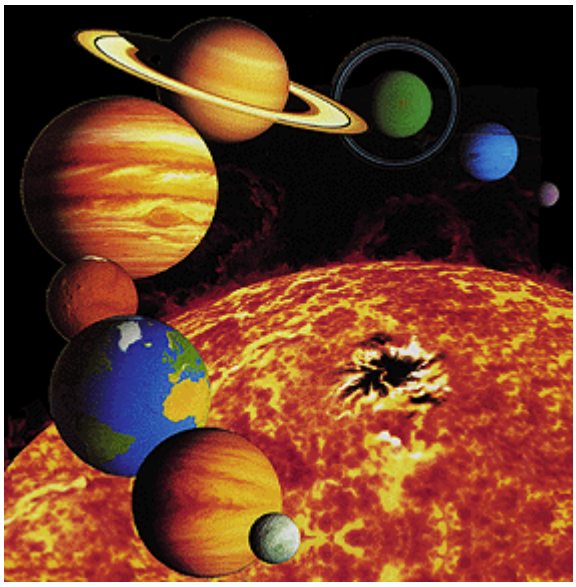
Adventurer's Mk
ASTRONOMY

The Solar System

What is the solar system? It is our Sun and everything that travels around it. Our solar system is elliptical in shape. That means it is shaped like an egg. The Sun is in the centre of the solar system. Our solar system is always in motion. Eight known planets and their moons, along with comets, asteroids, and other space objects orbit the Sun. The Sun is the biggest object in our solar system. It contains more than 99% of the solar system's mass. Astronomers think the solar system is more than 4 billion years old.



Astronomers are now finding new objects far, far from the Sun which they call dwarf planets. Pluto, which was once called a planet, is now called a dwarf planet.

The words “solar system" refers to the Sun and all of the objects that travel around it. These objects include planets, natural satellites such as the Moon, the asteroid belt, comets, and meteoroids. Our solar system has an elliptical shape and is part of a galaxy known as the Milky Way. The Sun is the centre of the solar system. It contains 99.8% of all of the mass in our solar system. Consequently, it exerts a tremendous gravitational pull on planets, satellites, asteroids, comets, and meteoroids. Astronomers believe the solar system formed 4.5 billion years ago. However, they differ in their beliefs about how the system formed. Some believe the whole solar system formed from a single flat cloud of gas, while others believe it formed when a huge object passed near the Sun, pulling a stream of gas off of the Sun. Astronomers theorize the planets then formed from this gas stream.

The Sun

Some people from long ago thought of the Sun as a god. They did not want the god to be angry with them. To keep the Sun happy, they offered it gifts such as gold and food.

The Sun is our closest star. It is a member of the Milky Way galaxy. The Sun is a yellow dwarf star, which means it is a medium size star. It is believed to be over 4 billion years old. The Sun spins slowly on its axis as it revolves around the galaxy. The centre, or core, of the Sun is very hot. A process called "nuclear fusion" takes place there. Nuclear fusion produces a lot of energy. Some of this energy travels out into space as heat and light. Some of it arrives at Earth! Streams of gas particles known as the solar wind also flow out from the Sun.

On the Sun's surface, we can see storms. We call these storms "sunspots" because they look like dark spots on the Sun's surface. The Sun also produces big explosions of energy called solar flares. These flares shoot fast moving particles off the Sun's surface. These particles can hit the Earth's atmosphere and cause a glow called an aurora.

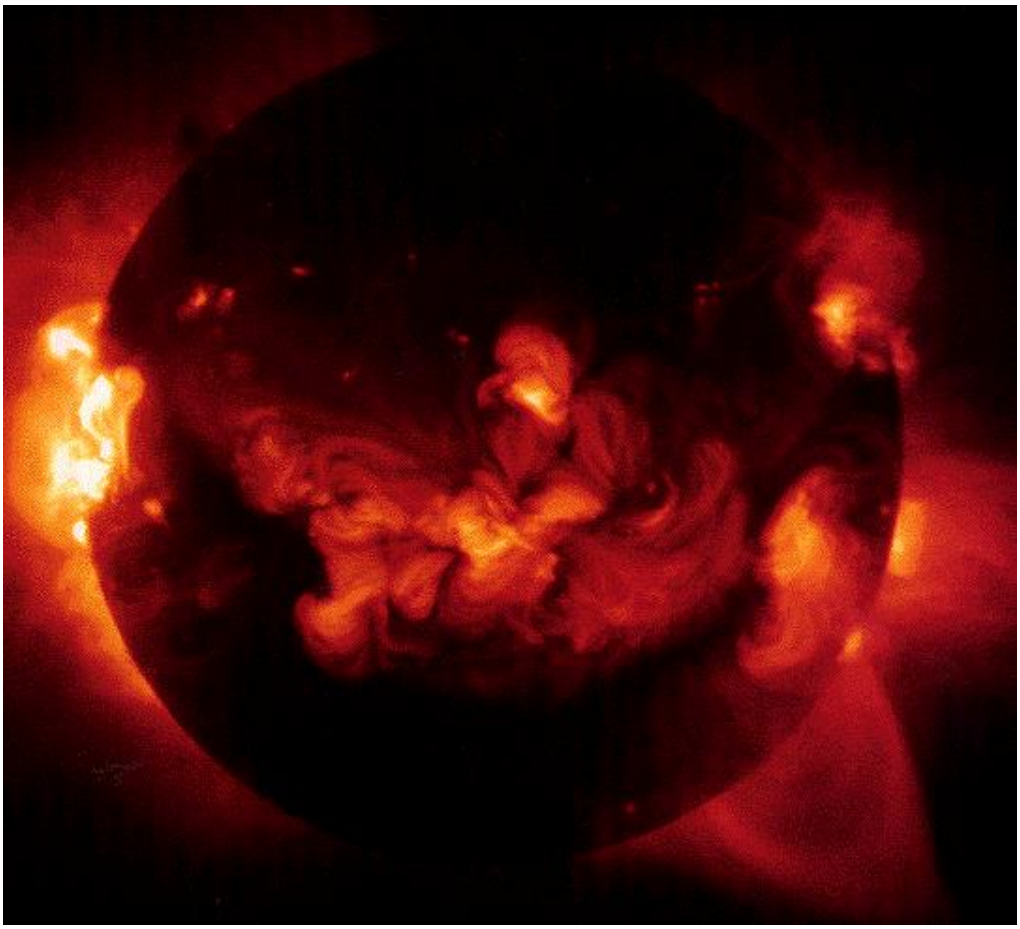
Sun Fact:
Heat from the centre of the Sun takes a million years to reach the Sun's surface. Once the heat leaves the Sun's surface, though, it only takes it 8.5 minutes to reach Earth!

Question One
A sunspot is a _____?

1. solar flare
2. vacation spot
3. Sun storm

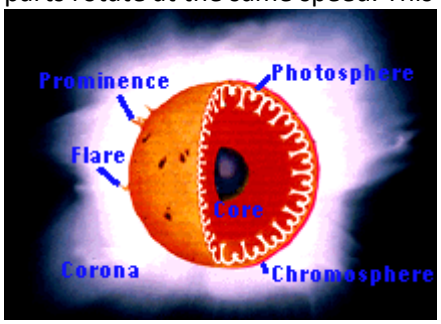
The diameter of our closest star, the Sun, is 1,392,000 kilometres. The Sun is thought to be 4.6 billion years old. The Sun is a medium size star known as a yellow dwarf. It is a star in the Milky Way galaxy and the temperature in its core is estimated to be over 15,000,000 degrees Celsius. In the Sun's core, hydrogen is being fused to form helium by a nuclear fusion process. The energy created by this process radiates up to the visible boundary of the Sun and then off into space. It radiates into space in the form of heat and light. Because the Sun is so massive, it exerts a powerful gravitational pull on everything in our solar system. It is because of the Sun's gravitational pull that Earth orbits the Sun in the manner that it does.

X-rays from the Sun



This picture of the Sun was taken on January 24, 1992. The image shows the Sun at X-ray wavelengths and it was recorded by the Soft X-ray Telescope on the Yohkoh (which means "Sunbeam" in Japanese) satellite. The bright areas are where the Sun's magnetic fields are strong enough to trap the very hot gases in the corona of the Sun. The fields are not strong enough to do this at the poles of the Sun. Notice that the surface of the Sun is dark: the X-rays Yohkoh records are from gases which are heated to millions of degrees. The surface of the Sun is much cooler than this, so it appears dark.

The Sun gives off many kinds of radiation other than light and heat. It also emits radio waves, ultraviolet rays, and X-rays. The Earth's atmosphere protects us from the harmful effects of the ultraviolet rays and the X-rays. The Sun does rotate, but because it is a large gaseous sphere, not all parts rotate at the same speed. This is known as a differential rotation.



Parts of the Sun

The Sun has several layers: the core, the radiation zone, the convection zone, and the photosphere (which is the surface of the Sun). In addition, there are two layers of gas above the photosphere called the chromosphere and the corona. Events which occur on the Sun include sunspots, solar flares, solar wind, and solar prominences. Sunspots are magnetic storms on the photosphere which appear as dark areas. Sunspots regularly appear and disappear in eleven year cycles. Solar flares are spectacular discharges of magnetic energy from the corona. These discharges send streams of protons and electrons outward into space. Solar flares can interrupt the communications network here on Earth. Solar winds are the result of gas expansion in the corona. This expansion leads to ion formation. These ions are hurled outward from the corona at over 500 kilometres per second. Solar prominences are storms of gas which erupt from the surface in the form of columns which either shoot outward into space or twist and loop back to the Sun's surface.

Question Two

Our Sun is classified as what type of star?

The Moon: Earth's Satellite

The Moon is the only place in our solar system, other than Earth, where humans have visited. On July 20, 1969, astronauts Neil Armstrong and Edwin Aldrin landed the Lunar Module of Apollo 11 on the Moon's surface. Neil Armstrong was the first human to set foot on the Moon.

The Moon is like a desert with plains, mountains, and valleys. It also has many craters, which are holes created when space objects hit the Moon's surface at a high speed. There is no air to breathe on the Moon. Recently water ice was discovered at the poles (or top and bottom) of the Moon. The ice is buried beneath some of the dust of the Moon's surface. Scientists think the ice may be left over from a comet that once collided with the Moon.

The Moon travels around the Earth in an oval shaped orbit. Scientists think the Moon was formed long ago when Earth collided with another space object. The collision may have caused a big chunk of rocky material to be thrown out into space to form the Moon.

The Moon is a little lopsided. Its crust is thicker on one side than the other. The Moon is much smaller than the Earth. However, the pull of its gravity can still affect the Earth's ocean tides. We always see the same side of the Moon from Earth. You have to go into space to see the other side.

Question Three
Who was the first human to touch the Moon's surface?

The Moon travels around Earth in an oval orbit at 3680 kilometres per hour. The Moon does not have an atmosphere, so temperatures range from -184 degrees Celsius during its night to 214 degrees Celsius during its day except at the poles where the temperature is a constant -96 degrees Celsius. The Moon is actually a little lopsided due to the lunar crust being thicker on one side than the other. When you look at the Moon, you will see dark and light areas. The dark areas are young plains called Maria and are composed of basalt. The basalt flowed in and flooded the area created by a huge impact with an asteroid or comet. The light areas are the highlands, which are mountains that were uplifted as a result of impacts. The lunar surface is covered by a fine-grained soil called "regolith" which results from the constant bombardment of the lunar rocks by small meteorites. Scientists theorize that the Moon was the result of a collision between Earth and an object the size of Mars. One theory states that the debris from the impact was hurtled into space where, due to gravity, it combined. This resulted in the formation of the Moon. The gravitational pull of the Moon on the Earth affects the ocean tides on Earth. The closer the Moon is to Earth, the greater the effect. The time between high tides is about 12 hours and 25 minutes.

