REVISED HIGHER PHYSICS

REVISION BOOKLET

OUR DYNAMIC UNIVERSE

Kinross High School

Motion – equation of motion

Displacement is defined as the shortest distance between two points, with a direction. It is measured in metres or kilometres (depending on the problem given) with a direction (usually a bearing)

Velocity is defined as the **rate of change of displacement** and measured in ms^{-1}, with a direction.

$$\boxed{\bar{v} = \frac{d}{t}} \quad \left(average\ speed = \frac{distance}{time}\ ;\quad average\ velocity = \frac{displacement}{time}\right)$$

Remember: displacement and velocity are vector quantities: they have a size and a direction.

Acceleration is defined as the **rate of change of velocity** and measured in ms^{-2}.

$$a = \frac{v-u}{t} \quad (v = final\ velocity,\quad u = initial\ velocity,\quad t = time)$$

Equation of motion, of an object travelling at constant acceleration, in a straight line:

$\boxed{v = u + at}$ $\boxed{s = ut + \tfrac{1}{2}at^2}$ $\boxed{v^2 = u^2 + 2as}$

Remember: an object thrown upwards is decelerating, with ***a = -9.8*** ms^{-2}

an object falling downwards will accelerate, with ***a = +9.8*** ms^{-2}.

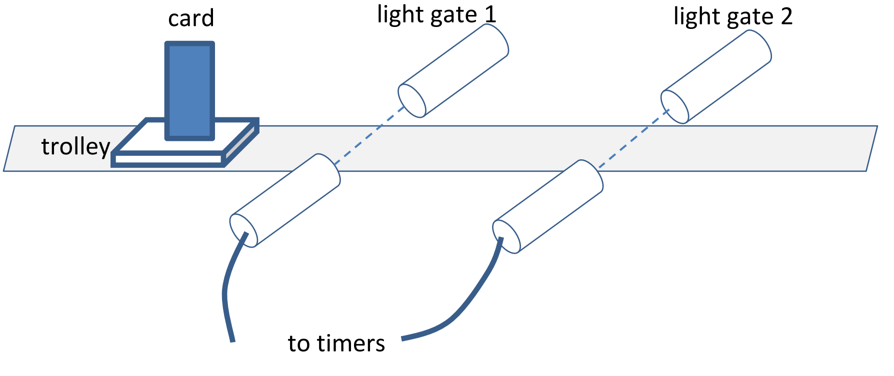
Directions: Take original direction/forwards as positive (+), backwards as negative (-). Take up as positive (+), down as negative (-)

Measuring acceleration:

- A card has a length L. It passes though light gate 1, causing the timer connected to that light gate to start timing.
- The timer stops when the card passes through the second light gate.
- The timer records, t_A – time to pass through light gate 1.
- The timer records, t_B – time to pass through light gate 2.
- The timer records, t – time taken between two light gates.

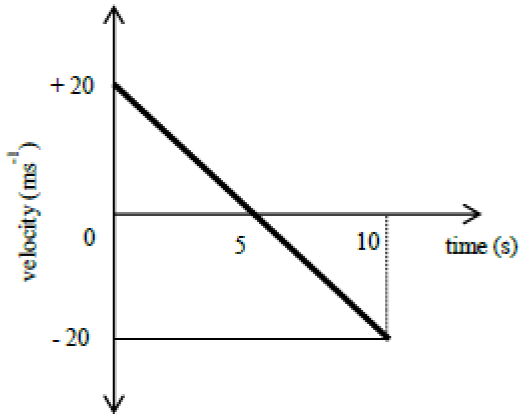
- Initial velocity: $u = L \div t_A$.
- Final velocity: $v = L \div t_B$.
- Acceleration:

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



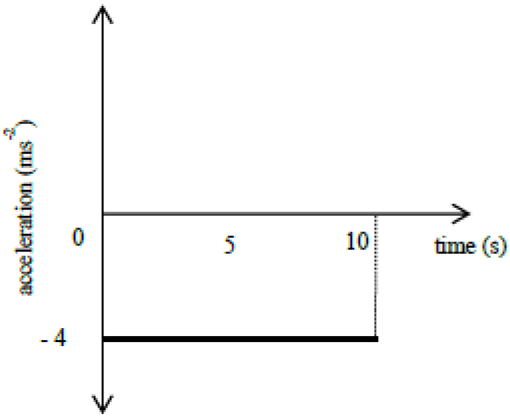
Graphs of an object travelling at a constant acceleration.

Velocity-time graph



- *The object changes its direction when t = 5s.*
- *The area under the v-t graph gives the displacement.*
- *From the above graph, the displacement = ½ x 20 x 5 = 50 m for the first 5 s.*
- *Between 5 to 10 s, the displacement = -50 m.*
- *Total displacement after 10 s = 0 m.*

