Module 11

Forces

Revision Booklet

North Chadderton School

http://www.webschool.org.uk

Module 11 – Forces

Introduction

This module includes the following:

Interpreting graphical representations of speed and acceleration.

Examining the effects of forces on motion :-

- unbalanced forces which produce accelerations as expressed in the relationship $F=ma$

- frictional forces which oppose motion and which are not only important for slowing down and stopping vehicles but are also responsible for steady driving forces eventually resulting in steady speeds.

Calculating:

- the work done by forces which act on bodies to affect their movement;
- the kinetic energy of a moving body.

Exploring the role of gravitational forces:
- in keeping satellites in orbit;
- in maintaining the stability of the solar system;
- in the life histories of stars.

Considering, at the higher tier only, the implications of the estimated speeds of distant galaxies for the origins of the Universe.

How can we describe the way things move?

Even when things are moving in a straight line, describing their movement is not easy. They can move with different speeds and can also change their speed (accelerate).

Graphs showing how either the distance of a body from its starting point or its speed change over a period of time can help us to describe the movement of the body.

KS3 (prior learning)

For an object moving at a steady speed in a straight line, the distance it travels and the time it takes are related as shown:

$$\textbf{speed}\ \text{(metres per second, m/s)} = \frac{\textbf{distance move}\ \text{(metres, m)}}{\textbf{time taken}\ \text{(seconds, s)}}$$

The average speed of this javelin can be calculated from the measurement of the distance moved, and the time of flight. The actual speed at any time during the flight will vary.

FT and HT

If an object moves in a straight line, how far it is from a certain point can be represented by a distance-time graph.

Candidates should be able to construct and recognise the shape of a distance-time graph when a body is:

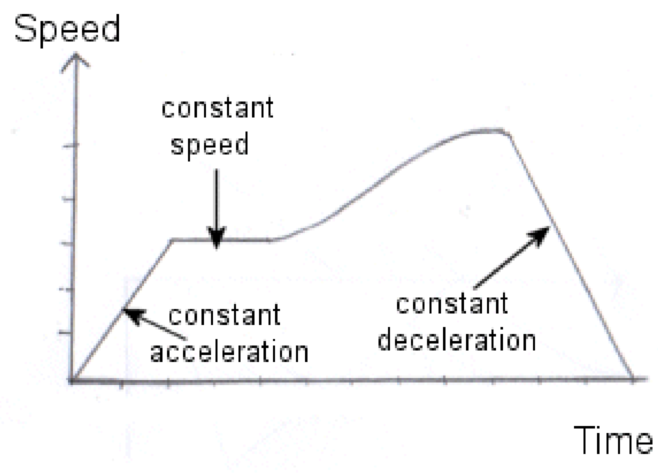
- stationary;
- moving with a steady speed.

The steeper the slope of the graph, the greater the speed it represents. The velocity of an object is its speed in a given direction.

Velocity-time graphs can represent the motion of a body.

Candidates should be able to recognise the shape of the velocity-time graph when a body is moving with:

- constant velocity;
- constant acceleration.



The steeper the slope of the graph, the greater the acceleration it represents. The acceleration of an object is the rate at which its velocity changes.

For objects moving in a straight line with a steady acceleration, the acceleration, the change in velocity and the time taken for the change are related as shown:

$$\textbf{acceleration} = \frac{\textbf{change in velocity} \text{ (metres per second, m/s)}}{\textbf{time taken} \text{ (seconds, s)}}$$

(metres per second squared, m/s^2)

HT

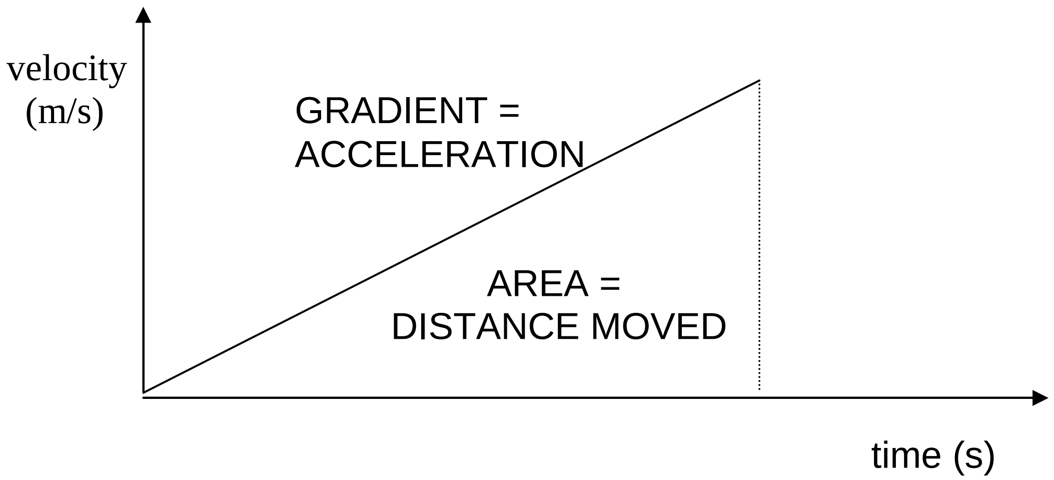
Candidates should be able to calculate the gradient of a distance-time graph.