The phases or changing appearance, of the Moon depend on its position relative to the position of the Sun. When the Moon is between the Sun and the Earth, the side of the Moon facing the Earth is dark. This is called a "new moon". As the Moon travels eastward in its orbit, more of its sunlit side becomes visible to Earth and the Moon is said to be "waxing". More specifically, the phase after a new moon is called a "waxing crescent" because we can see no more than a quarter of the Moon at this point. As the Moon continues eastward, the Sun, Moon, and Earth form a 90 degree angle and the Moon appears half dark and half-light to us here on Earth. This is a "first quarter" phase. After the first quarter phase, more than a quarter of the Moon is visible to us, so it is now in a "waxing gibbous" phase. As the Moon continues its revolution around Earth, the Sun, Earth, and Moon align with the Earth in the middle. The side of the Moon facing Earth is now fully lit. This is called a "full moon" phase. As the Moon travels further around in its orbit, the lit portion of the Moon visible to Earth becomes smaller, so the Moon is now said to be "waning" as it enters the next phase. After the "waning gibbous" phase, the Moon enters the "third quarter" phase where once again the Moon appears half dark and half light from Earth. As it completes its revolution around Earth, the Moon enters a "waning crescent" phase just prior to starting the cycle again as a new moon.

Question Four
When we look at the Moon, it has light and dark areas which give it the appearance of a man's face. In actuality, what are the light and dark areas?

Meteoroids
In Greenland, people dig up meteorites and use the iron in them to make tools.

A meteoroid is a piece of stone-like or metal-like debris which travels in outer space. Most meteoroids are no bigger than a pebble. Large meteoroids are believed to come from the asteroid belt. Some of the smaller meteoroids may have come from the Moon or Mars. If a meteoroid falls into the Earth's atmosphere, it will begin to heat up and start to glow. This is

called a meteor. If you have ever seen a "falling star", you were actually seeing a meteor. Most of the original object burns up before it strikes the surface of the Earth. Any leftover part that does strike the Earth is called a meteorite. A meteorite can make a hole, or crater, in the ground when it hits it. The larger the meteorite, the bigger the hole.

Question Five
True or False
A meteor is called a "falling star" as it falls to Earth.

A meteoroid is a piece of stony or metallic debris which travels in outer space. Meteoroids travel around the Sun in a variety of orbits and at various speeds. The fastest meteoroids move at about 42 kilometres per second. Most meteoroids are about the size of a pebble. When one of these pieces of debris enters the Earth's atmosphere, friction between the debris and atmospheric gases heats it to the point that it glows and becomes visible to our eyes. This streak of light in the sky is known as a meteor. Most meteors glow for only a few seconds prior to burning up before hitting the Earth's surface. On most dark nights, meteors can be seen. The chance of seeing a meteor with the unaided eye increases after midnight. People often refer to meteors as "falling" or "shooting" stars. The brightest of the meteors are called fireballs. Sonic booms often follow the appearance of a fireball just as thunder often follows lightning. At certain times of the year, more meteors than normal can be seen. When the Earth passes through an orbiting stream of debris from a comet that has broken up, what's known as a meteor shower occurs. Meteor showers take place on about the same dates each year.

If the meteor does not burn up completely, the remaining portion hits the Earth and is then called a meteorite. Over 100 meteorites hit the Earth each year. Fortunately, most of them are very small. There has only been one report of a "HBM" (hit by meteorite), and that occurred in 1954. Ann Hodges of Sylacauga, Alabama was slightly injured when a 19.84 kilogram meteorite crashed through the roof of her home. The larger meteorites are believed to have originated in the asteroid belt. Some of the smaller meteorites have been identified as moon rock, while still others have been identified as pieces of Mars. Large meteorites that crashed onto the Earth long ago made craters like those found on the Moon. The Barringer Meteorite Crater near Winslow, Arizona is believed to have been formed about 49,000 years ago by the impact of a 300,000 ton meteorite. The Hoba iron meteorite is the largest single meteorite known. Its present weight is estimated at 66 tons. Part of the Hoba meteorite has rusted away; therefore its original weight may have been as much as 100 tons! It has never been removed from its landing site in Namibia. The largest single meteorite found in the United States is the fifteen ton Willamette (Oregon) iron meteorite found in 1902.

Question Six
How do meteorites differ from meteors and meteoroids?

The Planets and Dwarf Planets
A planet is a large space object which revolves around a star. It also reflects that star's light. Eight planets have been discovered in our solar system. Mercury, Venus, Earth, and Mars are the planets closest to the Sun. They are called the inner planets. The inner planets are made up mostly of rock. The outer planets are Jupiter, Saturn, Uranus, and Neptune. Jupiter, Saturn, Uranus, and Neptune

are large balls of gases with rings around them. All eight planets travel around the Sun in a different orbit. In its orbit, there are not many other objects like the planet.

Dwarf planets are objects that are similar to planets except that they orbit the Sun in areas where there are many similar objects.

The Inner Planets	The Outer Planets	Dwarf Planets
Mercury	Jupiter	Pluto
Venus	Saturn	Ceres
Earth	Uranus	Eris
Mars	Neptune	Haumea
		Makemake

A planet is a large space body which reflects the light of a star around which it revolves. The planets in our solar system are classified as inner planets and outer planets. The inner planets, the closest to the Sun, are solid spheres of rock and include Mercury, Venus, Earth, and Mars. The inner planets were constantly bombarded by asteroids and meteorites during their first 600 million years in existence. Consequently, you will find craters of varying sizes on the inner planets and their satellites. The outer planets are large gaseous spheres with rings and include Jupiter, Saturn, Uranus, and Neptune. Between the inner and outer planets is an asteroid belt. Every planet, except for Earth, was named for an ancient Roman god or goddess. Some of the planets have naturally occurring satellites, or moons, while others do not. All eight planets orbit the Sun in their own unique way.

Dwarf planet is a new class of astronomical objects. It was created in 2006 by the International Astronomical Union as part of their struggle to define the word 'planet'. The discovery of objects in the outer solar system which were larger than or of similar size as Pluto necessitated the need for a definition. (This distant region is called the Kuiper Belt and extends far beyond the orbit of Neptune.) After much debate, it was decided that to be a planet in our solar system, an object must be in orbit around the Sun, have enough mass so that it has become round in shape due to its own gravity, and have cleared out its orbital path around the Sun (so there are not similar objects to itself at roughly the same distance from the Sun). Dwarf planets were declared to be the class of objects which met the first 2 requirements, but failed the third. It was then made clear that planets and dwarf planets are distinct classes of objects. Dwarf planets are not planets.

Pluto, Ceres, and Eris became the first three members of this dwarf planet classification, and many others are expected to follow. In fact, there are about 70 other known objects which may be moved into this classification in the near future. More than a hundred other such objects are thought to still be lurking undetected in the Kuiper Belt.

Mercury: Planet Closest to the Sun
The temperature on Mercury gets so hot it could melt a tin pan.

Mercury is the smallest planet in our solar system. Mercury is about the same size as our Moon. It is very close to the Sun. Mercury travels around the Sun faster than any other planet. That is how it got its name. It was named after Mercury, the swift messenger of the gods in ancient Roman mythology. Mercury can only be seen from Earth just before sunrise or just after sunset, but not in the middle of the night. That is because Mercury always appears near the Sun when viewed from Earth. Mercury has a very thin atmosphere. Humans would not be able to live there. The surface of Mercury has holes in it where objects such as meteorites and asteroids crashed into it.

Question Seven

At what time of day can Mercury be viewed by people on Earth?

Mercury is only about one-third the size of the Earth. It is smaller than any other planet. Mercury is very close to the Sun and has no substantial atmosphere. These factors contribute to the fact that the surface of Mercury has the greatest temperature range of any planet or natural satellite in our solar system. The surface temperature on the side of Mercury closest to the Sun reaches 427 degrees Celsius, a temperature hot enough to melt tin. On the side facing away from the Sun, or the night side, the temperature drops to -183 degrees Celsius. Scientists have detected a magnetic field surrounding Mercury, though it is not as strong as the field around the Earth. Scientists theorize that Mercury's field is due to an iron-bearing core or possibly to the solar winds. Mercury's atmosphere is very thin and is composed of helium and sodium. The surface of Mercury has been shaped by three processes: impact cratering where large objects struck the surface resulting in crater formation, volcanism where lava flooded the surface, and tectonic activity where the planet's crust moved in order to adjust to the planetary cooling and contracting. Mercury does not have any naturally occurring satellites.

Question Eight

What is the difference in the temperature of Mercury's surface when it is facing towards and away from the Sun?

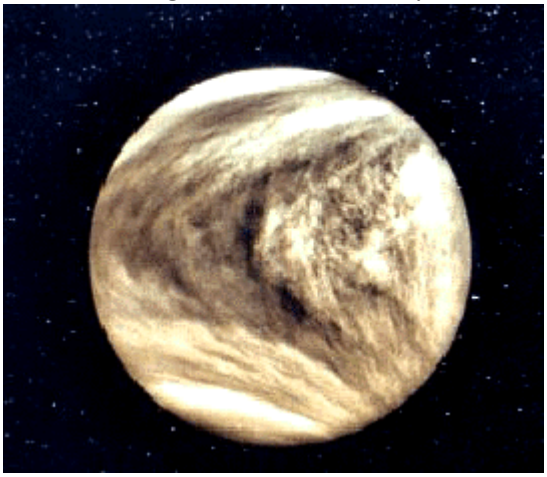
Venus: Earth's Twin

Venus is called the Evening Star. It is called this because it looks so bright to us from Earth.

Venus and Earth are almost the same size. Venus is the closest planet to Earth, but it does not have oceans or human life like Earth. Venus gets so hot during the day that it could melt a lead cannonball. The temperature rises to 484 degrees Celsius on the side facing the Sun. Venus has very thick, rapidly spinning clouds which cover its surface. These clouds hold heat in. That is why Venus gets so hot. These clouds also reflect sunlight. That is why Venus appears so bright to us here on Earth. There are constant thunderstorms in these clouds. Venus has several large inactive volcanoes. Much of the surface is covered by old lava flows from these volcanoes.
Venus is unusual because it rotates in a direction opposite that of all of the other planets. Venus spins very slowly as it orbits the Sun.

Question Nine
Why does the surface of Venus get so hot?

Venus and Earth are similar in size, composition, and mass. They differ in that Venus does not have oceans or human life, and its temperature during the day reaches 484 degrees Celsius. The daytime temperature is so hot it could melt lead. The dense atmosphere is composed of carbon dioxide and sulfuric acid which acts as a greenhouse and traps the heat. Venus revolves around the Sun in a circular orbit once every 225 Earth days. Venus rotates slowly on its axis in a clockwise direction, which is referred to as a "retrograde" rotation because it is the opposite of the seven other planets. A rotation takes 243 Earth days, so a Venusian day is longer than a Venusian year. As with the other inner planets, the surface of Venus has been shaped by impact craters, tectonic activity, and volcanoes which scientists believe to be ongoing. The volcanic activity is believed to be the source of the sulphur found in the atmosphere. Venus does not have any naturally occurring satellites.



If you look at Venus through a telescope, you would see something like the picture below. This image, taken by the Pioneer Venus Orbiter satellite, shows the thick clouds that completely obscure the surface of Venus below them.

Question Ten
If you were standing on Venus, why would the Sun appear to rise in the west and set in the east?

Earth: The Water Planet
Seventy percent of the Earth's surface is covered by water. The remaining 30 percent is covered by mountains, volcanoes, deserts, plains, and valleys.

Earth is the third closest planet to the Sun. It has an atmosphere made up of many different gases, but mainly it is nitrogen and oxygen. The atmosphere gives us air to breathe. We live on the planet Earth.
The Earth orbits around the Sun. It takes one year to go around the Sun one complete time. The Earth also rotates, or spins, on its axis. It takes one day to spin around one complete time. The Earth's axis is not straight up and down, but tilted a little bit. This tilt is responsible for us having seasons. Otherwise, the temperature would be pretty much the same all year long.