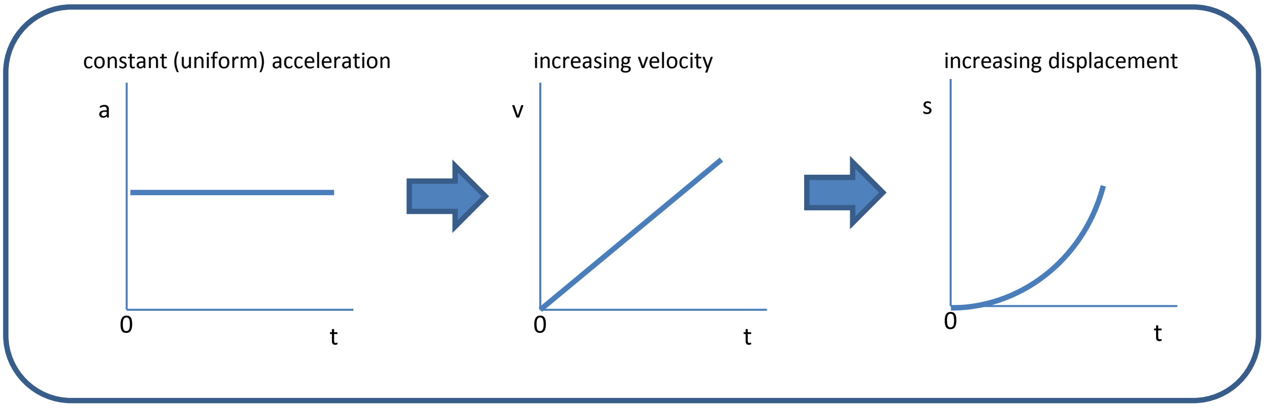
Corresponding acceleration-time graph

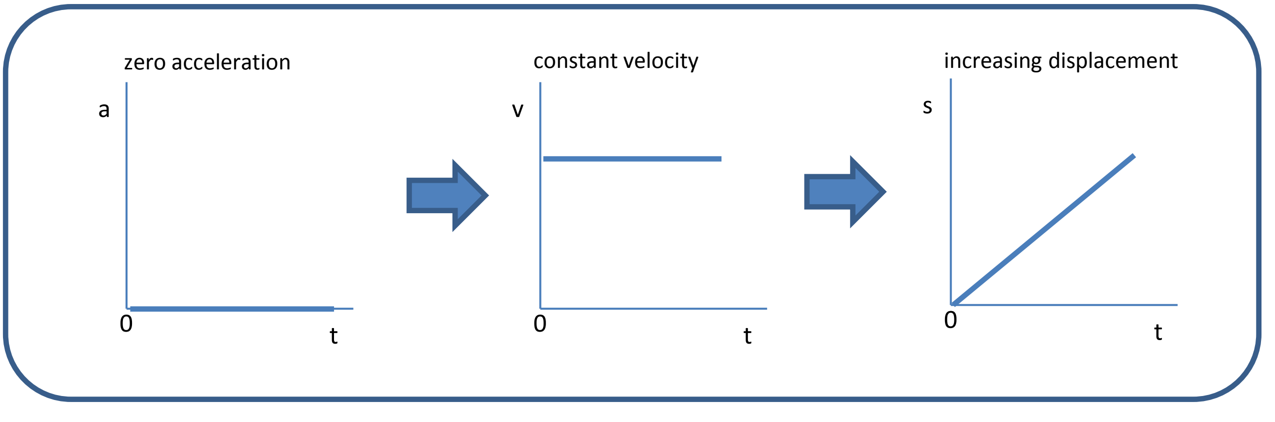


- *The gradient of the line on the v-t graph (on the left) gives the object's acceleration.*
- *Between 0 to 5 s, the object is decelerating along one direction.*
- *Between 5 to 10 s, the object is accelerating along the opposite direction.*

Recap on velocity-time graphs:

- The total displacement is worked out from the area under the graph.
- The gradient (slope) of each section gives the value of the acceleration for that section.
- If an object has a constant acceleration, then the gradient of the v-t graph will be constant.
- If the object is travelling at constant velocity, the gradient of the displacement-time graph will be constant.





Q

A ball is thrown upwards with an initial vertical velocity of 6 ms^{-1}. Calculate:

(i) maximum height reached (remember $v = 0\ ms^{-1}$)

(ii) time taken for it to reach its maximum displacement.

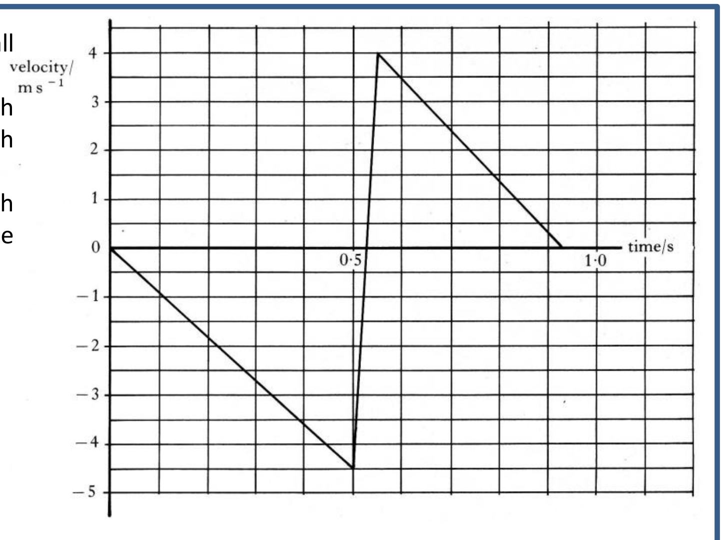
Answers: (a) 1.8 m (b) 0.61 s

Q

The velocity-time graph for a ball bouncing is shown below.

(i) Sketch, with numbers on both axes, the acceleration-time graph of the bouncing ball.

(ii) Sketch, with numbers on both axes, the displacement-time graph of the bouncing ball.

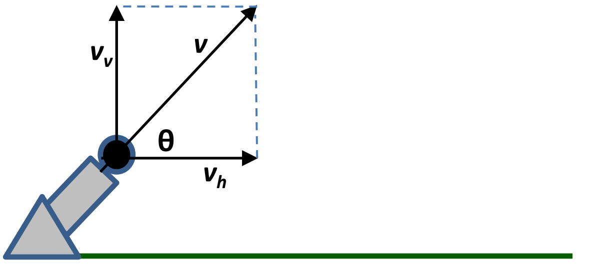


Resolution of vectors:

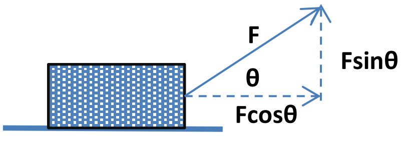
A vector quantity can be resolved into two components at right angles.

e.g. An object fired from the ground at an angle θ, with velocity, v.

Horizontal component: $v_h = v \cos \theta$
Vertical component: $v_v = v \sin \theta$

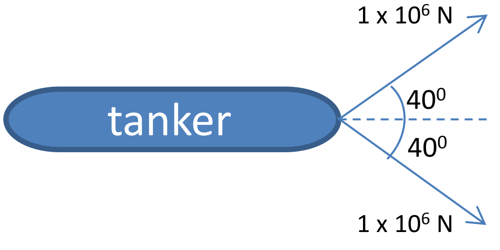


e.g. A resultant force, is found by vector addition (scale diagram or by calculation).
[Note: the term resultant force is the single force, which has the same effect as the sum of individual forces.]



Remember, when you are using scale drawing, make sure you introduce a scale, a head-to-tail diagram, with a resultant vector (from start to finish). If a bearing is used for the direction, then 000^0 is North.

Q Two tugs are pulling a tanker into dock. The angle between the two tow-lines is 80^0 and each tug exerts a pull of 1×10^6 N. Calculate the size and direction of the resultant force exerted by the tugs on the tanker?