The gradient of a velocity-time graph represents acceleration. The area under a velocity-time graph represents the distance travelled.

Candidates should be able to calculate:

- the gradient of a velocity-time graph and interpret this as acceleration;
- the area under a velocity-time graph and interpret this as distance moved;

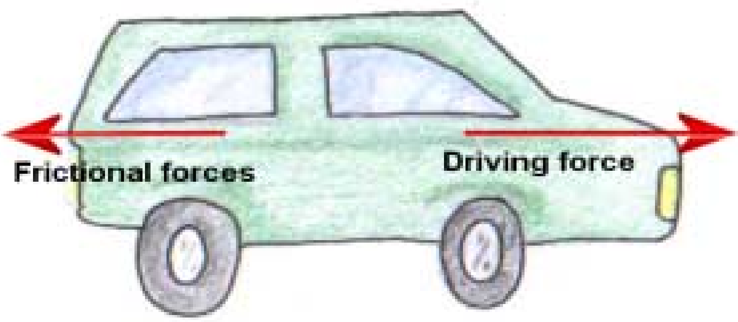
for an object moving with constant acceleration.



How do we make things speed up or slow down?

To change the speed of a body an unbalanced force must act on it.
We use the force of friction between two solid surfaces to slow down and stop bicycles and motor vehicles safely.

[Because of friction, a driving force is needed to keep a body moving at a steady speed.]



For a constant speed, the driving force must equal the total frictional forces. The frictional forces include the drag force (air resistance) sand rolling friction

KS3 (prior learning)

The forces acting on an object may cancel each other out (balance).
When an object rests on a surface:

- the weight of the object exerts a downward force on the surface;
- the surface exerts an upwards force on the object;
- the sizes of the two forces are the same.

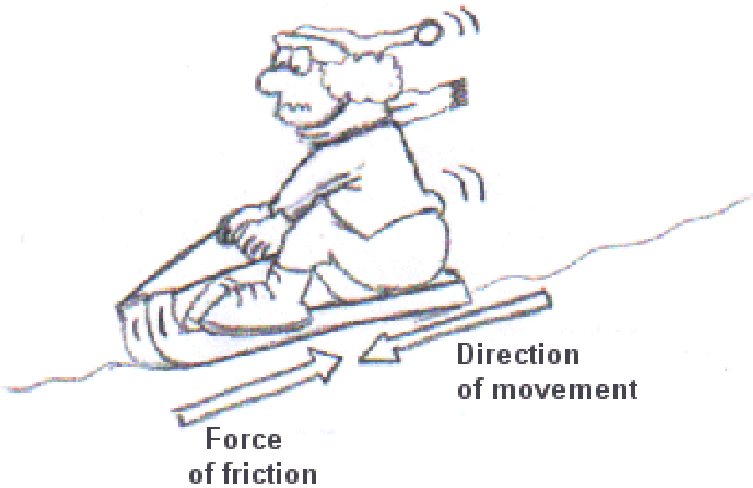
A force of friction acts:

- when an object moves through the air or water;
- when solid surfaces slide, or tend to slide, across each other.

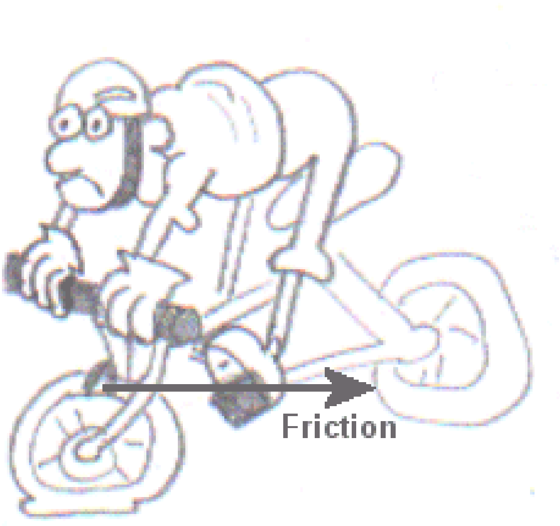
Friction forces oppose movement. This force meter can measure the size of the force needed to overcome friction.

The direction of this force of friction is always opposite to the direction in which the object or surface is moving. Friction causes objects to heat up and to wear away at their surfaces.

Friction is needed to move forward!



