through the air, the air molecules near the aircraft are disturbed and move around the aircraft. Exactly how the air re-acts to the aircraft depends upon the ratio of the speed of the aircraft to the speed of sound through the air.

As a spacecraft **re-enters** the earth's atmosphere, it is traveling very much faster than the speed of sound. The aircraft is said to be **hypersonic**. Typical low earth orbit re-entry speeds are near 7 820 ms^{-1} (approximately Mach 25).



The chief characteristic of re-entry aerodynamics is that the temperature of the air flow is so great that the chemical bonds of the diatomic molecules of the air are broken. The molecules break apart producing an electrically charged plasma around the aircraft. During re-entry the aircraft is actually an un-powered glider. The heat energy is so great (temperatures can reach 1650 ^{o}C) during re-entry that a special **thermal protection system** is used to keep the spacecraft intact.

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

The Soyuz, Shenzhou, and all of the early Apollo, Gemini, and Mercury spacecraft used a thermal protection system that is different to the Space Shuttle. Each of these older spacecraft use an **ablative**, **or "burning"**, heat shield. This heat shield is made of special ceramic materials and is designed to slowly burn away as it encounters the high temperature. Large amounts of energy are required to change phase from solid to liquid (and then to gas) therefore reducing the energy that can reach the skin of the spacecraft therefore protecting the astronauts from the heat of re-entry.

When you supply heat energy to a material two separate effects can take place.

The kinetic energy of the material's molecules increases and therefore the temperature of the material increases.

OR

The bonds between the molecules in the material change and the material changes state from solid to liquid [melting] or from liquid to a gas [vapourising].

The **space shuttle** missions used the first method and the **Apollo space** missions used the second effect for cooling.

Change of Temperature and Specific Heat Capacity

The same mass of different materials will heat up at different rates. The temperature rise will depend on the amount of energy supplied, the mass of the material and what the material is.

The temperature rise, ΔT, will be proportional to the amount of energy, E, and inversely proportional to the mass, m.

$$\Delta T \propto \frac{E_h}{m}$$

A constant of proportionality is required. This gives

$$E_h = mc\Delta T$$

Symbol	Name	Unit	Unit Symbol
E_h	Heat Energy	Joule	J
m	Mass	Kilogram	kg
c	Specific Heat Capacity	Joules per kilogram degrees Celsius	J/kg^0C
T	Temperature	Degrees Celsius	^0C

The constant, **c**, is called the **specific heat capacity**. This formula should be used whenever a material changes its temperature.

Definition

The **specific heat capacity** of a substance is the **amount of heat energy** required to **change the temperature** of **1 kg** of a substance by **1 °C**.

Why does the inside of space shuttle not get really hot?

The **same** mass of **different** materials needs **different** quantities of heat energy to change their temperature by one degree Celsius. A material with a **large** specific heat capacity will require **a lot of energy** to increase its **temperature** and will be able to store a lot of heat energy. The temperature of a material with a small specific heat capacity will rise more quickly and it will only be able to store a little heat energy.

The space shuttle is covered with specially designed heat tiles. These have a very high specific heat capacity, allowing the absorption of large amounts of energy with relatively little heat rise. In addition they have a very low density maintaining a low mass for the shuttle to reduce the required launch fuel.

Worked example - calculating specific heat capacity

A space shuttle tile of mass 5 kg is heated by using 6.28×10^6 J of energy. The temperature rises by 2000°C, calculate the specific heat capacity of the tile.

Solution

$E_h = 6\ 280\ 000$

$m = 5$

$\Delta T = 2000$

Equation $E_h = mc\Delta T$

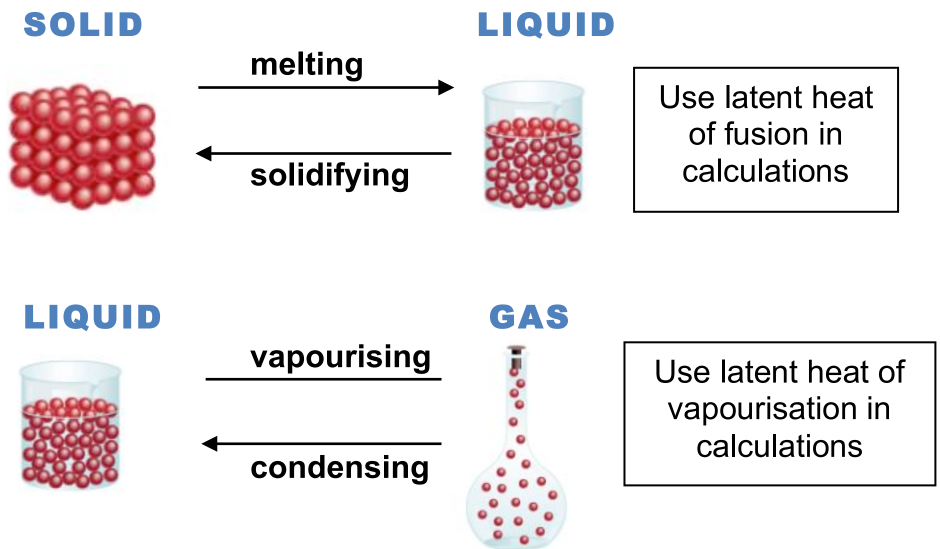
Substitute $6\ 280\ 000 = 5 \times c \times 2000$

Rearrange $c = 6\ 280\ 000/10\ 000$

Answer $c = 628\ \text{Jkg}^{-1\circ}\text{C}^{-1}$

Change of State and Latent Heats

A substance can undergo two changes of state.



http://science.taskermilward.org.uk/Mod1/Mod3/mod3img/Solid%20Liq%20Gas%20Parts.jpg

When a solid melts it requires extra energy to free the molecules into the liquid state. This extra energy involves **no change in temperature**.