Answers: 1.53×10^6 N, East

Forces, energy and power

Work done = energy transferred.

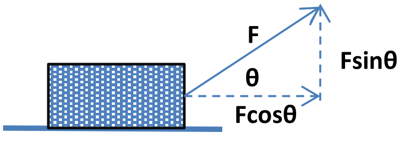
$$\boxed{W = E_w}$$

The work done on an object when a force is used to move an object a certain distance, d, is given by:

$$\boxed{E_w = Fd}$$

If the force is at an angle, θ, relative to the direction of the object's motion, then the work done is

$$\boxed{E_W = Fd\cos\theta}$$



Power is the **rate of doing work** or the **work done in unit time**.

$$\boxed{P = \frac{E_W}{t}}$$

Power is measured in watts (W) or joules per second (Js^{-1}).

If the problem involves a constant speed then

$$\boxed{P = \frac{E_W}{t} = \frac{Fd}{t} = Fv}$$

In problems involving flow rates assume a time of one second. The power will then be numerically equal to the energy e.g. 5 W = 5 Js^{-1}.

Potential energy:

The work done in raising an object, against the gravitational field is $\boxed{E_W = F\,d\ = (mg)h}$, where F is the weight of object being raised.

The work done = potential energy gained.

Kinetic energy:

When an unbalanced force is applied over a distance, the object will accelerate and the object's kinetic energy increases.

An apparent energy loss is usually due to work done against friction. This can be used to find the frictional force.

lost energy = F d

F – frictional force
d - displacement

Conservation of energy:

Energy is never created or destroyed, just changed from one form into another.

1. When a car accelerates from rest to a high speed, work changes to kinetic energy.

2. An apparent energy loss is usually due to work done against friction. This can be used to find the frictional force.

   lost energy = F d

   F – frictional force
   d – displacement

3. When a ball freefalls, through a height, *h*, its potential energy is converted to kinetic energy.

4. A skateboarder skates from one high hill to a lower one. The loss in potential energy will be converted into work done against the frictional forces, and the remainder is transferred to kinetic energy.

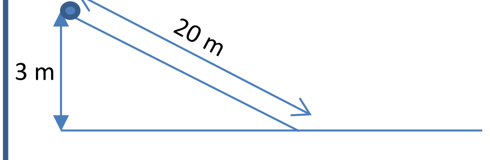
   $E_P = E_k + E_w$

   $mg(h_1 - h_2) = F_{friction} + \frac{1}{2} mv^2$

   If the skateboarder just reaches the second top of the hill, then E_k = 0 J.

When energy is transferred to the surroundings, it is usually in the form of **heat**. Energy is said to be degraded as it is hard to recover this energy.

Q A 500 g ball is placed on a slope as shown. It is 3 m high vertically but moves 20 m down the slope. At the bottom, it travels at 4 ms^{-1}. Show that the force of friction on the slope is 0.54 N.



Balanced forces:

Forces which are equal in size but opposite in direction are called **balanced forces**.
Balanced forces and no force gives the **same effect**.

Unbalanced forces:

The resultant of forces, which do not cancel out is known as the **unbalanced force.**
An unbalanced force causes **acceleration**.

Force:

1 N is the resultant (or unbalanced) force which causes a mass of 1 kg to accelerate at $1ms^{-2}$.

Newton's First Law of Motion
A body remains at rest or a constant velocity unless acted upon by an unbalanced force.

Newton's Second Law of Motion
The unbalanced force, F_{un} , is given as $\boxed{F_{un} = ma}$

Force in N, mass in kg and acceleration in ms^{-2}

Newton's Third Law of Motion

If A exerts a force on B, then B exerts an equal but opposite force on A.

Newton pairs are **equal in size but opposite in direction.**
For example: The balloon pushes the air out (action); the air pushes the balloon (reaction) in the opposite direction. Both forces occur at the same time.

The force of friction increases with velocity.

Q Sketch a velocity-time graph of a falling object when air resistance is present.

Weight:

Weight is a **force due to gravity**.

$\boxed{W = m\,g}$ g – gravitational field strength (Nkg^{-1}) is the **weight per unit mass**.

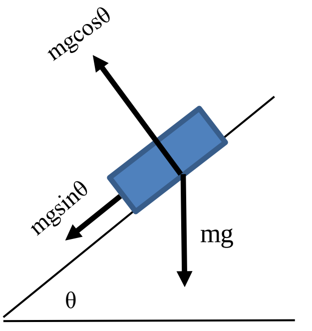
When dealing with vertical forces on an object, the object's weight must be included.

You should be able to sketch diagrams and identify the forces acting on the object.

Objects on a slope
For an object of weight W on a slope inclined at an angle θ to the horizontal (as shown):

Weight parallel to the slope = mgsinθ

Weight perpendicular to the slope (reaction) = mgcosθ



Q A 100 kg vehicle accelerates. The small engine force is 200 N, but friction exerts 50 N. Calculate the acceleration.

Answer: 1.5 ms^{-2}

Q A rocket of mass 9000 kg at take-off has a thrust of 180000 N. Calculate the acceleration.

Answer: 10.2 ms^{-2}

Q Calculate the acceleration of a 7 kg block, which is on a slope of 30^0, when there is a frictional force of 15 N.

Answer: 2.8 ms^{-2}

Q

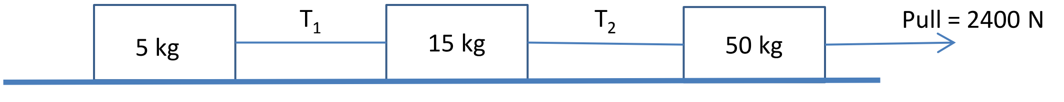
A 70 kg man stands on bathroom scales, in a lift.
Calculate the reading on the scales if the lift is:

(a) accelerating upwards at $2ms^{-2}$
(b) travelling upwards at a constant speed
(c) decelerating upwards at $2ms^{-2}$.

Answers: (a) 826 N (b) 686 N (c) 546 N

Q

The force of friction on each block is 100 N. Calculate the tension, T_1 and T_2, in the cables shown.



Answers: T_1 = 250 N T_2 = 800 N

Collision, explosion and impulse.

Momentum measures the motion of a body. Momentum is the product of **mass** and **velocity**.

Momentum: $\boxed{p = mv}$

Momentum is measured in **kgms^{-1}**.

Conservation of momentum:

The law of conservation of linear momentum states that in the absence of external forces, the total momentum before collision is equal to the total momentum after collision.