In many cases we need to reduce friction. This allows greater speeds to be reached. Polished and waxed surfaces can help to reduce friction

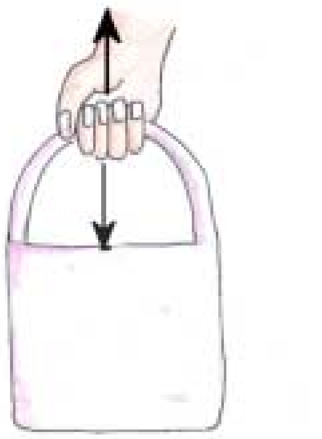


Applying brakes provide additional friction. This happens between the brake shows and the rim. Too much braking force can cause problems!

Without friction, the tyres of a car would not grip the road.

FT and HT

Whenever two bodies interact, the forces they exert on each other are equal and opposite.



There is a <u>downward force on the hand</u> from the weight of the bag. To balance this downward force an <u>equal and opposite force is applied upwards</u>

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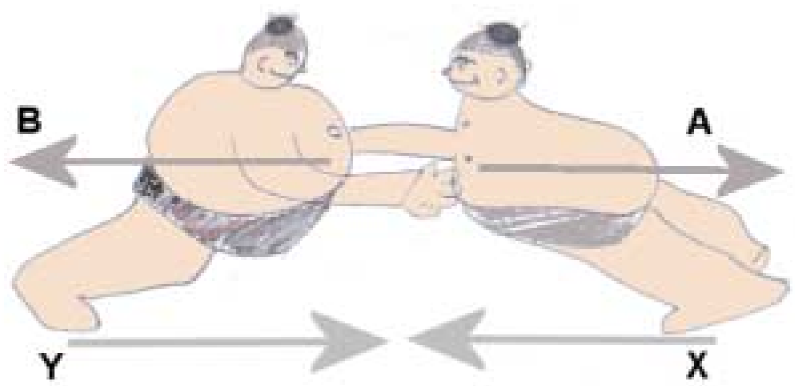
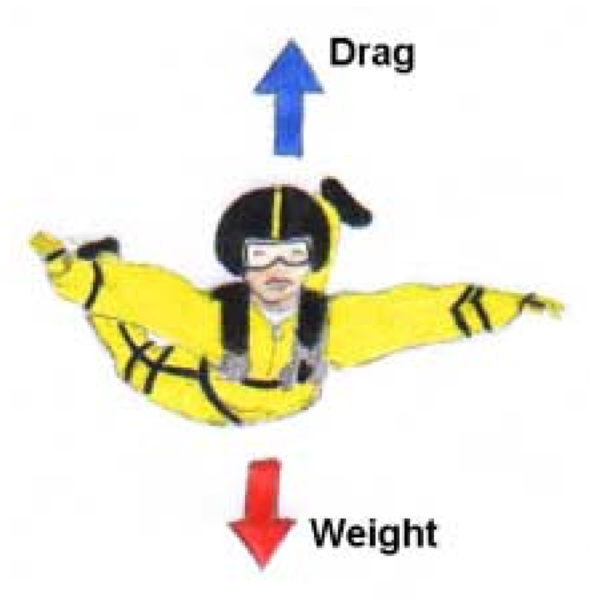
Balanced Forces

Balanced forces will have no effect on the movement of an object: it will remain stationary or, if it is already moving it will continue to move at the same speed and in the same direction.



These two wrestlers remain at rest. The total force on each wrestler is zero. Force A is balanced by a Frictional Force X. Force B is balanced by a Frictional force Y



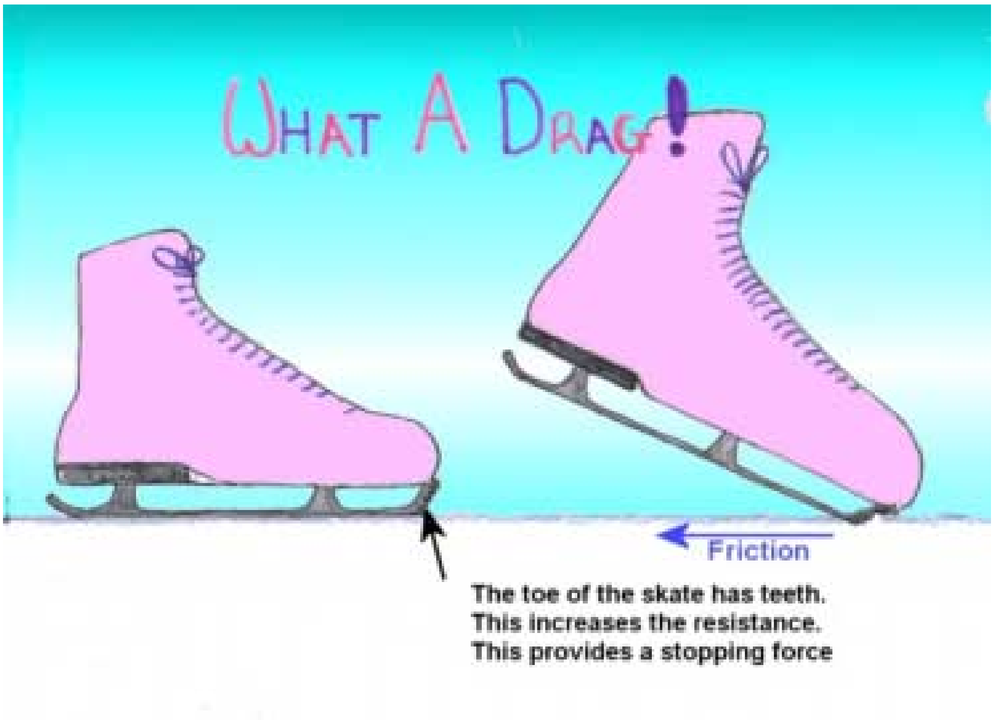
When these forces are equal and opposite, the total force on the object is zero. The object remains at rest.