When a liquid boils or vapourises it requires extra energy to free the molecules into the gaseous state.

When the change of state goes the other way energy is released with **no change in temperature**. When a gas condenses it gives off heat energy and when a liquid freezes it is also giving off heat energy.

The fact that a substance can gain or lose heat when it changes state, without a change in temperature is why this heat is called "latent". The word means hidden. The heat is used to rearrange the way the molecules are bound together without affecting their average kinetic energy, which is a measure of their temperature.

LATENT HEATOF **FUSION** (l_f) = the energy required to **melt or freeze** one kilogram of a substance with no change in temperature.

LATENT HEAT OF **VAPOURISATION** (l_v) = the energy required to **boil or condense** one kilogram of a substance with no change in temperature.

The specific latent heat of a substance is the energy involved in changing the state of 1 kg of the substance without any temperature change. Specific latent heat of a substance is calculated using the formula:

$$E_h = ml$$

Symbol	Name	Unit	Unit Symbol
E_h	Heat Energy	Joule	J
m	Mass	Kilogram	kg
l	Specific Latent Heat	Joules per kilogram	J/kg

The specific latent heat of **fusion** is the heat energy required to change 1 kg of a solid to liquid without change in temperature.

The specific latent heat of **vapourisation** is the heat energy required to change 1 kg of liquid to vapour without temperature change.

Units

The unit for specific latent heat is the joule per kilogram, J/kg.

Worked Example

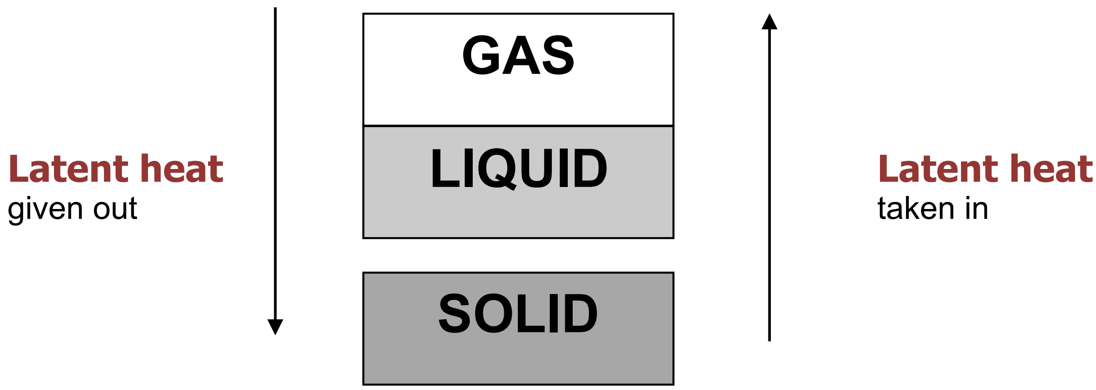
A mass of 2.5 kg of ammonia at its boiling point is vaporised when 6500 J of heat is supplied to it. Calculate the specific latent heat of vapourisation of ammonia.

Solution

E_h = 6 500	**E**quation	$E_h = ml$
m = 2.5	**S**ubstitute	6 500 = 2.5 x l
l = ?	**R**earrange	l = 6 500/2.5
	Answer	l = 2600 Jkg^{-1}

Latent Heat - Summary

When a substance changes its temperature it either gains or loses heat energy. When a substance changes its state it either gains or loses heat energy with no change in temperature.



If a question involves a substance changing temperature then use the equation **$E_h = mc\Delta T$**

If a question involves a substance changing its state then use the equation **$E_h = ml$**.

If a question involves a substance changing its temperature and a change in state then use both the equations and add the energies together.

Question involves ΔT	**Use $E_h = cm\Delta T$**
Question involves a change in state	**Use $E_h = ml$**

Worked Example
How much energy is required to melt 300 g of ice that is initially at -20 ºC?
Specific heat capacity of ice is 2100 $Jkg^{-1}{}^{o}C^{-1}$
Latent heat of fusion of ice is 3.34×10^5 Jkg^{-1}

Solution - Stage one – Heating from -20°C to 0°C

$E_h = ?$	**E**quation	$E_h = mc\Delta T$
$m = 300$ g $= 0.3$ kg	**S**ubstitute	$E_h = 0.3 \times 2\,100 \times 20$
$\Delta T = 20$	**R**earrange	
$c = 2\,100$	**A**nswer	$E_h = 12\,600$ J

Solution - Stage two – Melting 300 g of ice

$E_h = ?$	**E**quation	$E_h = ml$
$m = 0.3$ kg	**S**ubstitute	$E_h = 0.3 \times 3.34 \times 10^5$
$l = 3.34 \times 10^5$	**R**earrange	
	Answer	$E_h = 102\,000$ J

Therefore total energy required = 12 600 + 102 000 = 114 600J

Principle of Conservation of Energy

The total amount of energy remains constant during energy transfers. **Energy cannot be created or destroyed but simply transformed to one of its many forms.** The following example demonstrates this principle when it involves materials changing temperature or state.