Explosions:

The **total momentum before explosion = total momentum after explosion**

Energy has to be put in to cause the explosion. Chemical or potential energy changes to kinetic.

The total kinetic energy before an explosion (so long as the object is initially at rest) = 0 J

The total kinetic energy after the explosion = $\frac{1}{2} m_1v_1^2 + \frac{1}{2} m_2v_2^2$

The kinetic energy after is greater than before. E_k is not conserved.

Inelastic collisions:

In an inelastic collision, **momentum is conserved but kinetic energy is not**.

Momentum: Total momentum before = total momentum after.

$$\boxed{m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2}$$

Energy: Energy is given out in the form of sound and heat.

The total kinetic energy before: $E_k = \frac{1}{2} m_1u_1^2 + \frac{1}{2} m_2u_2^2$

The total kinetic energy after: $E_k = \frac{1}{2} m_1v_1^2 + \frac{1}{2} m_2v_2^2$

The kinetic energy after is greater than before. E_k is not conserved.

Elastic collisions:

In an elastic collision **both momentum and kinetic energy are conserved**.

Momentum: **Total momentum before = total momentum after**.

$$\boxed{m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2}$$

Energy: Energy is conserved.

The total kinetic energy before: $E_k = \frac{1}{2} m_1u_1^2 + \frac{1}{2} m_2u_2^2$

The total kinetic energy after: $E_k = \frac{1}{2} m_1v_1^2 + \frac{1}{2} m_2v_2^2$

If the total kinetic energy before and after are the same, then we have an elastic collision.

The total energy is always conserved.

Q A 7 kg block travels at 9 ms^{-1}. It collides into a 4 kg block, initially moving at 3 ms^{-1}. After collision, the 7 kg block is slowed down to 4 ms^{-1}. Calculate the speed of the 4 kg block after collision.

Answers: 11.75 ms^{-1}

Q Calculate the recoil velocity of a 2 kg gun, which fires a 50 g bullet at 150 ms^{-1}.

Answers: -3.75 ms^{-1}

Q A 2 kg ball travelling at 10 ms^{-1} collides into a 10 kg ball travelling at 1 ms^{-1}, in the same direction. After collision, the 2 kg ball recoils at 5 ms^{-1}. Show that the collision is elastic.

Answers: 4 ms^{-1} , E_k before and after = 105 J

The impulse of a force is defined as the **force multiplied by the time for which the force acts:**

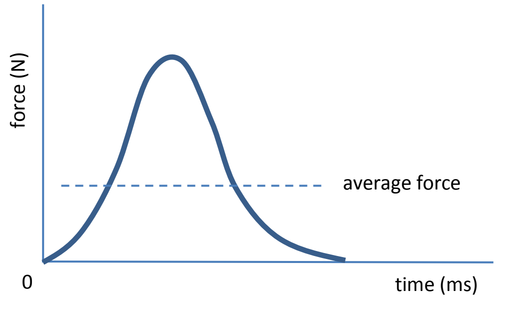
$\boxed{\text{Impulse} = F\,t}$ Impulse is measured in Ns or kgms^{-1}

From Newton's 2nd Law: $F = ma = m(v - u) \div t$

so $\boxed{Ft = mv - mu}$

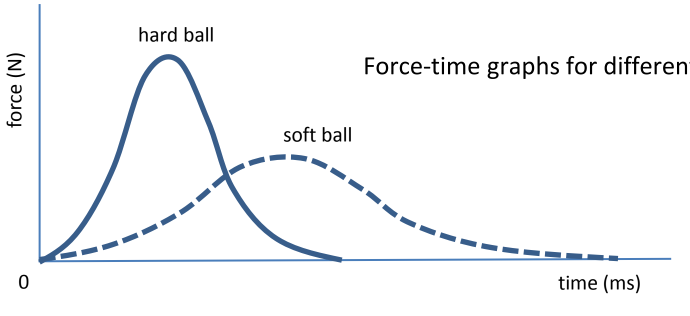
Impulse is equal to the **change in momentum caused by the force**.

Impulse (change in momentum) is given by the area under a force-time graph.



The applied force is not constant: it comes to a peak and then decreases.

A small force applied for a long time causes the same change in momentum as a large force applied for a short time. This effect is used for crumple zones in cars.



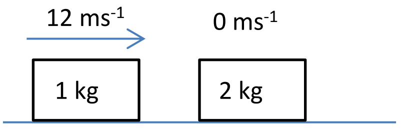
Force-time graphs for different ball types.

When you are doing calculations, the force calculated is the average force acting over the time of contact; the maximum force will be greater than this average value.

When two objects collide, the total momentum is conserved. However, since each individual object experiences a change in momentum, these changes must be equal but opposite.

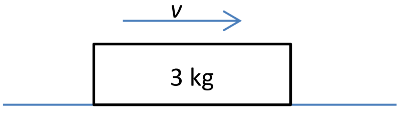
For example:

<u>Before collision</u>



Momentum = mv
= (1 x 12) + (2 x 0)
= 12 $kgms^{-1}$

<u>After collision</u>



Momentum = mv
= 3v

Since momentum is conserved in all collisions: 12 = 3v
v = 4 ms^{-1}

The change in momentum for object A is (4 - 12) = -8 $kgms^{-1}$
The change in momentum for object B is (8 - 0) = 8 $kgms^{-1}$.

This can be written:

$$(\Delta mv)_A = -(\Delta mv)_B$$

Since the change in momentum is equal to the impulse, this can be written as

$$(Ft)_A = (Ft)_B$$

Also, since the time of contact, t, is the same for both object A and B:

$$F_A = - F_B$$

i.e. the **forces are equal and opposite**.

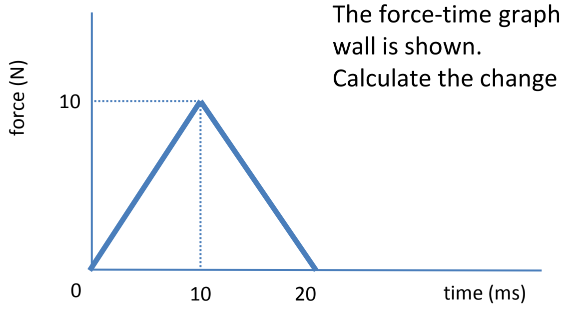
The Principle of Conservation of Momentum is another way of stating Newton's Third Law: "Action and reaction are equal and opposite."