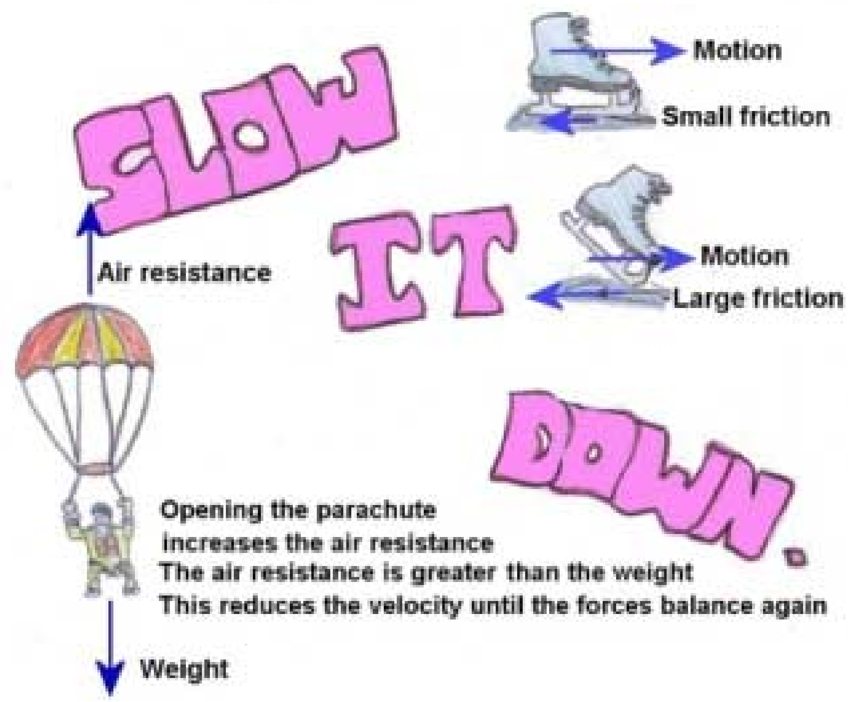
Unbalanced Forces

If the forces acting on an object do not cancel each other out, an unbalanced force will act on the object.

This unbalanced force will affect the movement of the object. How the movement is affected depends on the direction and the size of the unbalanced force:

- a stationary object will start to move in the direction of the unbalanced force;
- an object moving in the direction of the force will speed up;
- an object moving in the opposite direction to the force will slow it down;
- the greater the size of the unbalanced force, the faster the object will speed up or slow down.





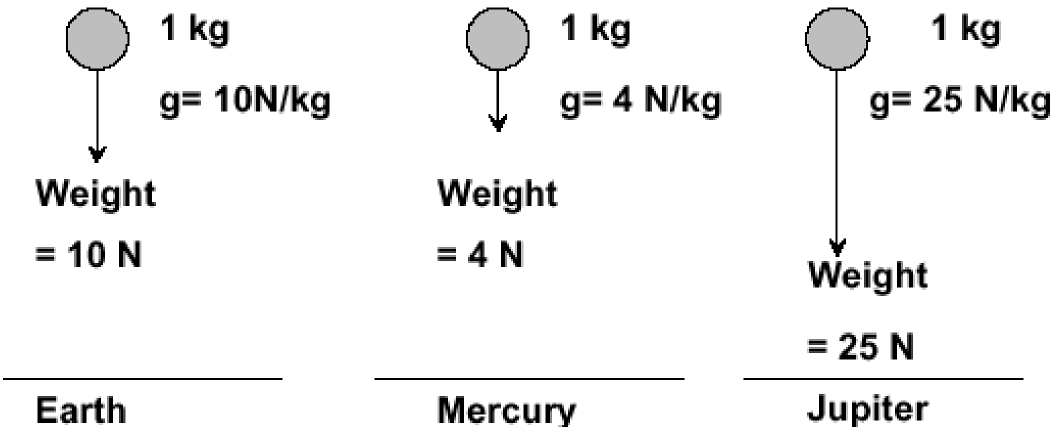
When an unbalanced force acts on an object in a particular direction its speed changes (it accelerates) in that direction. The greater the force, the greater is the acceleration. The bigger the mass of an object, the greater is the force needed to give the object a particular acceleration.