Worked Example

A piece of brass of mass 2 kg is dropped onto a hard surface without rebounding resulting in a temperature rise of 1 ºC. Calculate the speed with which the brass hits the surface.

Solution

$m = 2$

$\Delta T = 1 ^\circ C$

$c = 390\ Jkg^{-1} {}^\circ C^{-1}$

$E_h = ?$

$v = ?$

Conservation of energy gives

$$E_h = mc\Delta T = E_K = \frac{1}{2} mv^2$$

$$c\Delta T = \frac{1}{2} v^2$$

$$390 \times 1 = 0.5\ v^2$$

$$v^2 = 780$$

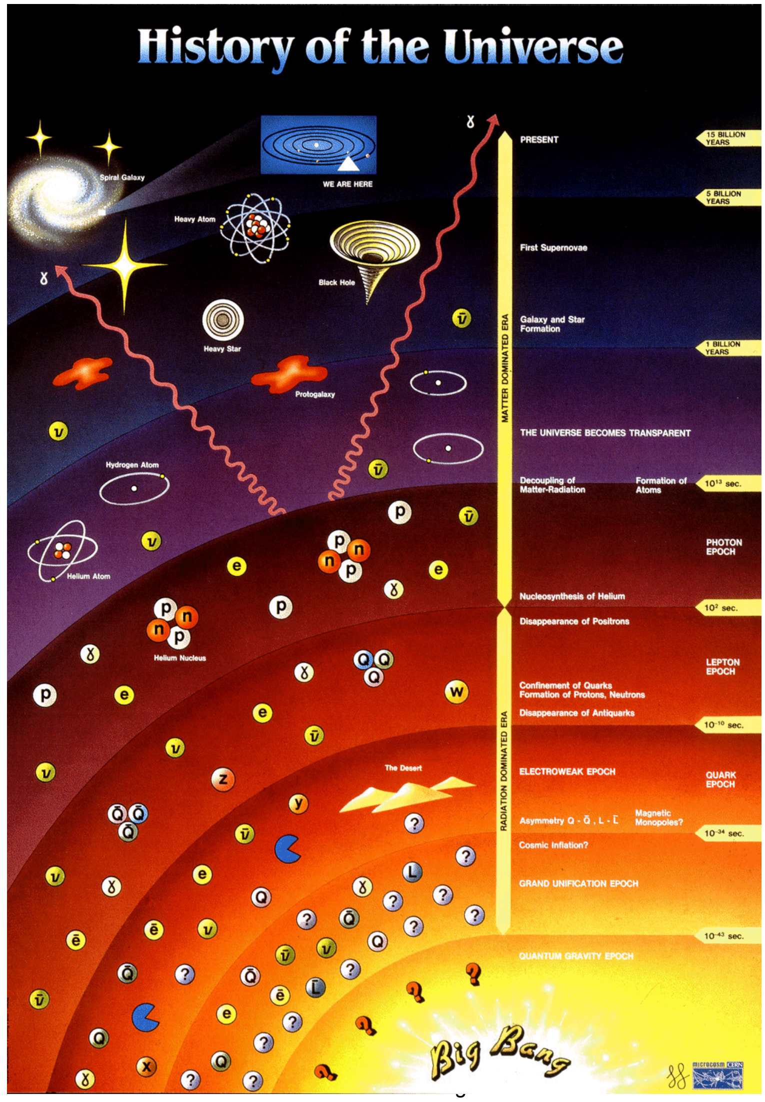
$$v = 27.9\ ms^{-1}$$

Cosmology

3. **Cosmology**
   - 3.1. Use of the term 'light year' and conversion between light years and metres.
   - 3.2. Observable universe — description, origin and age of universe.
   - 3.3. The use of different parts of the electromagnetic spectrum in obtaining information about astronomical objects.
   - 3.4. Identification of continuous and line spectra.
   - 3.5. Use of spectral data for known elements, to identify the elements present in stars.

The Universe

Scientific evidence indicates that we live in a finite but ever expanding universe. The universe started at a certain point in time and at that time all the matter, energy and space in the universe was squeezed into an infinitesimally small volume. Something caused a sudden and dramatic expansion, the story of this expansion has become known as the Big Bang Theory. It is just a model to describe what happened at the beginning but it was not an actual explosion. (The phrase "Big Bang" was introduced by accident when English astronomer Fred Hoyle used it as an insulting description of the theory he disagreed with). The Big Bang Theory is currently considered by many scientists as the most likely scenario for the birth of universe. The finer details of the early universe will continue to be revised as our understanding increases in years to come. Current best estimates are that the universe began 13.8 billion years ago.



What is the universe?

http://images.sciencedaily.com/2010/04/100413202858-large.jpg

The universe contains planets, which orbit stars (Solar systems). These stars exist in massive collections called galaxies. Galaxies exist in clusters (groups of galaxies) and these clusters exist in super clusters which are evenly dispersed across the whole of the universe.

http://www.le.ac.uk/ph/faulkes/web/images/galaxies.jpg

How Big is the Universe?