Q

A golf ball of mass 50 g, initially at rest, is hit with a force of 1600 N. The time of contact between the ball and the club is 2 ms. Calculate the final velocity of the ball.

Answers: 64 ms^{-1}

Q



The force-time graph for a 2 kg ball in contact with a brick wall is shown.
Calculate the change in momentum.

Answers: 0.1 kgms^{-1}

Q

A 50 g golf ball is hit by a club and moves off at 18 ms^{-1}.
The ball is in contact with the club head for a time of 6 ms.
Calculate the: (a) force of the club on the ball
(b) force of the ball on the club.

Answers: (a) 150 N (b) -150 N

Gravitation.

Projectiles:

Projectile motion occurs when there is a **constant horizontal velocity** and a **constant vertical acceleration** (provided air resistance is ignored).

The vertical acceleration is **normally due to gravity**.

The horizontal and vertical motions are completely independent. The one factor they have in common is **the time of flight.**

The path traced out by the projectile is called a **trajectory**.

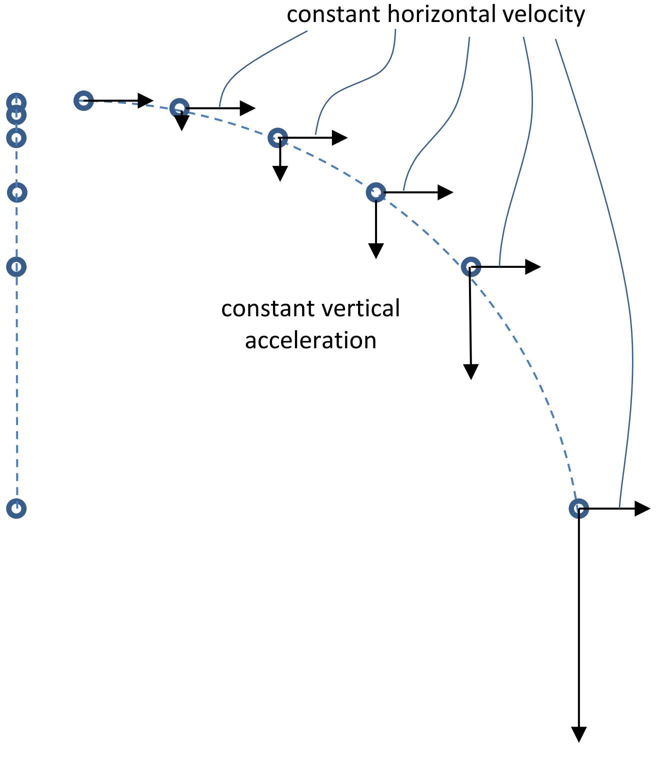
The trajectory for an object, with an upward vertical velocity, will be symmetrical – so long as air resistance is ignored. This means the object will hit the ground with the same vertical speed albeit in the opposite direction.

If an object is dropped from a moving vehicle, e.g. a box dropped from a helicopter, the initial velocity of the box is the same as that of the vehicle.

Since the trajectory is symmetrical, the total time of flight is double that of the time to the top. The total time of flight applies to both the horizontal and vertical motion.

Compare an object dropped vertically with an object projected horizontally. Provided air resistance is negligible, they should both take the same time to hit the ground.

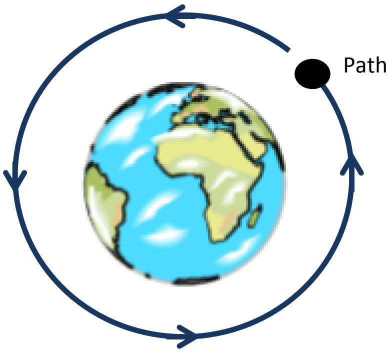
The resultant velocity can be calculated by vector addition.



Satellites:

Satellites remain in orbit around the Earth because:

1. They are travelling with an appropriate horizontal velocity that allows them to fall at the same rate as the surface of the Earth curves.
2. There is no air resistance and so it does not slow down.



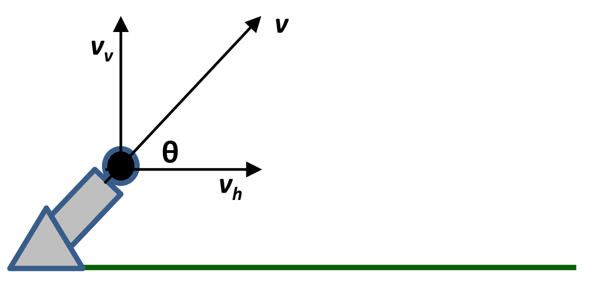
The orbital velocity of the satellite depends on its altitude above the Earth.

Satellites that take 24 hours to orbit around the Earth are called **geostationary satellites**. They generally orbit around the equator.

Satellites that do start to curve towards the Earth more than the Earth curves away, will eventually burn up as they start to make contact with some air particles in the upper atmosphere.

For an object launched at an angle, θ, to the horizontal, the object's velocity (v) is resolved into two components:

Horizontal component: $\mathbf{v_h = v \cos \theta}$
Vertical component: $\mathbf{v_v = v \sin \theta}$



In projectile motion, **the horizontal velocity is constant**, but the **vertical velocity changes**. At its maximum point, the vertical velocity is 0 ms^{-1}.

You can use any equation of motion to work out the maximum height.

For an object fired upwards, the vertical acceleration = -9.8 ms^{-2}.

To work out the height of the object, at any point above the ground, use $s = ut + ½ at^2$, where u is the initial vertical velocity, t is any time during its trajectory and a = -9.8 ms^{-2}.

Horizontal distance travelled = horizontal speed x time of flight.

Q

A ball is kicked horizontally at 5 ms^{-1} off a 45 m high cliff. Ignoring air resistance, calculate:

(a) the time taken for the ball to land;

(b) the distance the ball lands from the foot of the cliff, and

(c) the velocity just as the ball lands.

Answer: (a) 3 s (b) 15 m (c) 29.8 ms^{-1} at 80^0 below the horizontal

Q

A golf ball is hit at 38 ms^{-1} at an angle of 30^0 to the horizontal . Ignoring air resistance, calculate:

(a) the time taken for the ball to land;

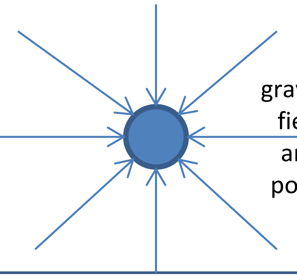
(b) the maximum height reached, and

(c) the range of the golf ball.