Question Eleven
What causes the seasons to change on Earth?

Earth's amazing gaseous atmosphere is responsible for making life possible on this, the third planet from the Sun. Our atmosphere contains water vapour which helps to moderate our daily temperatures. Our atmosphere contains 21% oxygen, which is necessary for us to breathe, 78% nitrogen, and .9% argon. The other 0.1% consists of water vapour, carbon dioxide, neon, methane, krypton, helium, xenon, hydrogen, nitrous oxide, carbon monoxide, nitrogen dioxide, sulphur dioxide, and ozone. These latter elements are important to have because they help to absorb harmful solar radiation before it can reach the surface of the Earth. If present in larger amounts, most of these latter elements would be poisonous to humans. The atmosphere protects us from meteors as well. Due to the friction generated between a meteor and the atmospheric gases, most meteors burn up before hitting Earth's surface as a meteorite.

Earth rotates on an imaginary axis which is tilted at a 23.5 degree angle. The rotation is what causes the change from day to night. The tilt is what determines our change in seasons. If the Earth was not tilted, we would have the same season all year long. Earth has a core of molten iron-nickel. The rapid spin of the Earth along with the liquid, hot metallic core causes a magnetic field to surround the Earth. This magnetic field traps the charged particles which are hurled at the Earth by the Sun during solar wind activity. When these charged particles react with the gases in our atmosphere, the gases begin to glow. These aurorae, or glowing gases, are seen in the Arctic Circle and the Antarctic Circle. As with all inner planets, Earth's surface has been affected by volcanism, tectonic activity, and to a lesser degree, meteorite impacts. Earth has one naturally occurring satellite, the Moon.

Question Twelve
What produces the magnetic field which surrounds the Earth?

Mars The red planet
Some of the meteorites found on Earth are actually pieces of the planet Mars. As of June 2006, thirty-four "Martian meteorites" have been found.

The temperature on Mars can be very, very cold. On its warmest day, Mars can still be a very cold place. At the top and bottom of the planet are poles just like on Earth. During the Martian winter, ice caps can be seen at the poles.

Space probes have landed on Mars. These probes were sent on a fact-finding mission by the United States. They performed experiments on the Martian dirt and atmosphere. The dirt was found to contain clay which was rich in iron. The iron is what gives Mars its red colour.

Mars has many craters which were formed by meteorites or asteroids hitting it. Mars also has some of the tallest volcanoes and some of the deepest valleys in our solar system. Mars has two moons, Phobos and Deimos which have unusual shapes. Scientists think these potato-shaped moons were once asteroids captured by Mars' gravitational pull.

Question Thirteen
Why does Mars look red to anyone looking at it through a telescope?

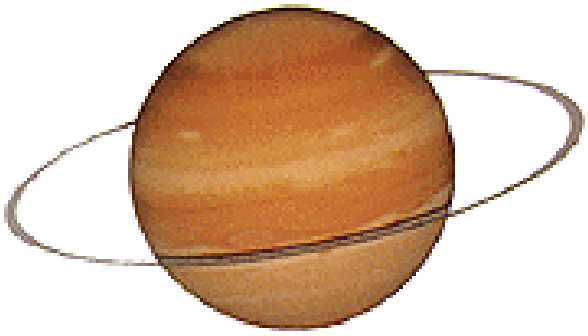
The orbit of Mars around the Sun is extremely elliptical. Because the distance between the Sun and Mars varies, temperatures range from -125 degrees Celsius in the Martian winter to 22 degrees Celsius in the Martian summer. The Martian atmosphere is composed of over 95% carbon dioxide. Solar winds carry the thin, weak atmosphere away because Mars has a weak gravitational and magnetic field. At the Martian poles are polar ice caps which shrink in size during the Martian spring and summer. From data gathered by the Viking 1 and 2 probes, we know that the Martian surface is covered by various rocks and a soil which is rich in an iron-laden clay. The presence of iron explains the planet's reddish-orange appearance. Mars contains highlands which occur in the southern hemisphere and are composed of the oldest, most heavily cratered crustal material. Mars also contains lowlands which are found in the northern hemisphere. The extremely weak magnetic field of Mars suggests that its iron core is no longer fluid and circulating.

The surface of Mars has not only been affected by meteorite impacts, but also by volcanic and tectonic activity. In fact, Mars has some of the largest volcanoes in the solar system; Olympus Mons is over 600 kilometres wide and 26 kilometres high! Tectonic activity is in evidence at the tremendous Valles Mariners canyon system, which is over 8 kilometres deep and 4500 kilometres long. Mars has two small natural satellites, Photos and Deimos. They are highly irregular in shape and are believed to be asteroids captured by Mars' weak gravitational field.

Question Fourteen
What element in the Martian soil might explain the reddish appearance of Mars?

Jupiter. The largest planet
Jupiter is so large that all of the other planets in the solar system could fit inside of it

Jupiter is a large gas planet whose clouds change colours daily. This planet is made mostly of hydrogen and helium gases. Jupiter gives off two times more heat than it gets from the Sun. It shines very brightly in the night sky for nine months of the year when it is closest to Earth. Huge areas of swirling gases can be found in Jupiter's atmosphere. The largest swirling area of gas is called the Great Red Spot. Scientists believe this is a large hurricane-like storm which has lasted for hundreds of years. Large bolts of lightning



have also been seen in Jupiter's atmosphere. Pictures taken by space probes have shown thin rings around Jupiter. As of January 2011, Jupiter has 50 named moons. 13 more have been discovered but not given official status or names. One of Jupiter's moons, Io, has active volcanoes on it. Areas on Io that are near the volcanoes are very, very hot.

Question Fifteen
What is the Great Red Spot?

Jupiter is a large gas planet whose rapid rotation causes the planet to flatten at the poles and bulge at the equator. Jupiter emits twice as much heat as it absorbs from the Sun, which indicates it has its own internal heat source. Astronomers estimate the core temperature at 20,000 degrees Celsius, approximately three times greater than the temperature of the Earth's core. The planet's powerful magnetic field is thought to be generated by the electric currents produced by pressurized hydrogen in the mantle. Jupiter's atmosphere is thought to be composed of hydrogen, helium, sulphur, and nitrogen. Clouds in the atmosphere move in alternating bands from east to west or west to east. Lightning, more powerful than any that has been experienced on Earth, has been noted in Jupiter's atmosphere. Also in Jupiter's atmosphere are oval features which are thought to be circular winds. The most prominent of these is the Great Red Spot, a hurricane-like storm that has been seen in Jupiter's southern hemisphere since Jupiter was first discovered. Jupiter has 50 named moons. 13 more have been discovered but not yet given official status or names. One of these satellites, Io, is volcanically active. Instruments aboard the space probe Galileo have detected surface temperatures on Io higher than any other planetary body in our Solar System. Voyager 2, also a space probe, has confirmed that Jupiter is surrounded by a system of thin rings. The majority of the rings are made up of very small particles thought to be debris from meteoroid collisions.

Question Sixteen
For over three hundred years, the Great Red Spot has been observed on Jupiter. What do astronomers believe has caused this feature?

Saturn: The Ringed Planet
When seen through a telescope, Saturn is one of the most beautiful sights in the night sky. It looks like a big ball inside of rings.

Saturn is a very large gas planet which spins very rapidly on its axis. It spins so fast that it flattens out the top and the bottom of the planet. The fast spin also causes Saturn to bulge at its equator. Saturn's atmosphere has winds which can blow at over 1800 kilometres per hour! The white spots on Saturn are believed to be powerful storms. Saturn is surrounded by over 1000 rings made of ice and dust. Some of the rings are very thin and some are very thick. The size of the particles in the rings range from pebble-size to house-size. Scientists believe that the particles came from the destruction of moons circling the planet. As comets and meteorites smashed the moons, Saturn's gravitational pull shaped the particles into rings. Saturn has at least 53 moons. Some of these moons orbit the planet within the rings, creating gaps in the rings.

Question Seventeen
True or False
The rings around Saturn contain pieces of ice which are all the size of a baseball.

Saturn is a large gas planet with an atmosphere composed of hydrogen and helium. Saturn's rapid spin tends to flatten out the poles while causing a bulge at its equator. The winds in Saturn's atmosphere reach speeds up to 1800 kilometres per hour! Astronomers see large white spots (or clouds) on Saturn which they believe are storms. Just like Jupiter, Saturn emits twice as much heat as it absorbs from the Sun indicating it also has an internal heat source. Saturn has an extensive ring system which is formed by a thousand individual rings. The rings appear to contain water ice and dust. The thickness of the rings ranges from 10 to 100 meters and the rings vary in brightness. There are gaps between some rings, while other rings appear to be braided together. Astronomers believe the rings developed from particles that resulted from the break-up of naturally occurring satellites. The particles in the rings closer to the planet orbit the planet at a faster speed than the particles in the rings farther from the planet. There are satellites within the rings which result in the gaps that are present between some rings. As with Jupiter, the pressurized hydrogen in Saturn's mantle produces electric currents which create a strong magnetic field around the planet. Saturn has at least 53 naturally occurring satellites.

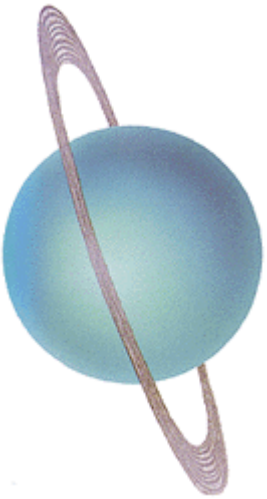
Question Eighteen
Saturn's most prominent feature is its ring system. What is the composition of the rings?

Uranus: Neptune's Twin
Uranus is one of the smaller gas giants in our solar system, but it is still large enough to hold 64 planets the size of Earth.

Uranus tilts over so far on its axis that it rotates on its side. Because of this, its poles are sometimes pointed almost directly at the Sun. Uranus' atmosphere is made up of hydrogen, helium, and methane. The temperature in the upper atmosphere is very cold. The cold methane gas is what gives Uranus its blue-green colour. The rapid rotation of Uranus causes winds up to 600 kilometres per hour to blow in its atmosphere. Uranus has eleven known rings which contain dark, boulder-sized particles. Uranus has 27 named moons. Some of these moons are less than 100 kilometres wide and black as coal.

Question Nineteen
What makes Uranus look blue-green in colour?

Uranus is unique in our solar system because it is tilted 98 degrees. When viewed from Earth, it appears to rotate on its side! At different times throughout its orbit, we can actually view one of the planet's poles head-on. The atmosphere is composed of hydrogen, helium, and methane. The temperature in the upper atmosphere is so cold that the methane condenses and forms a thin cloud layer which gives the planet its blue-green appearance. The winds on Uranus blow mainly to the east and can reach speeds up to 600 kilometres per hour. The rapid spin of Uranus influences the winds in the atmosphere. Uranus has a very strong magnetic field. This planet has a system of rings which was not discovered until 1977. The ring system contains eleven dark rings composed of varying sized particles. Satellites embedded in the rings create gaps between the rings. Uranus has 27 known natural satellites, both within the rings and outside of the rings.



Question Twenty
Why are we occasionally able to view a pole of Uranus head-on?

Neptune: The Blue Planet
It is so cold on Neptune that you would need skin thicker than a polar bear's to stay warm.

Neptune and Uranus are very much alike. They are both large gas planets that look like big blue-green balls in the sky. Neptune has winds in its atmosphere which blow at over 2000 kilometres per hour! This planet has large, dark circles on its surface which astronomers believe to be storms. Neptune has two thick and two thin rings which surround it. Neptune also has thirteen known moons. Four of these moons orbit the planet within the rings. One of Neptune's moons, Triton, orbits the planet in a direction opposite to Neptune's other moons. Neptune is the farthest planet from the Sun.