The Force of Gravity

Falling bodies are accelerated by gravity.

On Earth the gravitational field strength is about 10 N/kg.
The **weight** of an object is the force of gravity acting on it.
The weight can be calculated from:

weight	**=**	**mass**	**X**	**gravitational field strength**
(newton, N)		(kilogram, kg)		(newton/kilogram, N/kg)



The gravitational field strength (g) varies from planet to planet. Your weight changes because the value of g changes. Your mass, in kg, remains the same!

Thinking Distances

It takes time to react to an event. During this time the vehicle is still moving. The distance a vehicle moves during the reaction time is called the thinking distance. This all happens before the brakes are even applied.

Thinking distances are affected by the drivers concentration, including the use of mobile phones, and being distracted from driving. Alcohol and drugs can also severely affect reaction times, and this can be very dangerous, when a driver cannot react quickly enough.

Braking Distances

The greater the speed of a vehicle:

- the greater the braking force needed to stop in a certain time;
- the greater the distance needed to stop it with a certain braking force.

If too great a braking force is applied, friction between a vehicle’s tyres and the road surface may not be great enough to prevent skidding.

Braking distances are affected by the condition of the types, the effectiveness of the braking system, and the nature of the road surfaces. Ice and water can increase the braking distance by large amounts.

Stopping Distances

The stopping distance of a vehicle depends on:

- the distance the vehicle travels during the driver’s reaction time;
- the distance the vehicle travels under the braking force.

Stopping distance = distance moved in the reaction time + braking distance

The overall stopping distance is greater if:

- the vehicle is initially travelling faster;
- the driver’s reactions are slower (due to tiredness, drugs, alcohol);
- there are adverse weather conditions (wet/icy roads, poor visibility);
- the vehicle is poorly maintained (e.g. worn brakes/tyres).

Moving Through a Liquid or Gas

The faster an object moves through a gas or a liquid (a fluid) the greater is the force of friction which acts on it.

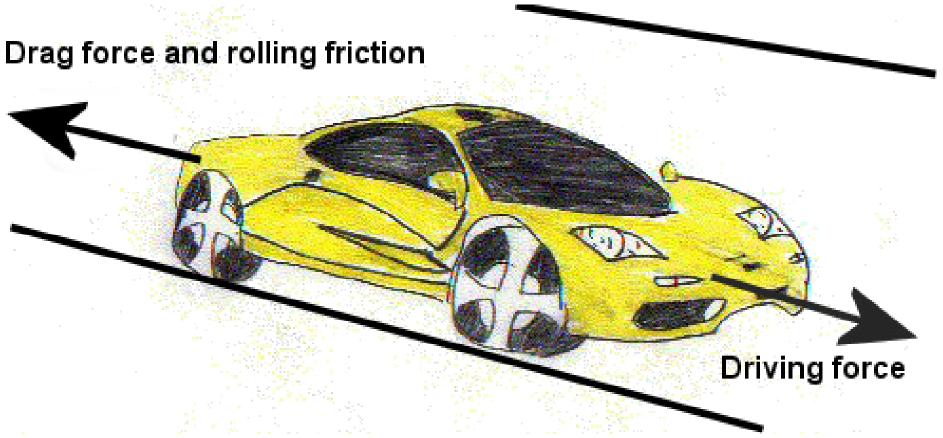
Falling

When a body falls:

- initially it accelerates due to the force of gravity;
- frictional forces increase until they balance the gravitational forces;
- the resultant force eventually reaches zero and the body falls at its terminal velocity.

Balanced Forces on a Moving Vehicle

When a vehicle has a steady speed the frictional forces balance the driving force.



The drag and rolling friction forces are balanced by the driving force when the car is traveling at constant speed. The overall force is zero, because these forces are balanced

HT

One newton is the force needed to give a mass of one kilogram an acceleration of one metre per second squared.

Force, mass and acceleration are related as shown:

Force	**=**	**mass**	**X**	**acceleration**
(newton, N)		(kilogram, kg)		(metres per second squared, m/s^2)

What happens to the movement energy when things speed up or slow down?

When a body speeds up or slows down, its kinetic energy increases or decreases.
The forces which cause the change in speed do so by transferring energy to, or from, the body.

FT and HT

When a force moves an object, energy is transferred and **work** is done:

work done = energy transferred
(joules, J) (joules, J)

The amount of work done, force and distance are related as shown:

work done = force applied X distance moved in direction of force
(joule, J) (newton, N) (metre, m)

Work done against frictional forces is transferred mainly as heat.

Elastic potential energy is the energy stored in an elastic object when work is done on the object to change its shape (e.g. squashing a spring).

HT

Kinetic energy is the energy an object has because of its movement.