Answer: (a) 1.9 s (b) 18.4 m (c) 125 m

Gravity and mass

An object, which has a mass, has an associated gravitational field. Any other object, which is close up to that object will experience a gravitational force of attraction and both objects will move close to each other.
The bigger the mass of an object, the **stronger** its gravitational field.



How are stars formed?

1. Large clouds of dust build up together to form larger masses
2. As the mass increases, its own gravitation applies huge pressures on the atoms in the core
3. As this continues, and under the right conditions, the atoms in the core will undergo fusion and begin to radiate large amounts of energy.

The gravitational field strength is used to compare the gravitational force on a mass of 1 kg at various positions on planets.

On Earth, the gravitational field strength (g) is 9.8 Nkg^{-1}. A 1 kg mass will experience a force (due to gravity) of 9.8 N. This force is called the weight.

The weight of an object is worked out using the equation: $\boxed{W = m\,g}$

Examples of g: Sun – 274 Nkg^{-1} ; Mercury – 2.6 Nkg^{-1} ; Moon – 1.6 Nkg^{-1} ; Jupiter – 26 Nkg^{-1}`.

Remember: g decreases in size the further an object is from the surface of a planet.

The force experienced by objects close up to larger masses depends upon:

1. The mass of each object
2. The distance between them.

The equation used to calculate the gravitational force of attraction:

$$\boxed{F = \frac{G m_1 m_2}{r^2}}$$

where F – gravitational force between masses (N);
G is the Universal Gravitational constant ($6.67 \times 10^{-11}\ Nm^2kg^{-2}$)
m_1, m_2 – mass of two objects (kg)
r – distance between two masses (m).

This formula is suitable for objects placed at some distance away.

All planets/objects in our Solar System apply forces on each other and these forces combine to cause movement of planets, moons and asteroids. The Sun has the biggest influence, which extends beyond the Kuiper Belt (a region in the distant edges of the Solar System, where many objects are found.)

Q

The Earth has a radius of 6.38×10^6 m and has a mass 5.97×10^{24} kg. Calculate the gravitational force due to the Earth acting on a woman of mass 60 kg standing on the surface of the Earth?

Answer:587 N

Q

The weight of an object of mass m_1 can be defined as the gravitational field exerted on it by the Earth

$$m_1 g = \frac{G m_1 m_2}{r^2}$$

where m_2 is mass of the Earth and r is the radius of the Earth.

Calculate g on the surface of Earth, if $m_2 = 5.97 \times 10^{24}$ kg and $r = 6.38 \times 10^6$ m.

Answer: 9.78 Nkg^{-1}

Special relativity.

Galilean invariance:

The laws of nature are the same for all observers in a steady speed motion, relative to each other.
For example, an experiment done in a lab, on an island, would provide the same results if it was carried out on a ship at sea.

Newtonian relativity:

Newtonian relativity applies to low-velocity motions. Displacement is taken as a position from the origin; velocity is the rate of change of displacement, and acceleration is the rate of change of velocity.
Newtonian relativity works well for low-velocity motion. This theory works well on calculating trajectories in space.

It does not work well on very high velocity (i.e. at speeds at least 10% of the speed of light) motions.

Einstein's postulates:

To overcome the above problem, Einstein postulated the following:

1. The speed of light is a constant in every frame of reference.
2. The laws of nature are the same for all observers in a steady speed motion, relative to each other.

He used these to derive his Theory of Special Relativity. Einstein worked out that measurements of 'time' and 'length' made by a stationary observer differs from that of a moving observer. He discovered that the stationary observer would:

1. record time passing more quickly (time dilation)
2. measure the length of the moving object to be shorter than that measured by the moving observer.

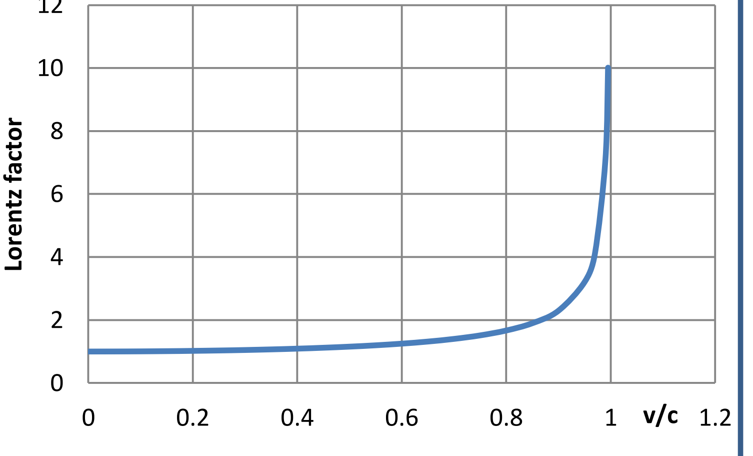
Remember, these results apply to a moving observer travelling at speeds close to that of light.

Lorentz factor:

The time dilation and length contraction is scaled by a factor, called the Lorentz factor, ϒ, which depends on the velocity, v, of the moving object relative to the stationary observer.

$$\boxed{\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}}$$

Note: when v is about 10% of c, then the Lorentz factor begins to rise. ϒ is at infinity when v = c.



Time dilation:

Time dilation is the difference in time interval as measured by a stationary observer and a moving observer.

The relationship for time dilation is given as:

$$t' = \frac{t}{\sqrt{1 - \frac{v^2}{c^2}}}$$

OR

$$t' = \gamma t$$

Length contraction:

Length contraction is the decrease in length (in the direction of motion) of an object moving relative to an observer.

The relationship for length contraction is given as:

$$l' = l\sqrt{1 - \frac{v^2}{c^2}}$$

OR

$$l' = \frac{l}{\gamma}$$

Q

A spaceship travels at a speed 0.7c relative to a stationary observer on Earth. The ship takes 10 years for this journey. Calculate the ship's journey time according to the observer on Earth.

Answer: 14 years

Q

A spaceship is 14 m in length. It travels at a speed of 0.995c relative to a stationary observer on Earth. Calculate the length of the ship according to the observer on Earth.