Question Twenty-one
Multiple choices
Astronomers believe that the large, dark circles on Neptune's surface are:

1. forest fires
2. storms
3. black holes

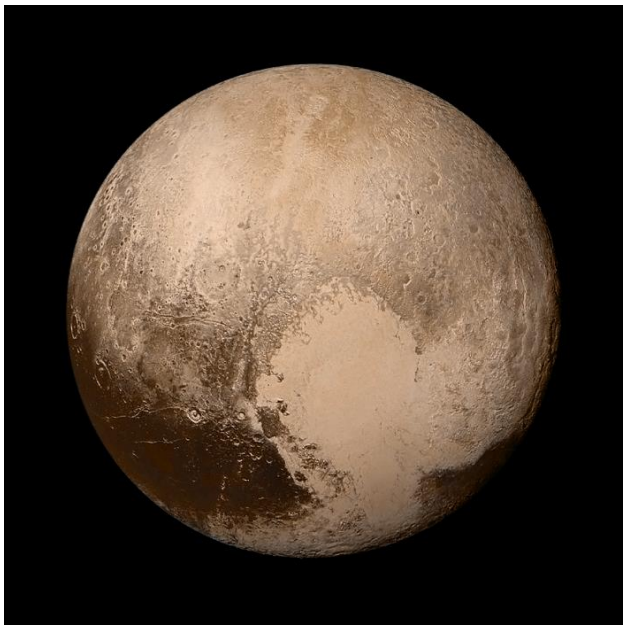
Voyager 2, a space probe, passed within 4900 kilometres of Neptune in 1989. From the data collected, we know that Uranus and Neptune are very similar in composition. Neptune has a mantle of liquid hydrogen while the atmosphere is a combination of ammonia, helium, and methane. In the upper atmosphere, methane freezes and forms an ice cloud which casts a shadow on the clouds below. Neptune has bands in its atmosphere where wind speeds may reach 2000 kilometres per hour! Neptune has large, dark ovals on its surface which astronomers believe are hurricane-like storms. Neptune generates more heat than it absorbs from the Sun, indicating it has its own internal heat source. Neptune has a very strong magnetic field. It also has a ring system consisting of four rings; two thin and two thick. The rings are composed of dark particles which vary in size. Neptune has thirteen known natural satellites, four of which orbit within the rings. The largest satellite is Triton. Due to Triton's retrograde orbit, its density, and its composition, astronomers theorize that Triton was not originally a satellite of Neptune. They theorize that Triton was captured by Neptune's gravitational pull, forcing it into an orbit around the planet. Triton is thought to be a combination of rock and ice. Its surface temperature is -245 degrees Celsius, and it has a thin atmosphere of nitrogen and methane.

Question Twenty-two
Why do astronomers not believe that Triton was an original satellite of Neptune?

Pluto: The First Dwarf Planet
Pluto is named for the ruler of the underworld in classical mythology.

Pluto was discovered in 1930 by astronomer Clyde Tombaugh. However, it was not until the year 2015 that we finally got a close-up look at the dwarf planet. After a nine-year journey, NASA's New Horizons spacecraft flew by Pluto, taking pictures and collecting data.

We now know that the surface of the dwarf planet is a tannish-red colour. Scientists also observed a large bright area shaped like a heart and dark regions near the equator. There are high mountains made out of water ice. These mountains are covered by layers of frozen gases. While a few craters were seen, there was not nearly as many as expected. This means that something must be changing the surface of Pluto. Scientists do not yet know what could be causing these changes.



From the data collected by the spacecraft, scientists also learned that Pluto has a rocky core surrounded by a thick mantle of ice. Some scientists wonder if there might be a thin liquid ocean beneath the frozen surface.

Data from the experiments on-board New Horizons determined Pluto's diameter to be 2,372 kilometres. It has an atmosphere of gases that expands when Pluto is nearer to the Sun. When Pluto is at its greatest distance from the Sun, the atmosphere freezes and falls to the surface.

It takes 6.39 Earth days for Pluto to make one spin on its axis. It takes Pluto 248 Earth years to make one orbit around the Sun. Pluto is about 40 times farther from the Sun than Earth. Pluto has five known moons: Charon, Nix, Hydra, Kerberos, and Styx.

Question Twenty-three
What is the name of the spacecraft that flew by Pluto in 2015?

Until the fly-by of NASA's New Horizons spacecraft in 2015, little was known about Pluto. It was believed to be composed of rock and ice. It was also believed that it had a very thin atmosphere composed of nitrogen and methane, which would expand or freeze to the surface depending on how far Pluto was from the Sun. It was known that it had one large moon named Charon, which was about half of Pluto's size, and that Pluto was tilted 122.5 degrees on its axis, which basically meant that it was rotating on its head. It was known that Pluto had an extreme, elliptical orbit. Because of the shape of Pluto's orbit, it actually slips inside of Neptune's orbit once every 248 Earth years for a period of twenty years. Pluto was thought to be heavily cratered from billions of years of impacts.

Observations made by New Horizons showed that Pluto was a much more interesting place than scientists had ever imagined. It has a tannish-red surface, probably from the presence of tholins. Tholins are created by the interaction of ultraviolet light from the Sun with methane. Tholins will form red debris on the surface, possibly giving Pluto its colour.

Contrary to what scientists had believed, only a few craters were seen on the surface. This proves that the surface of Pluto is somehow still being shaped. Scientists are currently unsure how a cold place could have enough geologic activity to change the surface, but the evidence for it is abundant. Resolving this mystery is currently the focus of many astronomers around the world.

The side of Pluto facing Charon looks different than the opposite side. On the side facing Charon, there is a series of four dark areas located near the equator. Each area is about the size of the State

of Missouri (200-300 kilometres across). On the opposite side, there is a very bright area that is shaped like a heart and one large elongated dark area along the equator.

Close up images of Pluto's surface shows tall water ice mountains, covered with layers of frozen methane and nitrogen. The average surface temperature for Pluto is around 40 Kelvin. At such low temperatures, water ice behaves like rock and can rise up to great heights without collapsing.

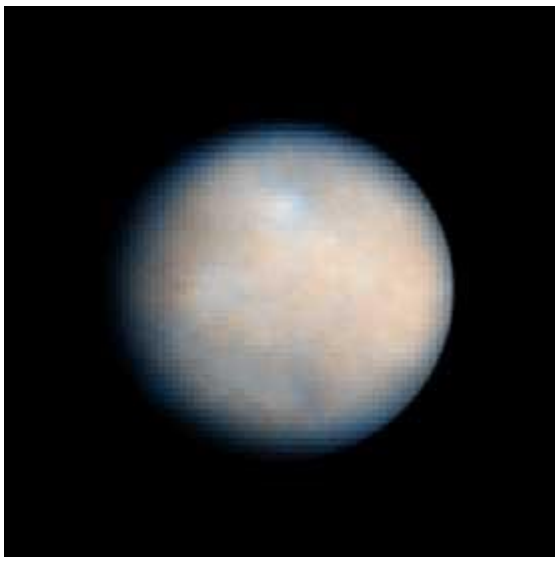
Observations during the New Horizons fly-by have allowed scientists to theorize what the inside of Pluto must be like. It is believed that Pluto has a small rocky core surrounded by a thick mantle of ice. Scientists arrived at these conclusions by looking at materials common in the outer solar system and how such materials react to temperature and pressure. In addition, Pluto's interaction with Charon allowed for a determination of Pluto's mass, and therefore its density.

We now know there are at least five moons of Pluto. Charon, Nix, Hydra, Kerberos, and Styx have all been confirmed by both ground and fly-by observations. However, there are still many things we do not know or understand about Pluto. Data from the New Horizons mission will be analysed for many years to come in an effort to unravel the mysteries uncovered at Pluto.

Question Twenty-four
What is so unusual about Pluto's moon Charon?

Ceres
When Ceres was first discovered it was called a comet. Within a year it was called a planet. Within one more year it was called an asteroid. Since 2006, it has been called a dwarf planet.

Ceres was discovered on January 1, 1801 by Italian Giuseppe Piazzi. He discovered it while searching for a star. Ceres is named after the goddess of growing plants, harvest, and motherly love. Piazzi originally named it Ceres Ferdinandea. Other astronomers around the world did not like the name, so it was changed to just Ceres.



Ceres is 415 million kilometres from the Sun. It is located in the asteroid belt between Mars and Jupiter. From 1802 until 2006, Ceres was the largest known asteroid in our Solar System. About one-third of all the material (or mass) found in the asteroid belt was in Ceres! When the new class of dwarf planets was made in 2006, Ceres fit the definition perfectly. Ceres is now the smallest of the known dwarf planets.

Ceres formed about 4.5 billion years ago when the solar system was forming. It is 950 kilometres wide. It is believed to have a rocky centre. Scientists also believe it may have a liquid layer somewhere below the surface.

Question Twenty-five
If Ceres were to suddenly depart the asteroid belt, by what percentage would the mass of the belt be decreased?

Italian Giuseppe Piazzi discovered Ceres on January 1, 1801 while he was searching for a star. He first believed that he had discovered a comet, but he was not confident in his belief. By the end of the year, with the help of other astronomers, he had collected enough evidence to call it a planet.

It takes approximately 4.6 Earth years for Ceres to make one revolution around the Sun. Ceres is located 415 million kilometres from the Sun and revolves around the Sun in an orbit between Mars and Jupiter. In 1802, additional objects were also found to be orbiting in the same area. Sir William Herschel labelled these objects as asteroids, so in 1802 Ceres became known as an asteroid, not a planet. Ceres was the largest known asteroid in the asteroid belt until 2006. In 2006, the International Astronomical Union formed a new class of solar system objects known as dwarf planets. By definition a dwarf planet is spherical and travels in an orbit around the Sun. Ceres fit the definition perfectly.

Because Ceres is spherical, it is unlike the majority of the members of the asteroid belt. Its composition is also slightly different than its neighbours in the belt. Its surface is probably covered with a mixture of water ice, carbonates, and clays. This leads astronomers to believe that it formed differently from the other bodies in the asteroid belt. It is now believed that Ceres formed 4.6 billion years ago when the solar system was forming. Apparently, Ceres never accumulated enough matter to get larger than the 950 kilometres in diameter that it currently is. Ceres contains one-third of the mass found in the asteroid belt.

Scientists believe that Ceres has a rocky core and an icy mantle. Some scientists also believe that it has a liquid water layer in its interior. This possibility makes Ceres very intriguing to scientists that are searching for signs of extra-terrestrial life. NASA has launched a probe called Dawn, whose mission is to travel to the asteroid belt. It will first travel to observe the asteroid Vesta. After collecting data from Vesta, Dawn will intercept with Ceres where it will observe its surface features and collect data about its chemical composition.

Eris

When Eris was first found, it was called Xena. Xena was the name of a warrior princess on a television show.

Eris is the largest known dwarf planet in our solar system. It is a little larger than Pluto. Eris is about 2400 kilometres wide.

Eris was first found by a team of astronomers at Palomar Observatory in California. Mike Brown and his team found Eris in 2003. It was not until 2005 that Eris was identified as another possible planet in our solar system. In 2006, astronomers decided that Eris should not be called a planet. They also decided that Pluto should no longer be called a planet. Both Eris and Pluto became known as dwarf planets. This is a special name created for objects in our solar system that don't meet all of the planet requirements.

Eris is the most distant member of our solar system known at this time. It is 3 times farther out than Pluto. One trip around the Sun takes 557 Earth years for Eris.

Observations of Eris have led scientists to believe it has frozen methane on its surface. Eris appears grey in colour. Dysnomia is the only moon of Eris that we now know about.

Question Twenty-six
As you are traveling out of our solar system, will you reach Pluto or Eris first?