The Universe is massive, so big it is pretty much impossible to really imagine how big it is! It is estimated that the universe is at least 9.2×10^{26} metres wide. This number is too large to really comprehend, indeed all distances in the universe are huge. The Earth is approximately 150 million kilometres away from the Sun and approximately 39.9×10^{12} km away from Proxima Centauri (the nearest star to our Solar system). These numbers are just too big so astronomers use a longer standard unit of distance – **The Light Year**.

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

How many metres are in a light year?

d = ?
$v = 3 \times 10^8$ m/s
t = 1 year = 365 x 24 x 60 x 60
= 31 536 000 s

d = s x t
$d = 3 \times 10^8 \times 31\,536\,000$
$= 9.46 \times 10^{15}$ m

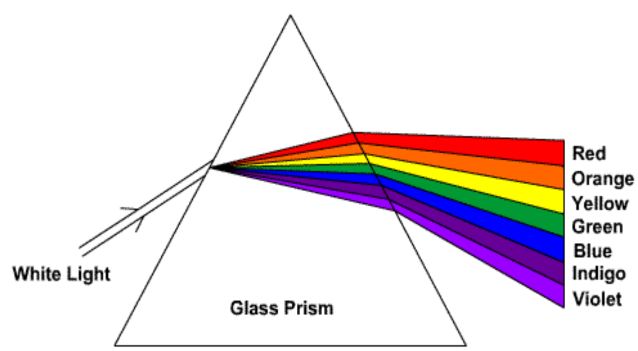
> *There are **9.46×10^{15} m** in a light year. You must be able to convert distances in light years into metres.*

How Do Scientists Know the Composition of the Universe?

The simple answer is by looking! Looking with our eyes we can see (on a very clear night) approximately 2000 stars in the night sky at any one time. However, using telescopes we can capture more light and so we can see stars that are not visible to the naked eye. This is when the fun really begins.

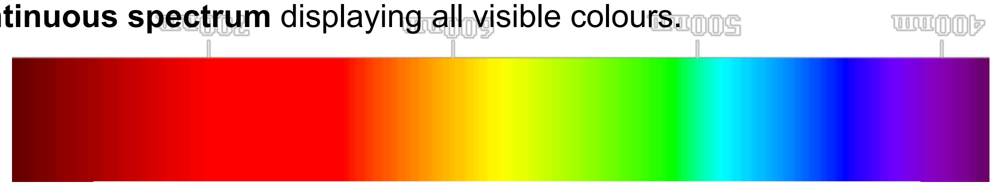
Most stars look white to the naked eye (some look blue or red) however much like when watching TV or using an energy efficient bulb our brain is being tricked. Red, blue and green light shone together look white. When white light is shone through a prism, a continuous spectrum is visible.

http://www.winsornewton.com/assets/hints_tips/Colour%20Mixing/add_colour.jpg



http://annandiluz.files.wordpress.com/2012/08/light_dispersion1.gif

Looking at this spectrum in details reveals all the visible colours as shown below. White light produces a **continuous spectrum** displaying all visible colours.



http://highered.mcgraw-hill.com/sites/dl/free/0072415932/9304/spectrumc.gif

All atoms give off **light** when **heated**, although sometimes this light is not visible to the human eye. (eg Infra red and UV). A **prism** can be used to split the light from the atoms to form a **spectrum**. Each element produces a distinctive and unique **line spectrum**. The coloured lines (or Spectral Lines) are a kind of "fingerprint" or “barcode” for the atoms. This technique is known as **spectroscopy**. A Spectroscope is a device that allows detailed spectra to be captured. Example spectra are given below.

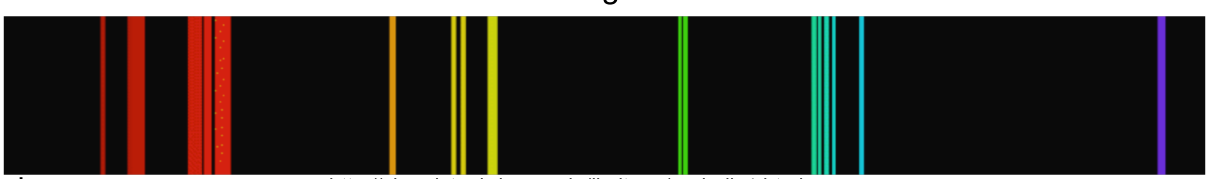
Hydrogen

Red Violet

Helium

Red Violet

Nitrogen



Red http://chemistry.bd.psu.edu/jircitano/periodic4.html Violet

As can be seen above, each atom has its own colour spectrum.

A gas can also absorb energy, the emission and absorption lines appear in the same position but for an absorption spectra we see dark lines as shown below. It is the absorption lines that are used to identify gases within stars. Shown below is the absorption spectra for hydrogen.

Using the Rest of the Electromagnetic Spectrum to Investigate the Universe.

Observations of light from other parts of the e.m. spectrum have allowed a greater understanding of the origin, composition and history of the Universe.