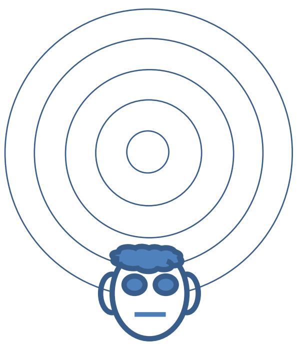
Answer: 1.4 m

The expanding Universe.

When an object (emitting sound) moves towards a stationary observer, an increase in frequency is heard. This is because there are more waves received every second. As the source moves away, the frequency heard decreases.

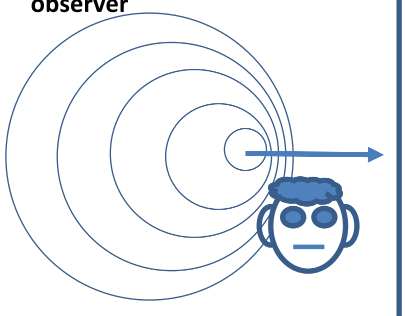
The Doppler effect is the **change in frequency** observed when a source of sound waves moves relative to an observer.

Source not moving



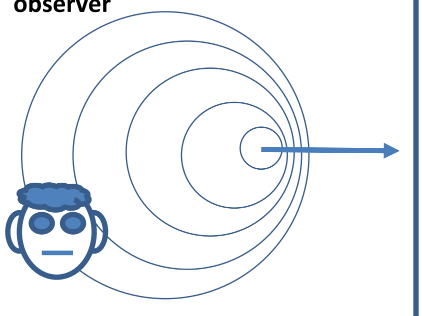
The source emits sound waves which spread out in a circular pattern. The number of wave-fronts per second, reaching the observer is kept the same, since the source is not moving.
A stationary observer will not hear any change in frequency.

Source moving towards observer



Waves bunch-up in front of the moving source.
A stationary observer will hear a higher frequency as the source approaches because more wave-fronts pass per second.

Source moving away from observer



Waves spread out behind the moving source.
A stationary observer will hear a lower frequency as the source moves away because fewer wave-fronts pass per second.

The speed of sound in air = v

The speed of the source = v_s

The frequency of the source = f_s

The frequency heard by the stationary observer = f_{ob}

For a source moving towards an observer:

$$f_{obs} = f_s \frac{v}{(v - v_s)}$$

For a source moving away from an observer:

$$f_{obs} = f_s \frac{v}{(v + v_s)}$$

Use of the positive or negative sign is best remembered by considering the physics.
Source moving TOWARDS – HIGHER frequency; moving AWAY – LOWER frequency.

Q

A motor bike, sounding its horn at 500 Hz, passes a stationary man near the road. The motor bike travels at 20 ms^{-1}.
Calculate the frequency of the notes heard by the man as the bike passes. State when these notes are heard. (Speed of sound in air = 340 ms^{-1}.)

Answer: towards observer 531 Hz; away from observer 472 Hz

The Doppler effect equations for sound cannot be used with light from fast moving galaxies because relativistic effects need to be taken into account.

The light from objects (such as galaxies) moving away from us will shift to longer wavelengths i.e. **towards the red part of the visible spectrum**.
The red-shift of a galaxy is the change in wavelength divided by the emitted wavelength.

$$\boxed{z = \frac{\lambda_{observed} - \lambda_{rest}}{\lambda_{rest}}}$$

For slow moving galaxies, redshift is the ratio of the velocity of the galaxy to the velocity of light.

$$\boxed{z = \frac{v}{c}}$$

Q

A moving galaxy emits light with a wavelength of 400 nm. The rest wavelength, of that light, is 480 nm.
Calculate (i) the galaxy's redshift
(ii) the speed of the galaxy.

Answer: (a) -0.167 (b) -5 x 10^{7} ms^{-1}

Hubble's Law.

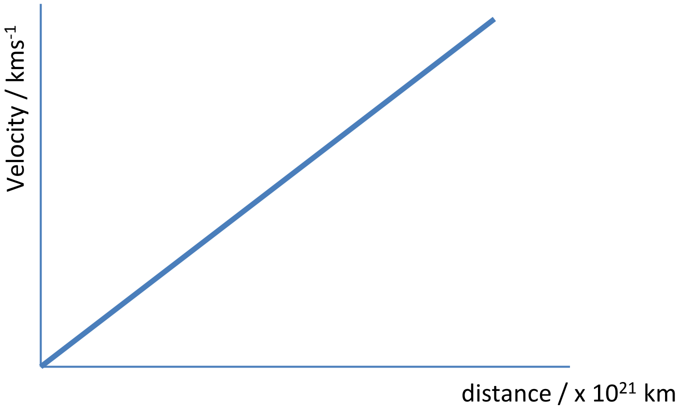
Hubble's Law:

This shows the relationship between the recession velocity, v, and its distance, d, from us.

He studied very bright stars and stated the relationship: $\boxed{v = H_0 d}$

Hubble discovered that further stars were moving away at a greater velocity than closer stars. This law suggests that the Universe is expanding. Matter was created and emitted from a single point. Objects moving quickly are at the extreme ends of the Universe; objects moving less quickly are 'nearest' to the explosion.

From observations of very distant stars, the constant H_0, is estimated to $2.3 \times 10^{-18}\ s^{-1}$.



If the rate at which the Universe expands is constant, then we can work out when the Universe began.

This means: time = distance ÷ speed

$\boxed{\text{time} = 1 \div H_0}$

Q Calculate when the Universe began.

Answer: 13.8 billion years

Q A star is travelling at a speed of 3.12 kms^{-1} relative to Earth. Calculate how far away the star is away from the Earth.

Answer: 1.36×10^{21} m

Expansion of the universe.

Measurements of the velocities of galaxies and their distance from us lead to the theory of the expanding Universe. Gravity is the force which slows down the expansion. The eventual fate of the Universe depends on its density.

There are three possible scenarios:

1. If the density of the Universe is **greater than the 'critical density'** then the Universe will shrink and lead to **the Big Crunch**;
2. If the density of the Universe is **equal to the 'critical density'** then the Universe will **expand at a slower rate**, and
3. If the density of the Universe is **less than the 'critical density'** then the Universe will **expand at a faster rate**.