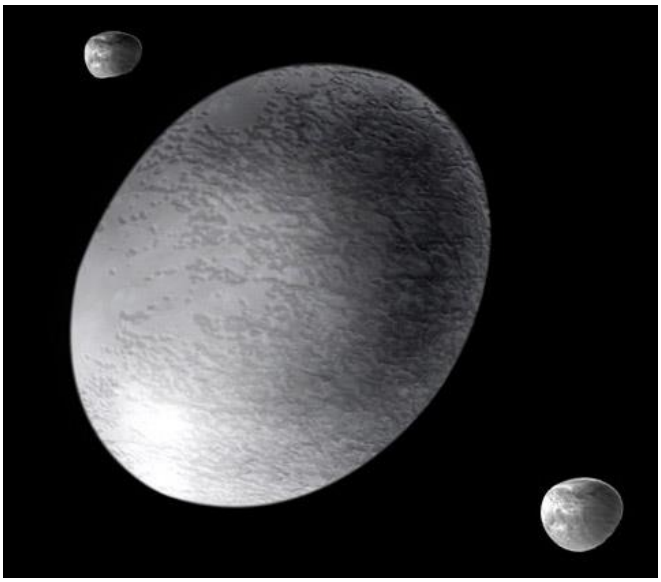
Eris, the largest known dwarf planet, was first detected in data collected in October of 2003. It was not identified until January of 2005. Mike Brown and his team of astronomers discovered what was considered to be the 10th planet while doing observations at the Palomar Observatory in California. At approximately 10 billion kilometres from the Sun, it is roughly 3 times farther out than Pluto. Eris is believed to be so far out that it is even out beyond the Kuiper Belt, which is at the outer fringe of the solar system. It takes 557 Earth years for Eris to make one orbit around the Sun. It has a highly eccentric orbit around the Sun, which causes its surface temperature to vary from -217 degrees Celsius to -243 degrees Celsius. Observations of Eris have led scientists to believe that it has frozen methane on its surface.

At 2400 kilometres in diameter, Eris is slightly larger than Pluto. Its discovery was one of the reasons the International Astronomical Union felt it was necessary to definitely define what should be considered a planet. Eris does not clear out its orbit, so it did not meet one of the requirements. Consequently, it was placed in the newly created category of dwarf planet along with Pluto and Ceres, which also did not meet all of the requirements to be called a planet.

Eris has one moon that we currently know about. Its name is Dysnomia. Dysnomia was the daughter of Eris and was considered to be the cause of lawlessness in the ancient world.

Question Twenty-seven
Why is Eris not considered to be the tenth planet in our solar system?

Haumea
Haumea is a dwarf planet found in the Kuiper Belt. The Kuiper Belt is a big cloud of gas, dust, and rocky debris located at the outer edge of our solar system.



Haumea was first discovered in 2004. It was accepted as one of our dwarf planets by the International Astronomical Union in 2008. Before being officially named, it was called Santa by one of its discovery teams because they first noticed it on December 28th.

Haumea is named after the Hawaiian goddess of childbirth. The two moons in orbit around Haumea were named after two of the children of Haumea. Hi'iaka is the larger moon, while the smaller moon was named Namaka. It is believed that these moons formed as a result of a collision between Haumea and some other body.

Haumea is shaped like a plump cigar. It spins very rapidly as it orbits around the Sun. It takes 285 Earth years for Haumea to make one trip around the Sun.

This dwarf planet has a mass less than half that of Pluto. It is believed to be solid rock covered in an icy crust.

Question Twenty-eight
How did Haumea's moons form?

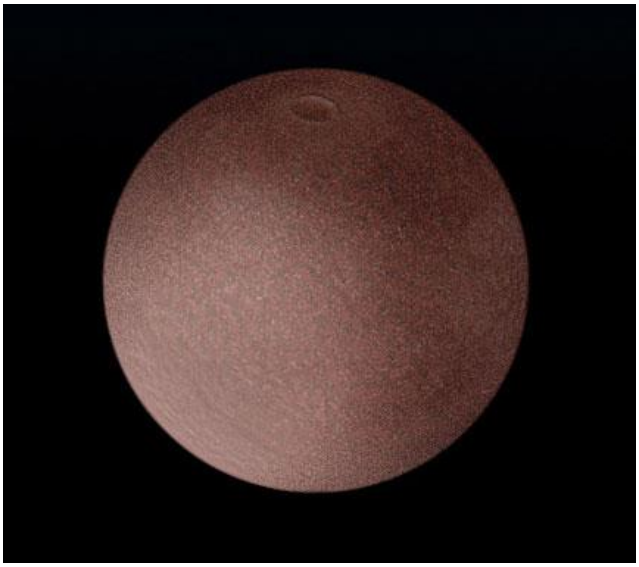
Like Pluto and Makemake, Haumea is a dwarf planet located in the Kuiper Belt. Its actual discovery is a controversial topic in the world of astronomy. A team of astronomers from Caltech first published the discovery online on July 20, 2005 using data they collected on May 6, 2004. It was called Santa by the Caltech team because they first noticed the dwarf planet on December 28, 2004 while analysing the images taken in May. On July 27, 2005, a Spanish team of astronomers from Instituto de Astrofisica de Andalucia published their discovery using data they collected on March 7, 2003. Regardless of who discovered Haumea, it was officially recognized as a dwarf planet by the International Astronomical Union in 2008.
Haumea (pronounced hah-oo-may-ah) is named after the Hawaiian goddess of fertility and childbirth. In Hawaiian mythology, Haumea's children sprang from different parts of her body. When two moons were discovered in orbit around Haumea, they were named after her children. The largest moon is called Hi'iaka. The smaller moon is known as Namaka.

Haumea is believed to have a mass that is one-third that of Pluto. It takes 285 Earth years for Haumea to make one orbit around the Sun.

Question Twenty-nine
Why was Haumea unofficially first called Santa?

Makemake
Makemake (pronounced mah-kee-mah-kee) was named after one of the gods from the Rapanui culture. The Rapanui people are natives of Easter Island. Easter Island is located in the south eastern Pacific Ocean.

Makemake was first discovered in 2005. It was formally recognized as a dwarf planet in 2008 by the International Astronomical Union.



Like its fellow dwarf planets Pluto and Haumea, Makemake is located in the Kuiper Belt. The Kuiper Belt is an area of gas, dust, and rocky debris located at the outer edge of our solar system. Makemake and Pluto are two of the brightest objects in the Kuiper Belt.

After Pluto and Eris, Makemake is the third largest dwarf planet. It takes this dwarf planet 310 Earth years to make one orbit around the Sun. At this time, no moons have been discovered in orbit around Makemake. The other dwarf planets found in the Kuiper Belt have moons in orbit around them. It is believed that Makemake has gases frozen into ice on its surface. When observed through a special instrument on a telescope, Makemake appears reddish in colour.

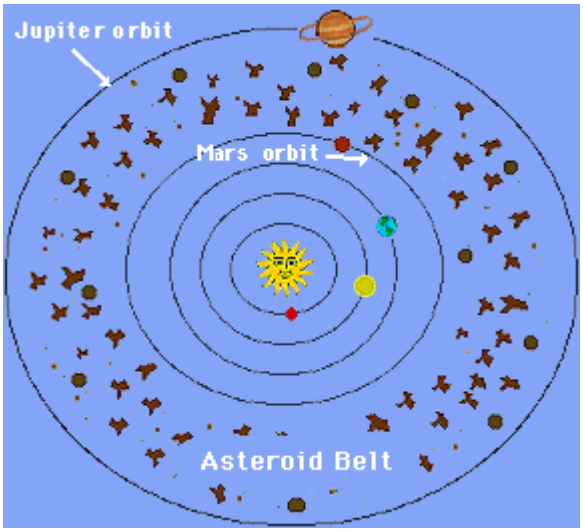
Question Thirty
How does Makemake differ from its fellow dwarf planets that are also found in the Kuiper Belt?

After Eris and Pluto, Makemake is the third largest known dwarf planet. Along with fellow dwarf planets Pluto and Haumea, Makemake is located in the Kuiper Belt, a region outside the orbit of Neptune. Pluto and Makemake are the two brightest objects that have so far been discovered in the Kuiper Belt. It takes 310 Earth years for this dwarf planet to make one orbit around the Sun. Makemake was first observed in 2005 by a team of astronomers led by Michael Brown. Its codename was Easter bunny. It was officially recognized as a dwarf planet by the International Astronomical Union in 2008. Observations have found evidence of frozen nitrogen on Makemake's surface. Frozen ethane and methane have also been detected on the surface. In fact, astronomers believe the methane may actually be present in pellets as large as one centimetre in diameter. Astronomers also found evidence of tholins. Tholins are molecules that form whenever solar ultraviolet light interacts with substances such as ethane and methane. Tholins, if present, usually cause a reddish-brown colour. During observations of Makemake, a reddish colour was observed.

Question Thirty-one
What is the possible explanation for the reddish colour of Makemake?

The Asteroid Belt
The dwarf planet called Ceres orbits the Sun in the asteroid belt.

An asteroid is a bit of rock. It can be thought of as what was "left over" after the Sun and all the planets were formed. Most of the asteroids in our solar system can be found orbiting the Sun between the orbits of Mars and Jupiter. This area is sometimes called the "asteroid belt". Think about it this way: the asteroid belt is a big highway in a circle around the Sun. Think about the asteroids as cars on the highway. Sometimes, the asteroid cars run into one another. When this happens, the asteroids may break up into smaller asteroids. Scientists think that most asteroids are the result of collisions between larger rocky space bodies.
Asteroids can be a few feet to several hundred miles wide. The belt probably contains at least 40,000 asteroids that are more than 0.5 miles across.



If an asteroid is captured by the gravitational pull of a planet, the asteroid can be pulled out of the belt and go into orbit as a moon around the planet that pulled on it.

Question Thirty-two
Between what two planets will you find the asteroid belt?

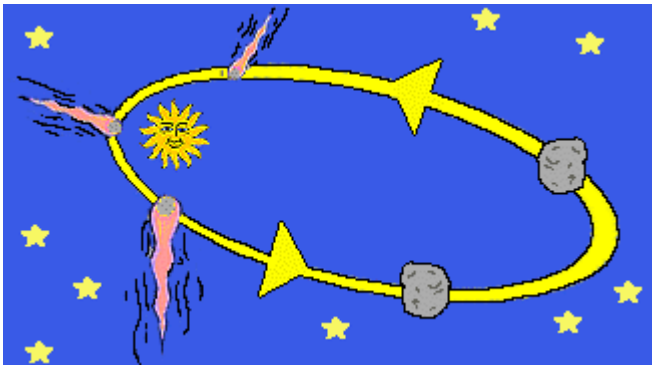
An asteroid is a rocky body in space which may be only a few hundred feet wide or it may be several hundred miles wide. They are considered to be debris left over from the formation of the solar system. Many asteroids orbit the Sun in a region between Mars and Jupiter. This "belt" of asteroids follows a slightly elliptical path as it orbits the Sun in the same direction as the planets. It takes anywhere from three to six Earth years for a complete revolution around the Sun. An asteroid may be pulled out of its orbit by the gravitational pull of a larger object such as a planet. Once an asteroid is captured by the gravitational pull of a planet, it

may become a satellite of that planet. Astronomers theorize that is how the two satellites of Mars, Phobos and Deimos, came to orbit that planet. An asteroid is also capable of colliding with a planet resulting in the formation of an impact crater. Some scientists believe that just such an impact in the area of the Yucatan Peninsula in Mexico started the chain of events which led to the extinction of the dinosaurs here on Earth. Astronomers think that if it were not for the giant planet Jupiter exerting its gravitational force on the asteroids in the belt, the inner planets would be constantly bombarded by large asteroids. The presence of Jupiter actually protects Mercury, Venus, Earth, and Mars from repeated asteroid collisions!

Question Thirty-three
What prevents the asteroids in the belt from plunging towards the Sun and hitting the inner planets in the process?