An object has more kinetic energy:

- the greater its mass;
- the greater its speed.

kinetic energy = 1/2 X mass X speed²
(joule, J) (kilogram, kg) [(metre/second)², (m/s)²]

Example: The runner has a mass of 60 kg and his speed is 10 m/s. We can find his kinetic energy using the equation

kinetic energy = 1/2 X mass X speed²

kinetic energy = $0.5 \times 60 \times 10^2$

kinetic energy = 3000 joules

Space – What you should already know

KS3

The Earth spins on its own axis once every day (24 hours). The half of the Earth which faces the sun is in daylight; the other half of the Earth is in night.

DAY AND NIGHT

The Earth moves round (orbits) the Sun once each year (just over 365 days).

THE YEAR

The stars in the night sky stay in fixed patterns (called **constellations**).

STARS

The planets which are visible to the naked eye look just like stars. Compared to the background of the stars, they **move** very slowly across the constellations.
The planets do not give out their own light. Like the Earth, they move in orbits around the Sun. We can see planets because they **reflect** light from the Sun.
Where we see the planets against the background of the stars depends on exactly where they, and the Earth, are in their orbits round the Sun.

PLANETS

Satellites can be put into orbit around the Earth.
They can be used:

- to send information between places which are a long way apart on the Earth;
- to monitor conditions on Earth, including the weather;
- to observe the Universe without the Earth's atmosphere getting in the way (e.g. Hubble space telescope).

SATELLITES

FT and HT

Orbits, Gravity and Satellites

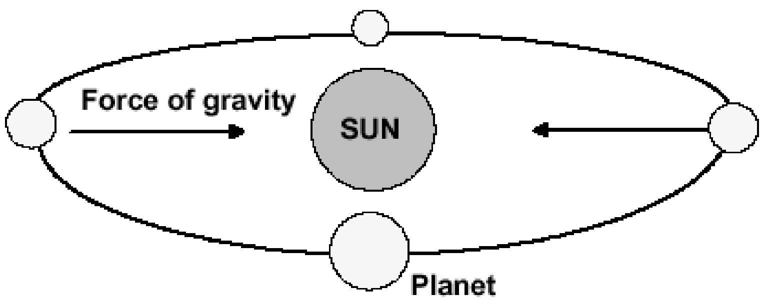
Planet and Comet Orbits

The orbits of the planets are slightly squashed circles (ellipses) with the Sun quite close to the centre.

Comets have orbits which are far from circular. They are very much closer to the Sun at some times than at others.
This is when they can be seen from Earth.

Gravity and Orbits

The Earth, the Sun, the Moon and all other bodies attract each Other with a force called **gravity**.



As the distance between two bodies increases, the force of gravity between them decreases more than in proportion to the increase in distance.
A smaller body will stay in orbit around a larger one because of the combination of its high speed and the force of gravity between the bodies.

To stay in orbit at a **particular distance**, smaller bodies, Including planets and satellites, must move at a **particular speed** around larger bodies. The further away an orbiting body is the longer it takes to make a complete orbit.

Satellite Orbits

Communication satellites, including those used for television programmes, are usually put into orbit high above the equator so that they move around the Earth in exactly the same time as the Earth spins. This means that they are always in the same position when viewed from Earth (a **geostationary** orbit). There is space for about only 400 geostationary satellites or they would interfere with each other's signals.

Monitoring satellites are usually put into a low polar orbit so that as the Earth spins beneath them and they can scan the whole Earth each day from much closer range than a geostationary satellite.

Origin of the Universe and the Life Histories of Stars

Astronomers believe that gravitational forces are responsible for the formation of galaxies of stars and for stars like the Sun having a long stable period. The speed with which other galaxies appear to be moving away from us suggests how the Universe might have begun.

FT and HT

Stars, Galaxies and Extra-terrestrial Life

Our Sun is just one of many millions of stars in a galaxy (large group of stars) called the Milky Way.

The stars in a galaxy are often millions of times further away from each other than the planets in the solar system.

The Universe as a whole is made up of at least a billion galaxies. Galaxies are often millions of times further apart than the stars within a galaxy.

Stars, including the Sun, form when enough dust and gas from space is pulled together by gravitational attraction. Smaller masses may also form and be attracted by a larger mass to become planets.

If there is, or has been, life on other planets, in our own solar system or around other stars:

- we may be able to observe living organisms (e.g. microbes), or their fossilised remains, directly, for example, by actually going to Mars or Europa (a satellite of Jupiter), by using robots to send back pictures or by using robots to collect samples to bring back to Earth;
- we may be able to detect living organisms by the chemical changes they produce in a closed system (e.g. inside a closed container or in the atmosphere of their planet);

(Because of living organisms, the atmosphere of the Earth is very different from what it would be purely from chemical and geological processes; for example, there is much more oxygen)

- we may be able to receive signals from other species with technologies that are at least as advanced as our own.
- The search for extra-terrestrial intelligence (SETI), using radio telescopes to try to find meaningful signals in a narrow band of wavelengths (i.e. not just "noise"), has gone on for more than forty years, so far without success.

Candidates should be able, when provided with appropriate information to evaluate:

- the methods scientists use to discover whether there is life elsewhere in the universe;
- evidence that such life exists.