Range of em spectrum	Information gained
Gamma rays & x rays	Extremely high energy particles, cosmic explosions, high speed collisions can be detected. Material moving at extremely high speeds emit these rays. Some emanate from supernovae remnants.
Ultra-violet	Very young massive stars, some very old stars, bright nebulae, white dwarfs stars, active galaxies and quasars shine brightly in the ultraviolet region.
Visible	Chemical composition of the stars, particles at the outer edges of nebula
Infra Red	Infrared observations are used to peer into star-forming regions and into the central areas of our galaxy. Cool stars and cold interstellar cloud are detected.
Radio Waves	The study of the radio universe brought us the first detection of the radiation left over from the Big Bang. Radio waves also bring us information about supernovae, quasars, pulsars, regions of gas between the stars, and interstellar molecules.

Useful links
http://www.atlasoftheuniverse.com/index.html

http://www.universetoday.com/13507/what-is-the-biggest-star-in-the-universe/

http://www.launc.tased.edu.au/online/sciences/physics/linespec.html

http://www.mhhe.com/physsci/chemistry/essentialchemistry/flash/linesp16.swf

Example Spectra - http://www.colorado.edu/physics/2000/quantumzone/index.html

Tutorial Problems on Projectiles

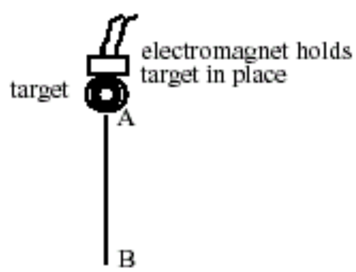
1. A stone thrown horizontally from a cliff lands 24 m out from the cliff after 3 s. Find:
   a) the horizontal speed of the stone
   b) the vertical speed at impact.

2. A ball is thrown horizontally from a high window at 6 m/s and reaches the ground after 2 s. Calculate:
   a) the horizontal distance travelled
   b) the vertical speed at impact.

3. An aircraft flying horizontally at 150 m/s, drops a bomb which hits the target after 8 s. Find:
   a) the distance travelled horizontally by the bomb
   b) the vertical speed of the bomb at impact
   c) the distance travelled horizontally by the aircraft as the bomb fell
   d) the position of the aircraft relative to the bomb at impact.

4. A ball is projected horizontally at 15 m/s from the top of a vertical cliff. It reaches the ground 5 s later. For the period between projection until it hits the ground, draw graphs with numerical values on the scales of the ball's:
   a) horizontal velocity against time
   b) vertical velocity against time
   c) From the graphs calculate the horizontal and vertical distances travelled.

5. In the experimental set-up shown below, the arrow is lined up towards the target. As it is fired, the arrow breaks the circuit supplying the electromagnet, and the target falls downwards from A to B.



   a) Explain why the arrow will hit the target.
   b) Suggest one set of circumstances when the arrow would fail to hit the target.
      It is assumed that the arrow is always lined up correctly.

Tutorial Problems on Space Exploration and Specific Heat

1. What is a satellite?

2. What is a geostationary orbit?

3. Explain the difference between an natural satellite and an artificial satellite.

4. What is a Galaxy?

5. What is a Star?

6. A large telescope array uses many curved reflecting dishes to receive signals from space.

7. What parts of the em spectrum are detected using large telescope arrays?

8. Show by means of a diagram how the em rays are received.

9. Explain, using a diagram how a curved reflector is used to transmit satellite TV images from a geostationary satellite to Britain.

10. How can a curved reflector be used to create a "solar cooker"?

11. There have been many technological advances due to space exploration, including infrared ear thermometers, scratch resistant lenses, high performance solar cells, freeze drying, robotic surgery etc. Pick any two technologies and research why they were developed for space and explain how they are benefiting the human race.

12. A satellite orbiting the Earth transmits radio signals to a receiver. The signals take a time of 150 ms to reach the receiver. What is the distance between the satellite and the receiver?

13. Explain what causes items of "space junk" to burn up on entry into the Earth's atmosphere.

14. Copy and complete the following sentence by selecting the correct words. Compared to infrared radiation, X-rays have a *longer/shorter* wavelength which means they have a *higher/lower* frequency.

15. The specific heat capacity of concrete is 800 J/kg0C. How much additional heat is stored in a storage heater containing 50 kg of concrete if the temperature is increased by 100^0C?

16. 1.344 MJ of heat energy is used to heat water from 20 0C to 100 0C. Calculate the mass.

17. 9600 J of heat energy is supplied to 1 kg of methylated spirit in a polystyrene cup. Calculate the rise in temperature produced.

18. When 2.0 x 104 J of heat is supplied to 4 kg of paraffin at 10 0C in a container the temperature increases to 14 0C.

a) Calculate the specific heat capacity of the paraffin.

b) Explain why the result in part a) is different from the theoretical value of 2200 J/kg0C.