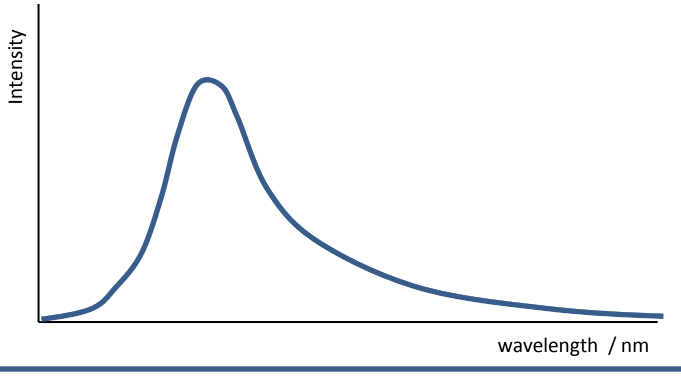
The orbital speed of the Sun and other stars allows us to work out the mass of our galaxy.
The Sun's orbital speed is determined almost entirely by the gravitational pull of matter inside its orbit. Measurements of the mass of our galaxy lead to the conclusion that there is a significant mass which cannot be detected, known as **dark matter**.

The Universe is expanding at an increasing rate. This means the Universe is getting bigger and bigger in size and there is something overcoming the force of gravity. This something is known as **dark energy**.

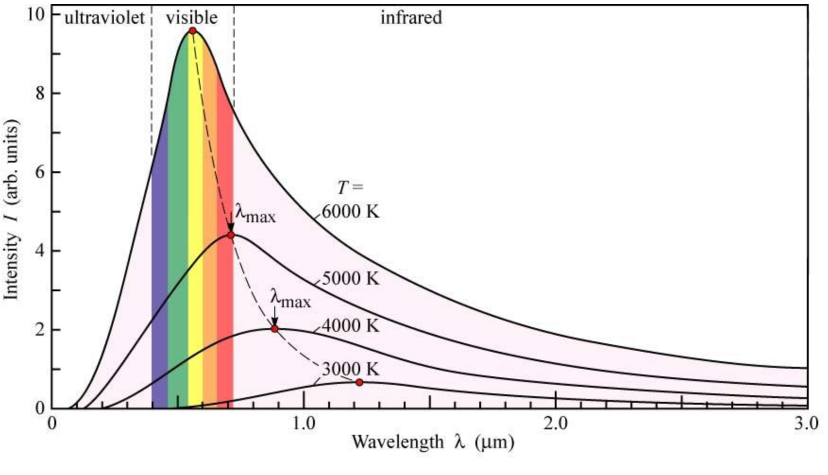
The Big Bang Model.

The temperature of stellar objects:

All stars are made up of a hot, dense interior and a cooler outer layer, or atmosphere. The interior of the star causes a continuous spectra, known as a blackbody spectrum. If there was no absorption or emission from the outer atmosphere, the star's spectrum would be close to a blackbody spectra.
The blackbody curve (below) represents the intensity of radiation emitted over all possible wavelengths.
A metal glowing red hot in a furnace is an example of blackbody radiation.
The shape of the blackbody spectrum depends on the temperature of the body.



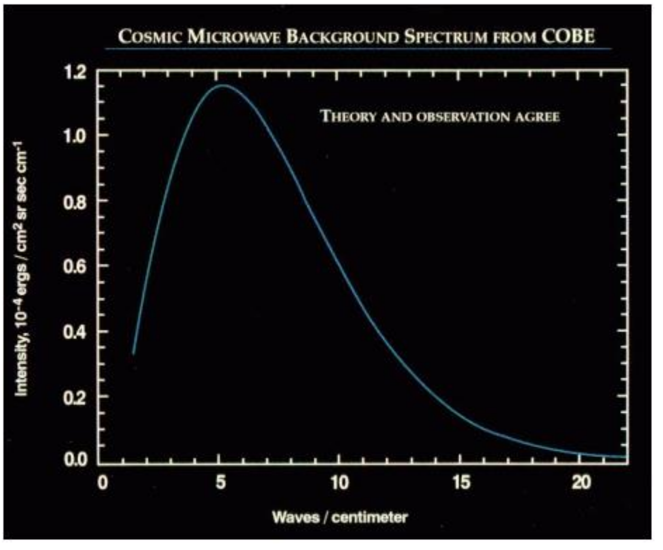
Although the distribution of energy is spread over a wide range of wavelengths, each object emitting radiation has a peak wavelength which depends on its temperature. From the diagram below, the peak wavelength is shorter for hotter objects than for cooler objects.



Also, hotter objects emit more radiation per unit surface area at all wavelengths than cooler objects.
It is possible to measure the temperature of a star, simply by measuring the intensities of the various wavelengths of light it emits. Note that the peak wavelength moves to the left of the graph and the area under the curve becomes larger as the star's surface temperature increases.

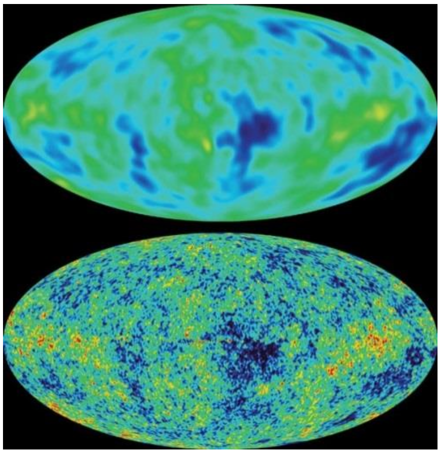
Evidence for the Big Bang

The Universe **cools down as it expands**. At the same time, the **wavelength of photons** (produced during the Big Bang) **was similarly expanded**. This radiation exists today as the **cosmic microwave background radiation**. This type of radiation is uniformly distributed across the Universe and it should have a radiation intensity curve like a blackbody radiator with a predictable peak wavelength. The peak wavelength of cosmic microwave background (CMB) allows the present temperature of the Universe to be determined. This temperature corresponds to that predicted after the Big Bang, taking into account the expansion and cooling of the Universe.



Other evidence for the Big Bang includes:

1. the observed abundance of the elements hydrogen and helium and
2. the darkness of the sky (Olber's Paradox). Olber's paradox states that no matter which part of the sky you are looking at, it will always reach a star. If that is the case, then the sky should be lit up all the time – but it isn't i.e. a paradox.



NASA's improving view of the cosmic microwave background. The upper image shows temperature anisotropies as observed by the COBE (Cosmic Background Explorer) satellite in 1992; the lower image shows the sharper view from the WMAP (Wilkinson Microwave Anisotropy Probe) satellite in 2003.