Comets
A comet's tail can be millions of kilometres in length, but the amount of matter it contains can be held in a large bookbag.

Scientists believe that comets are made up of material left over from when the Sun and the planets were formed. They think that about 100,000 million comets orbit the Sun. Some comets orbit the Sun like planets. Their orbits take them very close to and very far away from the Sun.



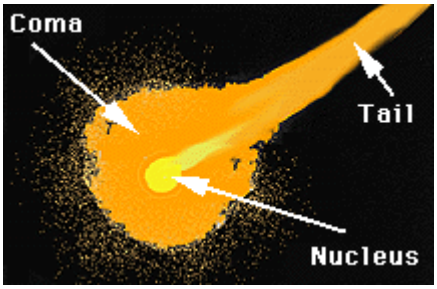
Comet orbits
A comet is made of dirty ice, dust, and gas. When a comet gets close to the Sun, part of the ice starts to melt. The solar winds then push the dust and gas released by the melting ice away from the comet. This forms the comet's tail. Every time a comet comes close to the Sun, a part of it melts. Over time, it will completely disappear.

A comet does not give off any light of its own. What seems to be light from the comet is actually a reflection of our Sun's light. Sunlight bounces off the comet's ice particles in the same way light is reflected by a mirror.

A few comets come close enough to the Earth for us to see them with our eyes. Halley's Comet, for example, can be seen from Earth every 76 years.

Question Thirty-five
Since comets have no light of their own, how are we able to see them?

Scientists believe that comets are the debris left from the solar nebula which condensed to form the Sun and planets in our solar system. Most comets are thought to originate in a huge cloud called the Oort Cloud. The Oort Cloud is believed to surround our solar system and reach over halfway to the nearest star, Alpha Centauri, which is 150,000 astronomical units away. Scientists think that about 100 million comets orbit the Sun. A comet has a distinct centre called a nucleus. Most astronomers think the nucleus is made of frozen water and gases mixed with dust and



rocky material. Comet nuclei are described as dirty snowballs. A hazy cloud called a coma surrounds the nucleus. The coma and the nucleus together form the comet's head.

Comets follow a regular orbit around the Sun. If the comet nucleus is pulled into an orbit which carries it close to the Sun, the solar heat will cause the outer layers of the icy nucleus to evaporate. During this process, dust and gases which form the coma around the nucleus are released. As the comet gets closer to the Sun, the coma grows. The solar winds push the dust and gas away from the coma causing them to stream off into space to form the comet's tail. The solar winds cause the comet's tail to point away from the Sun. The tails of comets can reach 150 million kilometres in length! Each time the comet passes close to the Sun, it loses some of its material. Over time, it will break up and disappear completely.
Many comets enter an elliptical orbit and repeatedly return to the inner solar system where they can be viewed from Earth at specific times. Short period comets, of which Halley's Comet is the most famous, reappear within a 200 year time frame. Halley's makes an appearance once every 76 years. The comet was named after Sir Edmond Halley.

A comet has no light of its own. We are able to see a comet because of the reflection of the Sun's light off of the comet and because of the gas molecules in the coma releasing energy absorbed from the Sun's rays.

Question Thirty-six
As a comet approaches the Sun, does its head or tail lead the way? As it moves around from the Sun, which parts leads?

The Universe

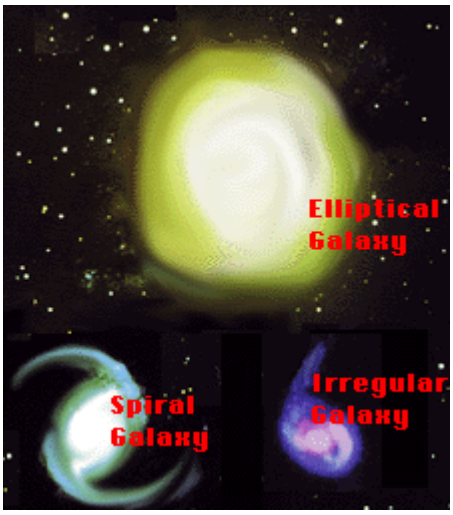
The universe is a huge wide-open space that holds everything from the smallest particle to the biggest galaxy. No one knows just how big the Universe is. Astronomers try to measure it all the time. They use a special instrument called a spectroscope to tell whether an object is moving away from Earth or toward Earth. Based on the information from this instrument, scientists have learned that the universe is still growing outward in every direction.

Scientists believe that about 13.7 billion years ago, a powerful explosion called the Big Bang happened. This powerful explosion set the universe into motion and this motion continues today. Scientists are not yet sure if the motion will stop, change direction, or keep going forever.

The universe is a vast expanse of space which contains all of the matter and energy in existence. The universe contains all of the galaxies, stars, and planets. The exact size of the universe is unknown. Scientists believe the universe is still expanding outward. They believe this outward expansion is the result of a violent, powerful explosion that occurred about 13.7 billion years ago. This explosion is known as the Big Bang. By looking at an object's electromagnetic spectrum, scientists can determine if an object is moving away from Earth or towards Earth. When distant objects, such as quasars, are viewed from Earth, their spectrum is shifted towards red. Whenever there is a shift in a spectrum, it is called a Doppler Shift. If the shift is toward red, the light given off by the object is in longer wavelengths. When an object moves away from Earth, the light that it is giving off is seen in longer wavelengths. When an object moves toward Earth, the light that it is giving off is seen in shorter wavelengths. This causes a shift in the object's spectrum towards violet. The amount of shift in an object's spectrum is determined by how fast the object is moving. All of the distant galaxies have tremendous red shifts. Based on these data, scientists believe the universe is still expanding outward.

Galaxies
A light-year is the distance light travels in one year. It is 9.5 trillion (9,500,000,000,000) kilometres. The size of a galaxy may be as little as a thousand light-years across or as much as a million light-years across.

A galaxy contains stars, gas, and dust which are held together as a group by gravity. There may be millions, or even billions, of stars in one galaxy. There are billions of galaxies in the universe.



Galaxies are labelled according to their shape. Some galaxies are called "spiral", because they look like giant pinwheels in the sky. The galaxy we live in, the Milky Way, is a spiral galaxy. Some galaxies are called "elliptical", because they look like flat balls. A galaxy may be called "irregular" if it doesn't really have a shape. A new type of galaxy was discovered recently, called a "starburst" galaxy. In this type of galaxy, new stars just seem to 'burst out' very quickly.

Question Thirty-seven
Which type of galaxy looks like a giant sky pinwheel?

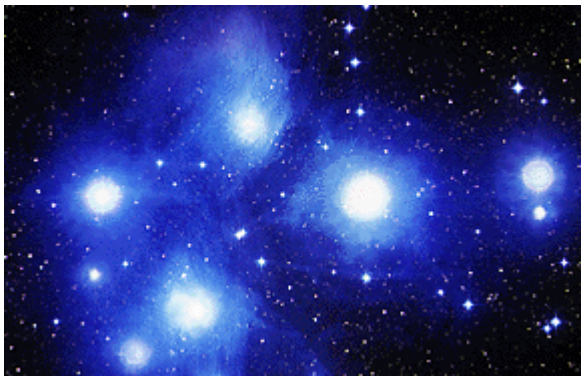
A galaxy is a cluster of stars, dust, and gas which is held together by gravity. Galaxies are scattered throughout the universe and they vary greatly in size. A galaxy may be alone or it may be in a large group of galaxies called a "supercluster". Galaxies are classified by scientists according to their shape and appearance. An irregular galaxy has an undefined shape and is full of young stars, dust, and gas. A spiral galaxy is shaped like a disk. The disk tends to resemble a pinwheel with arms which spiral outward as it rotates. Spiral galaxies tend to contain more middle-aged stars along with clouds of gas and dust. The next galaxy classification is an elliptical galaxy. The elliptical galaxies contain older stars and very little gas and dust. Elliptical galaxies vary in their shape from round to flattened, elongated spheres.

By studying the Doppler shift of different galaxies, scientists have concluded that all of the galaxies are moving away from each other. Galaxies that are the farthest from Earth appear to be traveling the fastest (relative to the Earth) of any galaxies.

A starburst galaxy has an exceptionally high star birth rate. The Hubble Space Telescope's high resolution has allowed astronomers to see dense star clusters, dust lanes with tiny regions of dense gas, and filaments of glowing gas in the core of a starburst galaxy.

Question Thirty-eight
What evidence do scientists have that galaxies are continuing to move away from each other?

Stars
Stars change over time. It may take millions to billions of years for a star to live out its life. That is a very, very long time!
A star is a big ball of gas which gives off both heat and light. So where do stars come from? What happens to them as they grow older?



A galaxy contains clouds of dust and gas, as well as stars. It is in the clouds of dust and gas that stars are born. As more and more of the gas (which is mostly hydrogen) is pulled together by gravity into a cloud, the cloud starts to spin. The gas atoms start to bump into each other faster and faster. This creates heat energy. The cloud gets hotter and hotter. Finally, it gets so hot within the cloud that something called "nuclear fusion" happens. The cloud begins to glow. The glowing cloud of gas is now known as a protostar. The protostar continues to grow. Once it stops growing, it is known as a main sequence star. A main sequence star can shine for millions of years or more. The amount of time it lives is determined by how big it is.

Medium stars

In medium size stars, after the nuclear fusion has used up all the fuel it has, gravity will pull the remaining material closer together. The star will shrink. In fact, it may get to be only a few hundred kilometres wide! The star is then called a "white dwarf". It can stay like this for a long time. Eventually, it will stop producing any light at all. It is then called a "black dwarf" and it will stay that way forever.

As a red giant, the hydrogen gas in the outer shell continues to burn as the temperature in the core continues to rise. At 200,000,000 degrees Celsius, the helium atoms fuse to form carbon atoms in the core. The last of the hydrogen gas in the outer shell is blown away to form a ring around the core. This ring is called a planetary nebula. When the last of the helium atoms in the core are fused into carbon atoms, the medium size star begins to die. Gravity causes the last of the star's matter to collapse inward and compact. This is the white dwarf stage which is extremely dense. White dwarfs shine with a white hot light but once all of their energy is gone, they die. The star has now reached the black dwarf phase.

Massive stars

In large size stars, nuclear fusion will continue until iron is formed. In stars, iron acts like an energy sponge. It soaks up the star's energy. This energy is eventually released in a big explosion called a supernova. The little bit of matter that used to be at the centre of the star before the supernova will then be either a neutron star or a black hole. Which object it becomes depends on the size of the original star. A star that is 1.5 to 4 times larger than our Sun will become a neutron star. Stars that are even bigger than that will become black holes

Once massive stars reach the red giant phase, the core temperature continues to increase as carbon atoms are formed from the fusion of helium atoms. Gravity continues to pull together the carbon atoms in the core until the temperature reaches 600,000,000 degrees Celsius. At this temperature, carbon atoms form heavy elements such as oxygen and nitrogen. The fusion and production of heavy elements continues until iron starts to form. At this point, fusion stops and the iron atoms start to absorb energy. This energy is eventually released in a powerful explosion called a supernova. A supernova can light the sky up for weeks. The temperature in a supernova can reach 1,000,000,000 degrees Celsius. This high temperature can lead to the production of new elements which may appear in the new nebula that results after the supernova explosion. The core of a massive star that is 1.5 to 4 times as massive as our Sun ends up as a neutron star after the supernova. Neutron stars spin rapidly giving off radio waves. If the radio waves appear to be emitted in pulses (due to the star's spin), these neutron stars are called pulsars. The core of a massive star that has 10 or more times the mass of our Sun remains massive after the supernova. No nuclear

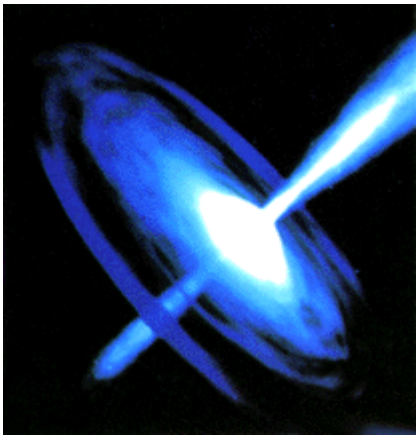
fusion is taking place to support the core, so it is swallowed by its own gravity. It has now become a black hole which readily swallows any matter and energy that comes too near it. Some black holes have companion stars whose gases they pull off. As the gases are pulled down into the black hole, they heat up and give off energy in the form of X-rays. Black holes are detected by the X-rays which are given off as matter falls down into the hole.