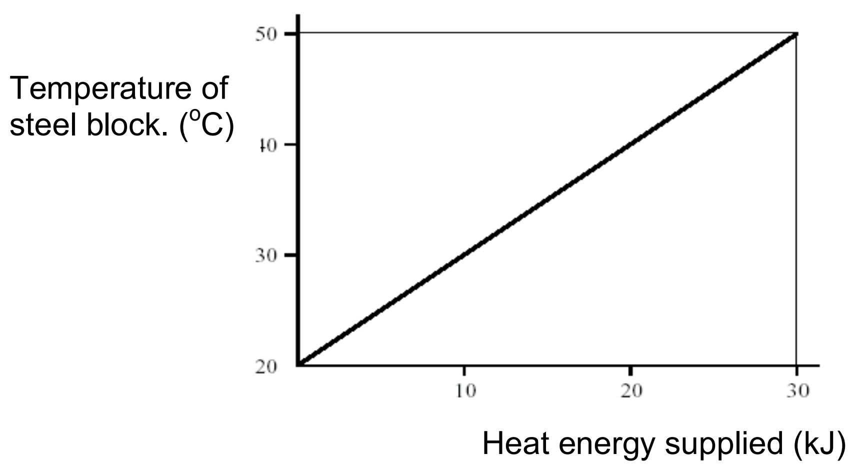
19. If a kettle containing 2 kg of water cools from 40 0C to 25 0C, calculate the heat given out.

20. The temperature of a 0.8 kg metal block is raised from 27 0C to 77 0C when 4200 J of energy is supplied. Find the specific heat capacity of the metal.

21. 10000 J of energy raises the temperature of 1 kg of liquid by 2 0C. How much energy will be required to raise the temperature of 4 kg of the liquid by 1 0C?

22. The tip of the soldering iron is made of copper with a mass of 30 g. Calculate how much heat energy is required to heat up the tip of a soldering iron by 400 0C.

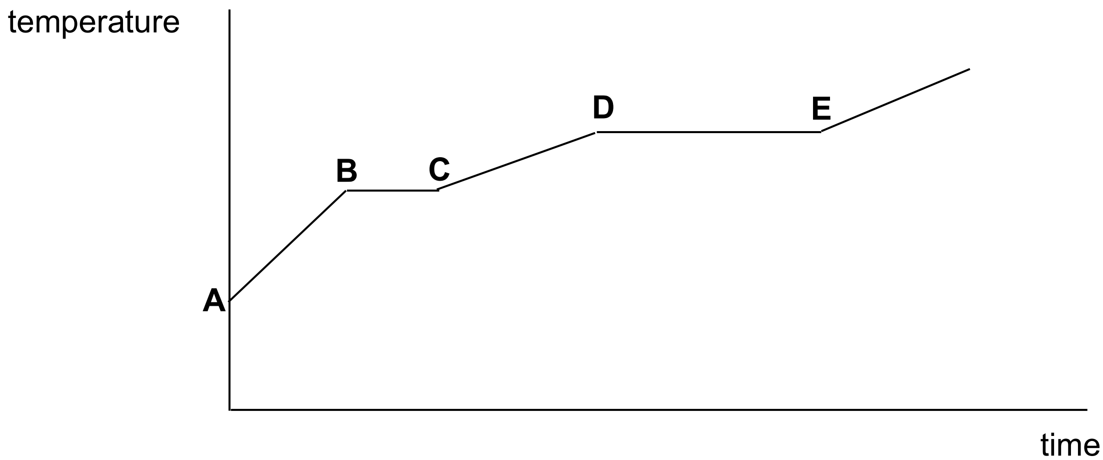
23. The graph below represents how the temperature of a 2 kg steel block changes as heat energy is supplied. From the graph calculate the specific heat capacity of the steel.



Tutorial Problems for Latent Heat

specific heat capacity of water is 4180 $Jkg^{-1}{}^{o}C^{-1}$
latent heat of fusion of ice is 3.34×10^{5} Jkg^{-1}
latent heat of vapourisation of water is 2.26×10^{6} Jkg^{-1}

1. Look at the graph below, which provides information on the temperature of a substance as it is being heated at a steady rate.



a) What is happening at the following parts of the graph? AB has been done for you.

AB A solid is increasing its temperature.

BC

CD

DE

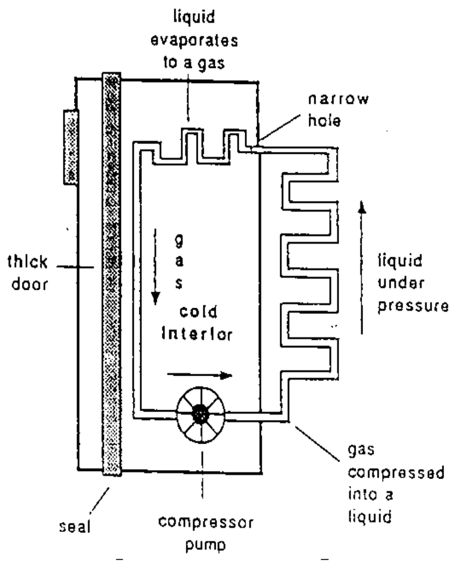
b) Does the solid or liquid state have the bigger specific heat capacity? Explain why.
c) Which latent heat is bigger? Explain why.

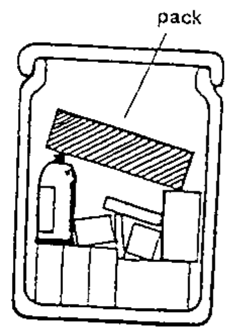
2. A steam burn is much worse than a burn from boiling water.
Do the following calculations to prove this.

a) Calculate the energy given out from 0.1 g of boiling water as it cools to 30 ^{o}C (skin temperature.)
b) Calculate the energy given out from 0.1 g of steam as it condenses to water at 100 ^{o}C.
c) What is the total energy release by 0.1 g of steam if it condenses and cools to 30 ^{o}C on your skin.
d) Explain why steam scalds are worse than scalds from water at the same temperature.