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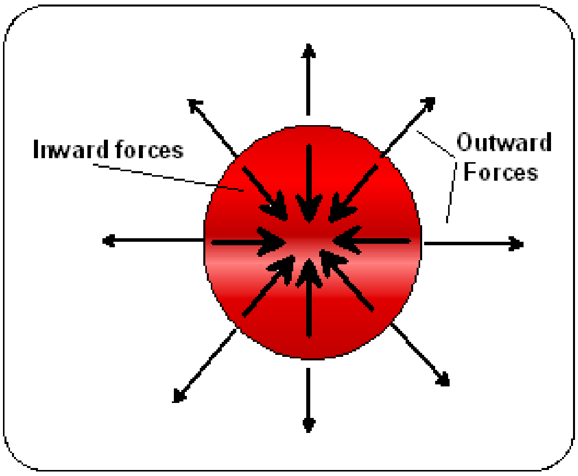
Life Histories of Stars

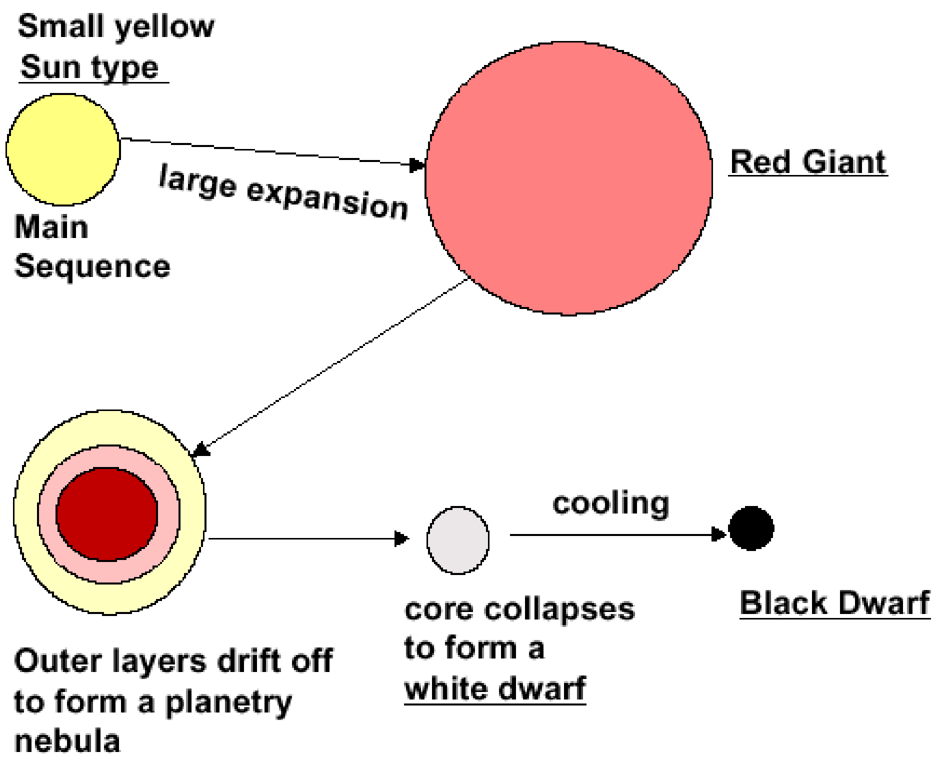
Balanced Forces inside Stars



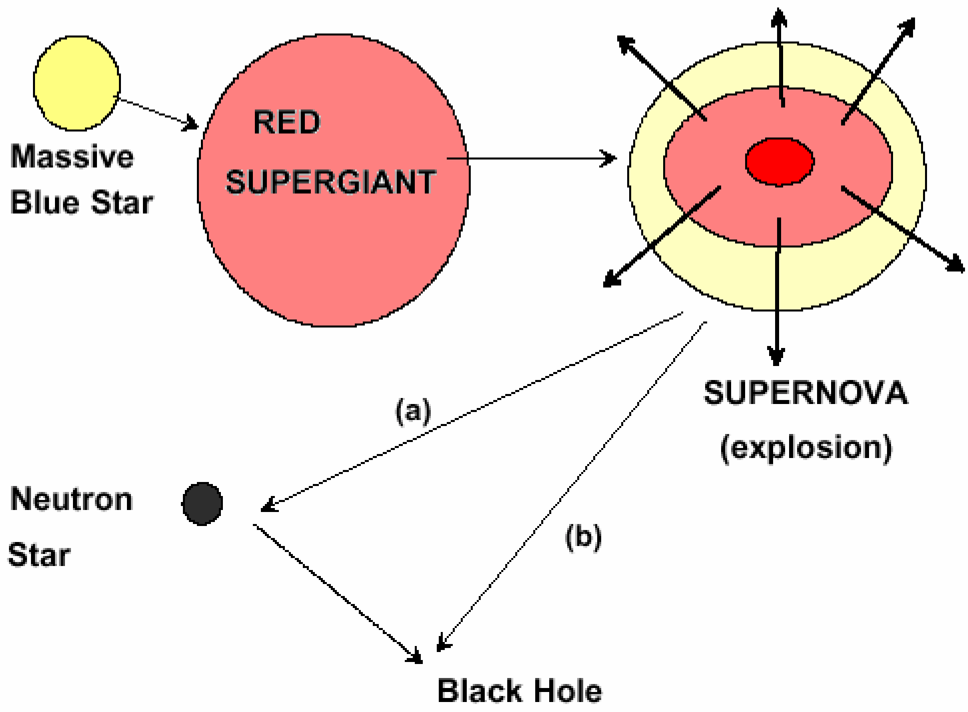
Individual stars, including the Sun, do not stay the same for ever. Stars are very massive so that the force of **gravity** which tends to draw together the matter from which they are made is very strong. The very high temperatures create **forces** which tend to make them expand. During the main stable period of a star, which may last for billions of years, these forces are balanced. The Sun is at this stage of its life.