Question Thirty-nine
What type of stars will become neutron stars as they are dying out?
1) Stars smaller than our Sun.
2) Stars more than 10 times larger than our Sun.
3) Stars the same size as our Sun.
4) Stars 1.5 to 4 times larger than our Sun.

A star is a brilliantly glowing sphere of hot gas whose energy is produced by an internal nuclear fusion process. Stars are contained in galaxies. A galaxy contains not only stars, but clouds of gas and dust. These clouds are called nebulae, and it is in a nebula where stars are born. In the nebula is hydrogen gas which is pulled together by gravity and starts to spin faster. Over millions of years, more hydrogen gas is pulled into the spinning cloud. The collisions which occur between the hydrogen atoms start to heat the gas in the cloud. Once the temperature reaches 15,000,000 degrees Celsius, nuclear fusion takes place in the centre, or core, of the cloud. The tremendous heat given off by the nuclear fusion process causes the gas to glow creating a protostar. This is the first step in the evolution of a star. The glowing protostar continues to accumulate mass. The amount of mass it can accumulate is determined by the amount of matter available in the nebula. Once its mass is stabilized, the star is known as a main sequence star. The new star will continue to glow for millions or even billions of years. As it glows, hydrogen is converted into helium in the core by nuclear fusion. The core starts to become unstable and it starts to contract. The outer shell of the star, which is still mostly hydrogen, starts to expand. As it expands, it cools and starts to glow red. The star has now reached the red giant phase. It is red because it is cooler than the protostar phase and it is a giant because the outer shell has expanded outward. All stars evolve the same way up to the red giant phase. The amount of mass a star has determines which of the following life cycle paths the star will take.

Question Forty
What determines just how large a star becomes?

Black Holes
Most scientists believe that there is a black hole in the centre of our very own Milky Way.



Black holes were once massive stars that used up all their fuel. As they died out, they collapsed inward due to the pull of their own gravity. The gravity of a black hole is so powerful that not even light can escape its pull! Once any matter falls into a black hole, it disappears from the visible universe.

It is very hard to see a black hole. Any object that gets too close to a black hole will be pulled inside it. We only know they are there because of the effects they have on other objects that are near them. Any object, whether some dust, or a star, or anything, that gets too close to a black hole will be pulled inside it. As the objects fall toward the black hole, they heat up and get very hot. Scientists can use special instruments to detect the

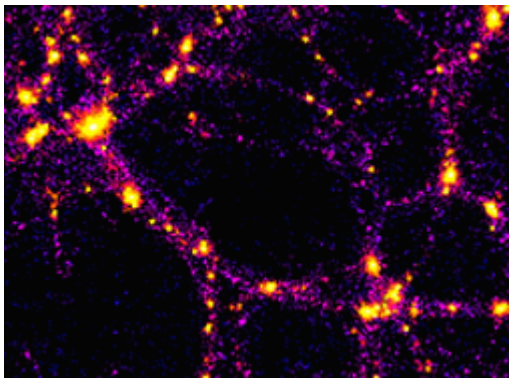
heat the objects give off. That is how we know the black hole must be there.

Question Forty-one
How do we know that there really are black holes?

Black holes are extremely compact space objects that were once massive stars which collapsed inward due to the force of their own gravity. Consequently, black holes are very dense. If it were not for the effect that black holes have on the objects around them, we would be unable to detect them. A black hole has a powerful gravitational field which traps everything that goes near it. Scientists now theorize that some galaxies have huge black holes in their centres which release tremendous amounts of energy that powers the spectacular energetic events that go on within the galaxy. The fuel for the black hole, scientists believe, may be the trapped gas, stars, and dust that are pulled into the hole. Gas that is pulled into a black hole swirls down into the hole much like a whirlpool. By using a spectroscope, the Hubble Space Telescope has the ability to clock the speed of this gas as it swirls around the entrance to the hole. The speed with which the gas swirls is considered the black hole's signature. By knowing the speed of the gas, the mass of the black hole can be calculated. A black hole in the centre of the M87 galaxy in the constellation Virgo, which is 50 million light-years away, has been calculated to have a mass equal to that of 3 billion Suns! An even more effective way of studying black holes is through the use of X-ray observations. X-rays have the capacity to penetrate through gas and dust much better than optical light. With the data delivered to us by X-ray observations and the Hubble Space Telescope, scientists now believe that the presence of black holes explains a lot of the powerful cosmological events which occur in the universe.

Question Forty-two
How are scientists able to detect the presence of a black hole in a galaxy?

Dark Matter
Dark matter was once called "missing matter". It was called this because scientists looking at the sky could not find it.
Matter is anything that takes up space and has mass. We are used to matter which we will call visible matter. Visible matter can be seen because it gives off light or reflects light given off by another object. Dark matter cannot be seen. It does not give off light or reflect light.



Scientists believe that over ninety-percent of the matter in the universe is dark matter. They also believe that by studying dark matter they will gain new information about the universe. Some of the information they hope to discover is the size, shape and future of the universe. Scientists also hope to learn about how galaxies formed by studying dark matter.

Scientists cannot see dark matter, so they have a special way of studying it. Scientists study dark matter by looking at how it affects visible matter. Scientists use computers and satellites to study dark matter. The Hubble Space Telescope has taken pictures that have helped scientists discover where dark matter can be found.

Question Forty-three
What is the difference between regular matter and dark matter?

There is no current problem of greater importance to cosmology than that of dark matter. Dark matter is composed of particles that do not absorb, reflect, or emit light, so they cannot be detected by observing electromagnetic radiation. Dark matter is material that cannot be seen directly. We know that dark matter exists because of the effect it has on objects that we can observe directly.

Scientists study dark matter by looking at the effects it has on visible objects. Scientists believe that dark matter may account for the unexplained motions of stars within galaxies. Computers play an important role in the search for dark matter data. They allow scientists to create models which predict galaxy behaviour. Satellites are also being used to gather dark matter data. In 1997, a Hubble Space Telescope image (seen on the right) revealed light from a distant galaxy cluster being bent by another cluster in the foreground of the image. Based on the way the light was bent, scientists estimated the mass of the foreground cluster to be 250 times greater than the visible matter in the cluster. Scientists believe that dark matter in the cluster accounts for the unexplained mass.

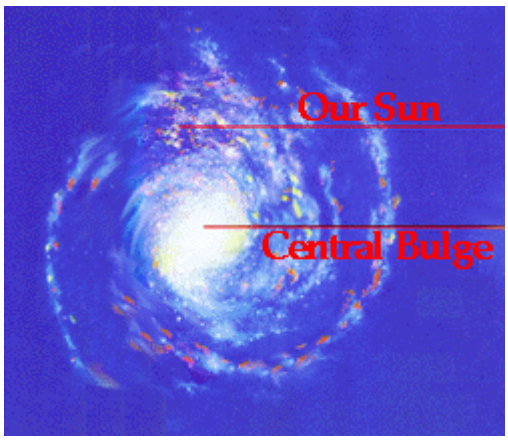
Scientists have produced many theories about what exactly dark matter may be. Some believe that it may be normal objects such as cold gasses, dark galaxies, or massive compact halo objects (called MACHOs, they would include black holes and brown dwarfs). Other scientists believe that dark matter may be composed of strange particles which were created in the very early universe. Such particles may include axioms, weakly interacting massive particles (called WIMPs), or neutrinos.

Understanding dark matter is important to understanding the size, shape and future of the universe. The amount of dark matter in the universe will determine if the universe is open (continues to expand), closed (expands to a point and then collapses) or flat (expands and then stops when it reaches equilibrium). Understanding dark matter will also aid in definitively explaining the formation and evolution of galaxies and clusters. As a galaxy spins it should be torn apart. This does not happen, so something is holding the galaxy together. The something is gravity; the amount of gravity required to do this, however, is enormous and could not be generated by the visible matter in the galaxy.

Question Forty-four
If dark matter cannot be seen, how do we know that there is the possibility that it exists?

The Milky Way
There are over 100 billion stars in the Milky Way galaxy. If you tried to count them one by one, it would take you over 3000 years!

The Milky Way is over 100,000 light-years wide. It is called a spiral galaxy because it has long arms which spin around like a giant pinwheel. Our Sun is a star in one of the arms. When you look up at the night sky, most of the stars you see are in one of the Milky Way arms.



Before we had telescopes, people could not see many of the stars very clearly. They blurred together in a white streak across the sky. A myth by the ancient Greeks said this white streak was a "river of milk". The ancient Romans called it the Via Galactica, or "road made of milk". This is how our galaxy became known as the Milky Way.

Question Forty-five
True or False
When you look up into the night sky, most of the stars you see are located in the centre of the Milky Way.

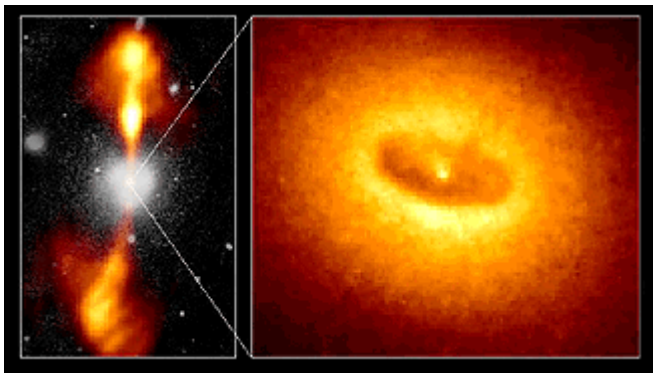
Our Sun is a star in the Milky Way Galaxy. If you were looking down on the Milky Way, it would look like a large pinwheel rotating in space. Our Galaxy is a spiral galaxy that formed approximately 14 billion years ago. Contained in the Milky Way are stars, clouds of dust and gas called nebulae, planets, and asteroids. Stars, dust, and gas fan out from the centre of the Galaxy in long spiralling arms. The Milky Way is approximately 100,000 light-years in diameter. Our solar system is 26,000 light-years from the centre of the Galaxy. All objects in the Galaxy revolve around the Galaxy's centre. It takes 250 million years for our Sun to pull us through one revolution around the centre of the Milky Way. The stars we see over our head every night are also members of the Milky Way family.
It is interesting to note that astronomers capitalize the "G" in galaxy when talking about our Milky Way!

Question Forty-six
The Milky Way is classified as what type of galaxy?

Quasars
Quasars give off more energy than 100 normal galaxies combined.

Quasars are farther away from Earth than any other known object in the universe. Because they are so far away from us, it takes billions of years for the light they give off to reach Earth. The light stays the same; it just has to travel a long time to get to us. When we look at a quasar, it is like we are looking back in time. The light we see today is what the quasar looked like billions of years ago. Some scientists think that when they study quasars they are studying the beginning of the universe.

Quasars give off huge amounts of energy. They can be a trillion times brighter than the Sun! Astronomers think that quasars are located in galaxies which have black holes at their centres. The black holes may provide quasars with their energy. Quasars are so bright that they drown out the light from all other stars in the same galaxy. The word quasar is short for quasi-stellar radio source. Quasars give off radio waves, X-rays, gamma-rays, ultraviolet rays, and visible light. Most of them are larger than our solar system.