3. It is possible to produce an extremely cold drink in the dessert by filling a clay jar with water and then splashing the outside of the jar with more water several times. Explain why this cools the water inside the jar.
4. Explain how a fridge manages to transfer heat from inside the fridge to outside the fridge by changing the state of a refrigerant fluid called Freon.

See website http://www.ior.org.uk/science/fridge1/fridgediag.htm





5. a) Explain how freezer packs keep a cool box cold.

   b) Explain why the freezer pack should be placed on top of the food.

6. Explain why sports players often get a "freeze" spray put onto a muscular injury.

7. Calculate the amount of heat energy required to melt 0.3 kg of ice at 0 ^{0}C.

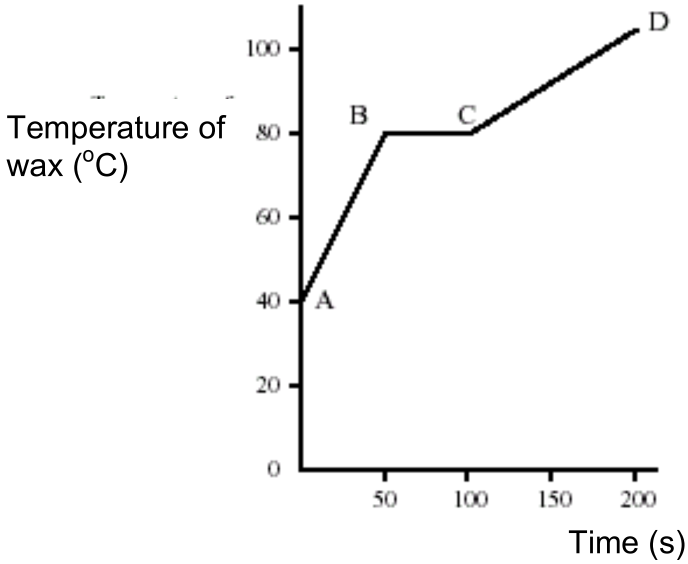
8. Calculate the specific latent heat of fusion of naphthalene given that 6 x 10^5 J of heat are given out when 4.0 kg of naphthalene at its melting point changes to a solid.

9. Calculate what mass of water can be changed to steam if 10.6 kJ of heat energy is supplied to the water at 100 ^{0}C.

10. Ammonia is vaporised in order to freeze an ice rink.
    a) Find out how much heat it would take to vaporise 1 g of ammonia.

    b) Assuming this heat is taken from water at 0 ^{0}C, find the mass of water frozen for every gram of ammonia vaporised.
    (Specific latent heat of vapourisation of ammonia = 1.34 x 10^6 J/kg)

11. The graph below shows how the temperature of a 2 kg lump of solid wax varies with time when heated.

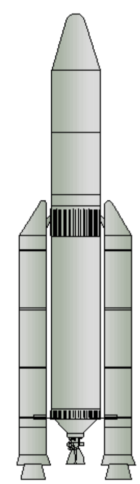


a) Explain what is happening to the wax in the regions AB, BC and CD.

b) If a 200 W heater was used to heat the wax, calculate the specific latent heat of fusion of the solid wax.

Tutorial Problems for Space Exploration and Energy

1. A multistage rocket jettisons its third stage fuel tank when it is empty. The fuel tank is made of aluminium and has a mass of 4 000 kg. (specific heat capacity of aluminium is 900 J/kg°C)



   a) Calculate the kinetic energy lost by the fuel tank as it slows down from 5 000 m/s to 1 000 m/s during its journey through the atmosphere.

   b) How much heat energy is produced?

   c) Calculate the rise in temperature of the fuel tank.

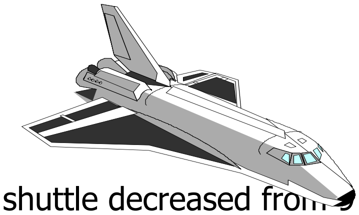
2. The space shuttle Columbia re-entered the Earth's atmosphere at a speed of 8 000 m/s and was slowed down by friction to a speed of 200 m/s. The shuttle has a mass of 2 x10^6 kg.

   a) How much kinetic energy did the shuttle lose?

   b) How much heat energy was produced during this process?

3. A space shuttle of mass 2 x 10^6 kg was travelling with a speed of 9 000 m/s as it entered the Earth's atmosphere. The speed of the shuttle dropped to 100 m/s at touch down, at which point

the brakes were applied, bringing the shuttle to rest.0



a) Explain why the speed of the shuttle decreased from 9 000 m/s to 100 m/s before the brakes were applied.

b) How much kinetic energy did the shuttle lose before the brakes were applied?

c) How much heat energy was created as the shuttle speed dropped from 9000 m/s to 100 m/s?

d) The shuttle was covered with special heat-resistant tiles. Why was this necessary?