How Stars End

During its life a star gradually uses up its nuclear fuel. Near the end of its life, when it has used up nearly all of its nuclear fuel, the star expands to become a **red giant**. At a later point in its history it contracts under its own gravity to become a **white dwarf**. The matter from which the star is made may then be millions of times denser than any matter on Earth.



Type I stars (Very large mass)



If a red giant is massive enough, it may eventually rapidly contract and then explode (become a **supernova**) throwing dust and gas into space. The matter that is left behind may form a very dense neutron star.

HT

Formation of a Black Hole

After a supernova explosion, if enough matter is left behind, it may be so dense, and its gravitational field so strong that nothing can escape from it, not even light or other forms of electromagnetic radiation. This is shown in the path indicated by (b). It is then called a **black hole**. We cannot see black holes but we can sometimes observe their effects on their surroundings, for example, the X-rays emitted when gases from a nearby star spiral into a black hole.

Energy from Nuclear Fusion in Stars

During a star's lifetime, nuclei of lighter elements (mainly hydrogen and helium) gradually fuse to produce nuclei of heavier elements. These nuclear fusion reactions release the energy which is radiated by stars.

Nuclei of the heaviest elements are present in the Sun and atoms of these elements are present in the inner planets of the solar system.
This suggests that the solar system was formed from the material produced when earlier stars exploded.

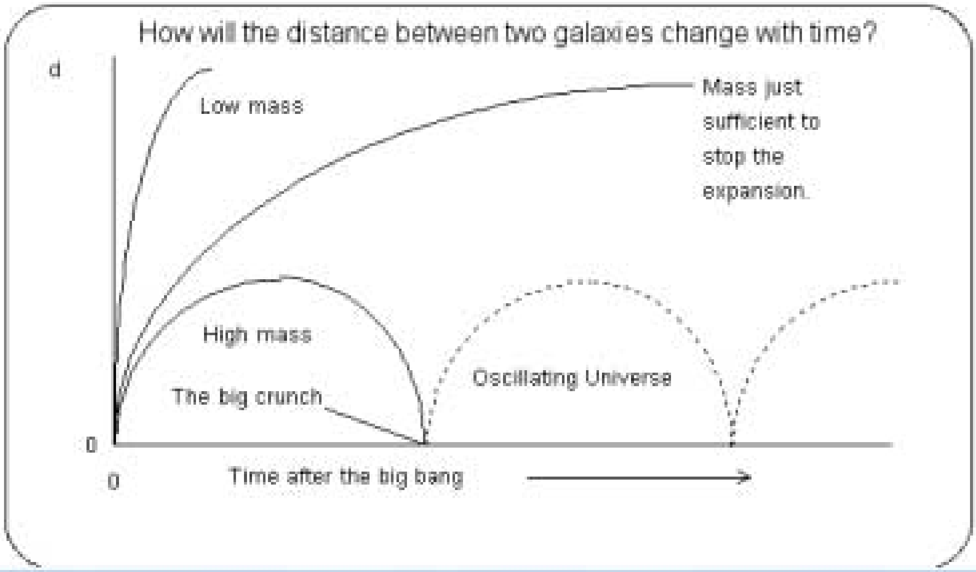
😐Theories of the origin of the Universe have to take into account:

- that light from other galaxies is shifted to the red end of the spectrum;
- that the further away galaxies are, the bigger this 'red-shift'.

The current way of explaining this is:

- that other galaxies are moving away from us very quickly;
- that the further away from us a galaxy is, the faster it is moving away from us.

This suggests that the whole Universe is expanding and that it might have started, billions of years ago, with a huge explosion ('**big bang**').



Possible scenarios of the future of the Universe. The actual expansion depends on the total mass of the universe. Scientists are looking for the 'missing mass', which determines the 'braking force' on the expansion. Until this is found, they are unable to predict with confidence, the fate of our Universe.