Question Forty-seven
Why is it so difficult to see a star located in the same galaxy as a quasar?

Many astronomers believe that quasars are the most distant objects yet detected in the universe. Quasars give off enormous amounts of energy - they can be a trillion times brighter than the Sun! Quasars are believed to produce their energy from massive black holes in the centre of the galaxies in which the quasars are located. Because quasars are so bright, they drown out the light from all the other stars in the same galaxy.

Despite their brightness, due to their great distance from Earth, no quasars can be seen with an unaided eye. Energy from quasars takes billions of years to reach the Earth's atmosphere. For this reason, the study of quasars can provide astronomers with information about the early stages of the universe.

The word quasar is short for "quasi-stellar radio source". This name, which means star-like emitters of radio waves, was given in the 1960s when quasars were first detected. The name is retained today, even though astronomers now know most quasars are faint radio emitters. In addition to radio waves and visible light, quasars also emit ultraviolet rays, infrared waves, X-rays, and gamma-rays. Most quasars are larger than our solar system. A quasar is approximately 1 kilo parsec in width.

Question Forty-eight
What is the average width of a quasi-stellar radio source?

Cosmology

Cosmology is a branch of science which studies the evolution of our universe. A scientist who studies cosmology is called a cosmologist. Cosmologists want to know what the universe was like billions of years ago. They want to understand how it is today. They also want to find out what the universe will be like billions of years in the future.

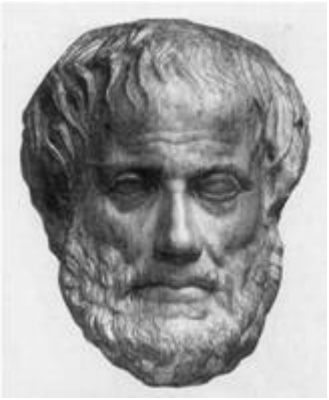
To understand the universe, cosmologists first needed to know our place in it. About 400 years ago, most people believed that Earth was at the centre of the universe. They thought the Moon, the Sun, and the other planets all travelled around Earth. Nicholas Copernicus, Galileo Galilei, and Isaac Newton helped us to learn the truth. We now know that the Moon travels around Earth. Earth and the other planets in our solar system travel around the Sun.

About 100 years ago, astronomer Edwin Hubble made observations that showed the universe was getting bigger and bigger! This led most cosmologists to believe in a theory called the Big Bang. The Big Bang theory says the universe began with a huge explosion ten to twenty billion years ago. Cosmologists think the universe did not exist before the Big Bang. Some cosmologists think the universe will keep getting bigger forever. Other cosmologists think the Universe will someday start getting smaller. They think it will shrink until it no longer exists. No one knows yet which opinion is correct.

Cosmologists use the data gathered by telescopes and astronomy satellites to help them understand the universe. They also use computers to model their ideas. Each new discovery helps them to understand more about the past, present, and future of our universe.

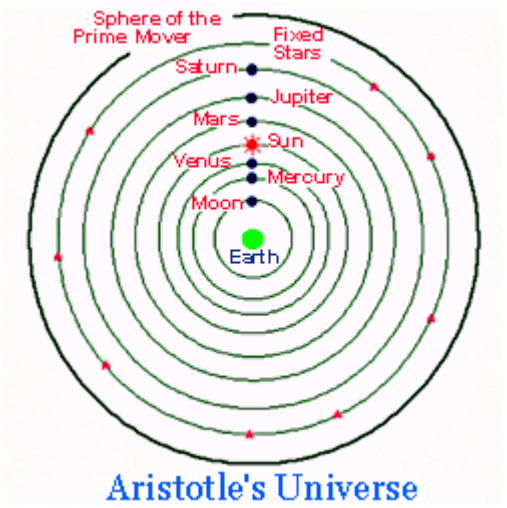
Question Forty-nine
Use one or more of the underlined words to help you fill in the blank.
People used to believe the ***Sun***, the ***other planets*** and ***the Moon*** travelled around Earth.
Today we know that only the _____ travels around Earth.

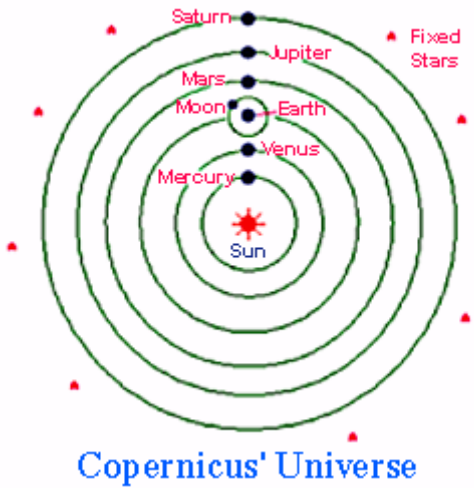
Like early astronomers from around the world, the ancient Greeks struggled to understand the universe. Thales, often called the father of Greek science and mathematics, asked questions about the universe that were not based on the actions of gods or demons. It is said that Thales provided the bridge between the world of myth and the world of reason. He used the astronomical records of the Babylonians and Egyptians to accurately predict a solar eclipse in the sixth century BC. Thales believed the Earth was flat and floated on water like a log.



Aristotle, who lived from 384 to 322 BC, believed the Earth was round. He thought Earth was the centre of the universe and that the Sun, Moon, planets, and all the fixed stars revolved around it. Aristotle's ideas were widely accepted by the Greeks of his time. The exception, a century later, was Aristarchus, one of the earliest believers in a heliocentric or sun-centred universe. In the 100s BC, Hipparchus, the most important Greek astronomer of his time, calculated the comparative brightness of as many as 1,000 different stars. He also calculated the Moon's distance from the Earth.

The first astronomer to make truly scientific maps of the heavens, Claudius Ptolemaeus (better known as Ptolemy of Alexandria), came along 300 years later. Like most astronomers before him, he believed the Sun, Moon, and other planets circled the Earth. He thought that each space body moved in a small circle (an epicycle) that was itself orbiting Earth. This explained why planets sometimes appeared to travel backward in the sky. The Earth-centred view of the universe was widely accepted for about 1500 years. It was not seriously challenged until 1543, when the Polish monk Nicolaus Copernicus suggested that the Sun was at the centre of the universe. Because the Church taught that the Earth was central, Copernicus' theory was regarded as heresy. Perhaps this is why he did not want it published until after his death. Copernicus' published theory, *On the Revolution of the Celestial Spheres*, met with great hostility from the Church. The two events most responsible for eventual acceptance of Copernicus' views were Tycho Brahe's precise observations of the sky and Galileo's use of the telescope.





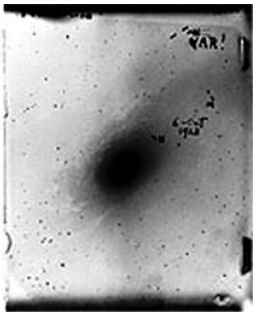
One night in 1572, Danish astronomer Tycho Brahe saw what he thought was a brilliant new star in the constellation Cassiopeia. (We now know he was observing a supernova.) In 1604, a second supernova was observed. These discoveries caused scientists to seriously question Ptolemy's theory that all stars were contained in an outermost sphere of the universe that never changed.
In 1609, Italian scientist Galileo Galilei heard about the invention of a spyglass. He made one for himself and turned it on the heavens. One of his first discoveries was of four moons circling the planet Jupiter. Galileo's telescope revealed a miniature version of Copernicus' solar system, with the moons moving around the planet in simple, circular orbits. Galileo's discoveries forever changed the face of astronomy.

The beginnings of modern science can be attributed to Galileo and to the British genius Isaac Newton. Newton was born in the same year that Galileo died. Isaac Newton took known facts and used mathematics to explain them. He developed mathematical laws that explained how objects

move on Earth as well as in space. Newton explained the movement of orbiting planets as the result of motion along a straight line combined with the gravitational pull of the Sun. His laws are all based on the idea that nothing is naturally at rest. He reasoned that all heavenly bodies are constantly moving, with no limits on space and time.

In 1917, Albert Einstein proposed a description of the universe based on his Theory of General Relativity. Einstein's theory inspired many other scientists, including Willem de Sitter in Holland and Alexandra Friedmann in Russia. In fact, much of today's cosmology is based on Freedman's solutions to the mathematical equations included in Einstein's Theory. Friedmann built on the General Relativity equations to develop models that helped explain the evolution of the universe.

A major breakthrough in our understanding of the universe took place in the 1920's thanks to American astronomer Edwin Hubble. For centuries, astronomers believed that the Milky Way made up the entire universe. Hubble was among the first to show that the fuzzy patches in the sky seen through telescopes were other galaxies, not distant parts of the Milky Way. By looking at the spectra of these galaxies, he concluded they were speeding away from us - that the universe was expanding!



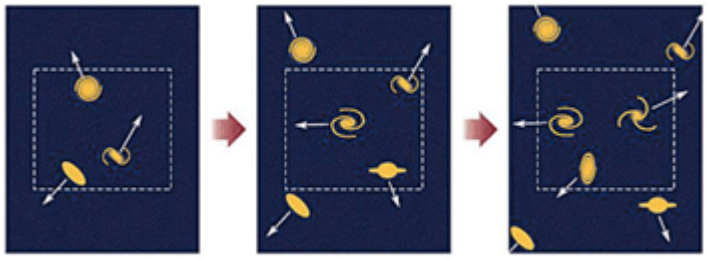
Big Bang

Georges Lemaitre, a Belgian astrophysicist and Catholic priest, came to be known as the "Father of the Big Bang". Lemaitre proposed that the universe began as a single primordial atom of energy, something hot and dense that exploded, causing space to expand outward. In the late 1940s, George Gamow, a Russian-American physicist, conceived of the Bang theory as we know it today. He and his colleagues proposed that if a big bang had occurred, it would have left an afterglow, traces of background radiation that would still be present.

In 1965, physicists Arno Penzias and Robert Wilson started to search for faint radio signals (actually microwaves) from the outskirts of the Milky Way Galaxy. While conducting their investigations, they actually found the afterglow predicted by Gamow. It was important evidence that the universe began with a hot big bang. More recently, NASA's COBE satellite measured this radiation in great detail. All of the measurements were consistent with the Big Bang theory.
In 1979, particle physicist Alan Guth performed calculations that led to the idea of "cosmic inflation", a brief period of rapid expansion in the early universe. Inflation solves many problems with the simple, original Big Bang. It explains why the universe is so big and so smooth, why at least four different forces act in it today, and where the large amounts of matter that makes up the universe came from.

Steady State

The idea that the universe had a specific beginning did not appeal to all scientists. The Steady State Theory, developed in 1948, concluded the universe had no beginning and no end. This theory describes an expanding universe that stays in perfect balance like a pool kept full to overflowing by a trickle from a faucet. The "faucet" of the universe would be the continuous creation of matter from energy. Arguments against the Steady State Theory include the discovery of background cosmic heat radiation. The fact that the amount of helium observed in the universe exactly fits what was predicted by the Big Bang and the discovery that galaxies were more crowded together in the past further discredit the Steady State theory.



Today's Views

Today cosmologists are concerned with the ultimate fate of the universe. Will it expand forever, expand to a certain size and stop, or will it stop and begin to collapse? Data suggesting that the universe is expanding at an accelerating rate were published in 1998. For more than ten years astronomers studied the expansion of the universe by measuring the redshift and brightness of distant supernovae. By 1998, enough information had been gathered to lead scientists to the startling discovery that the expansion of the universe is not slowing but accelerating. The supernova data combined with information from other cosmological studies strongly suggest that the universe is filled with an unidentified form of energy (currently being called "dark energy" since we know nothing about it) that is causing the expansion of the universe to accelerate. If these observations and analyses turn out to be correct, the universe would be expected to continue to expand forever.

Question Fifty

How do the Big Bang and Steady State theories differ in their explanations of how the universe was created?