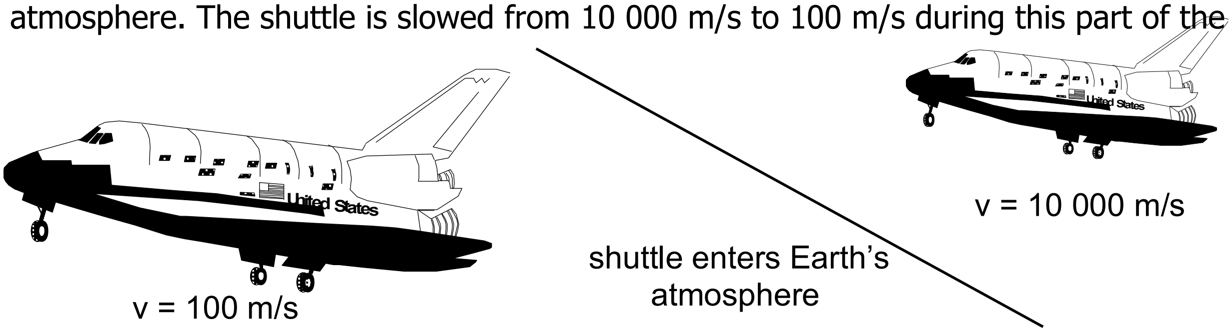
e) The specific heat capacity of the heat-resistant material used in the tiles is 35 700 J/kg^{0}C. The temperature of the tiles should increase by no more than 1 300 ^{0}C during re-entry.

What mass of tiles would be required to absorb all of the heat energy produced?

Explain why in practice the mass of the tiles was less than calculated in part (*e*).

How much work was done by the brakes to bring the shuttle to rest?

4. The nose section of the shuttle is covered with 250 kg of heat resistant tiles which experience a rise in temperature of 1 400 ^{o}C during the shuttle's journey back through the Earth's atmosphere. The shuttle is slowed from 10 000 m/s to 100 m/s during this part of the journey .



a) How much kinetic energy does the nose of the shuttle lose?

b) How much heat energy is produced at the nose during re-entry?

c) Calculate the specific heat capacity of the material used to make the nose tiles.

Tutorial Problems on Cosmology

1. What is a light year?

2. How many metres are in a light year?

3. Light from the Sun takes 8 minutes to reach earth.
   a) How many years is eight minutes?
   b) How far away is the sun (in metres)?

4. The star "Sirius" is 8.146×10^{16} m from Earth. How far is this in light years?

5. The dwarf planet Pluto is approximately 5.9×10^{12} m away from Earth, how many light years is this?

6. The nearest Galaxy to Earth is approximately 2.2×10^{6} light years away form Earth, how far is this in metres?

7. To the nearest billion years, how old is the universe?

8. State what is meant by the term solar system.

9. What is a planet?

10. What is a galaxy?

11. Radio waves emitted by galaxies are detected and used to provide images of the galaxies.
    a) How does the wavelength of the radio waves compare with the wavelength of light?
    b) Why are different kinds of telescope used to detect signals form space?

12. Read the following:-
    "Halley's Comet is famous because it is visible to the naked eye, orbiting from beyond the planet Neptune and returning to the solar system on average once every 76 years.
    Halley's Comet last visited the inner solar system in 1986. It will return again in 2061.
    Comets are made of ice mixed with frozen methane; substances very similar to those found on a moon called Miranda.
    Comets can only survive very far away from the Sun. Most comets reside in the Oort Cloud which contains many billions of comets. The Oort Cloud reaches a quarter of the distance from the Sun to the next nearest star called Proxima Centauri.
    The Oort Cloud is easily affected by the gravitational pull of the Milky Way galaxy which causes comets to move into new orbits that carry them closer to the Sun."

    Use information given in the passage to answer the following questions.
    a) State the name of one object that orbits a planet.
    b) State the name of one object that generates light.
    c) State the name of the object furthest away from the Earth.
    d) State the name of one object that orbits the Sun.

Answers to numerical problems

Projectiles

1. a) 8 m/s b) 30 m/s
2. a) 12 m b) 20 m/s

3. a) 1200 m b) 80 m/s c) 1200 m d) aircraft is above bomb
4. a) - b) - c) Horizontal – 75 m Vertical – 125m
5. a) - b) -

Space Exploration and Heat

15. 4 000 000 J
16. 4.019 kg
17. 3.8 ºC
18. a) 1 250 J/kgºC
19. 125 400 J
20. 105 J/kgºC
21. 20 000 J
22. 4 800 J
23. 500 J/kgºC

Latent Heat Problems

1.
2. a) 29.3 J b) 226 J c) 255 J
3.
4.
5.
6.
7. 100 000 J
8. 150 000 J/kg
9. 4.69 x 10^{-3} kg
10. a) 1 340 J b) 0.004 kg
11. 5 000 J/kg

Space Exploration and Energy

1. (a) 4.8 x 10^{10} J
   (b) 4.8 x 10^{10} J
   (c) 13 333 ºC
2. (a) 6.4 x 10^{13}J
   (b) 6.4 x 10^{13}J
3. (b) 8.1 x 10^{13} J
   (c) 8.1 x 10^{13} J
   (e) 1.75 x 10^{6} kg
   (g) 1 x10^{10} J
4. (a) 1.25 x 10^{10} J
   (b) 1.25 x 10^{10} J
   (c) 35 714 J/kgºC

Cosmology

1.
2. 9.46 x 10^{15} m
3. a) 1.52 x 10^{-5} b) 1.44 x 10^{11}
4. 8.61 ly
5. 0.00062 ly
6. 2.08 x 10^{21}
7. 14