Science Through Postcard

Dr Jayant Narlikar

Preface

It is not uncommon that at the end of a public lecture, I am surrounded by autograph-hunters, mostly students. Rather than oblige them with my signature, I decided to try out an experiment, on such occasions. I asked the typical autograph-aspirant to send me a question on a postcard. The question should ideally relate to my talk or, at least, fall within my area of study, namely the science of astronomy. My reply would carry my autograph.

The purpose of this experiment was to filter out the majority of students who were asking for the autograph, just for the fun of it and to concentrate my attention only on the few serious ones. For, only the latter would bother to write to me with a question. Although answering them involved some effort on my part (certainly more than scribbling my signature), I enjoyed doing so. The questions came in three languages English, Marathi and Hindi.

A few years ago, at the behest of the late Mr. Sharad Naik, Secretary of the Marathi Vidnyan Parishad, a collection of frequently asked questions and my answers, was published as a Marathi booklet. Now at the request of Mr. Anant Deshpande, Secretary MVP, an English translation is being published.

I thank my wife Mangala for translating the Marathi version and also for helping me polish the answers. I hope the English version is as successful as the Marathi original.

Jayant Narlikar

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About the Book

Whenever Dr. Jayant Narlikar delivered a lecture, people of all age groups including school going children queued up for his autograph. To circumvent this situation, he did an experiment. He started telling children to write him a postcard and ask him a question in Science, based on the lecture he just delivered. He started getting a number of such postcards. The questions asked in such postcards are of a repetitive nature. We have collected 44 such questions and answers of them given by Dr. Jayant Narlikar for the benefit of the students.

The booklet was published twice in Marathi (30 April 1995 and 28 April 1997). Because of a growing demand from children and their parents it is being published for the first time in English. We hope children will welcome this booklet. We thank Dr. Mangala Narlikar for translating the Marathi booklet into English very promptly.

1-1-2001

A.P.Deshpande
Hon. Secretary

Q.1 Why does the sky look blue?

In the atmosphere around the Earth, there are a lot of particles of gases as well as dust. The Sun's light coming to the Earth gets scattered by the dust particles. So, some of the Sun's rays do not reach the Earth but get scattered on the way.

The sunlight is formed of seven color bands. The different colors have different wavelengths. The red color has the longest wavelength while the purple-blue has the shortest wavelength. When a light wave hits a dust particle, the extent of its scattering depends on the wavelength. The longer wavelength has less chance of getting scattered.

When the sunlight comes to the Earth, the blue color waves get scattered most whereas the red waves can reach the Earth in larger quantities. In the sunlight, from the violet to blue colors, the blue color is the more dominant and since it gets scattered in the sky, to us on the Earth the sky appears blue.

From a spaceship, which is well above the Earth's atmosphere, the sky looks black, even if the Sun is shining. This is because; there are hardly any particles of dust around, which can scatter the sunlight.
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Q.2 Why does the Sun look red when it sets?

As explained in the answer to Question 1 above, the Sun's rays coming to the Earth are scattered by particles of dust in the atmosphere. The red color waves are scattered the least and reach the Earth on a larger scale.

The rays from the rising and the setting Sun have to pass through a much thicker layer of atmosphere when they reach the Earth, and they travel for a longer time nearer to the Earth. Thus, the number of dust particles they encounter on the way is larger and so is the scattering of the light waves. So most of the other shades in the Sun's light get scattered away and mainly the red color waves can reach the observer. Which is why, the rising and the setting Sun looks red.
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Q.3 What is meant by the statement "the ozone hole is growing?" Why is it dangerous? What precautions must be taken control it?

There are many different gases in the atmosphere of the Earth, mainly nitrogen, oxygen, and carbon dioxide. But there are also some other gases in smaller quantities. Ozone is one of them. Two oxygen atoms together form the oxygen molecule, which we breathe in. Three-oxygen atoms together form an ozone molecule. Ozone is much rarer than oxygen, but is nevertheless important.

A thin layer of ozone in the atmosphere protects us from the ultraviolet rays in the sunlight. Those rays are absorbed by ozone in the atmosphere and do not reach us. This causes the decomposition of the ozone into oxygen atoms. The cycle, however, proceeds further with the combination of the leftover oxygen with the remaining oxygen and reformation of ozone and again interaction with other gases to form oxygen. This cycle goes on. The ozone layer is at a height of about 15-20 kilometers, from the surface of the Earth.

If the ozone layer is broken at some place, with a hole in it, the cycle described above will be disturbed. The ultraviolet rays of the Sun will then be able to reach the Earth and will harm life. For example, these rays can cause cancer, blindness etc. The equipment in the man made satellites circling the Earth brought to light the fact that such a hole is formed over Antarctica and is growing. The ozone layer over the rest of the Earth is also becoming thinner.

A lot of research and discussion is taking place on this observation. The changes in the atmosphere, the effect of sunlight, the gases emanating from the Earth and going into the atmosphere, all have a part to play in these phenomena. How important is the role of each factor is a matter of opinion among the experts. Of the factors mentioned here, however, man has some control over the third factor.

The chemicals called 'chloro-fluoro-carbons' (CFCs) are part of this. These chemicals are created in the cooling process of a refrigerator, for example. They are also formed while making bubbles I balloons in plastic and spraying through aerosols. These chemicals travel upwards in the atmosphere and attack the ozone layer. One-opinion stresses the need to stop the production of these chemicals. But it is not certain that this alone will be sufficient to control the depletion of ozone.
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Q.4 If a tunnel is dug into the Earth to go all the way to the other side of the surface, and if a ball is thrown into it, what be the motion of the ball?

Let us suppose that the tunnel is dug in a straight line and that it is smooth and does not have friction. Let us also assume that the density of the Earth is uniform at all the places. Then, the ball thrown at one end of the tunnel, will reach the other end in about forty-one minutes. So, this will be the fastest way to travel from one point on the Earth, to its diametrically opposite end. Even if this tunnel does not pass through the center of the Earth, but is along a shorter chord of the sphere, despite its length being less the time taken to travel along it will be the same. This is so, because the speed of the ball will be less when it does not pass through the center. (It is assumed here that the Earth is spherical.)
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Q.5 Why is the weight of an object less on the equator than on the polar region?

The Earth is slightly flat at the poles and this flatness is caused by its rotation around the axis. If the Earth were spherical, its force of gravity would have been the same everywhere on its surface. But because of this flattening, the gravitational force and hence the weight changes at different latitudes. The maximum difference is between the weight on the equator and that at the poles. This difference, however, is very small, only half a percent. Besides, the centrifugal force on the equator also causes a reduction in the weight but this effect is even smaller.
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Q.6 Why do we see shooting stars, i.e., stars falling on the Earth?

The solar system has, apart from the planets and their satellites many small and large rock-like objects orbiting around the Sun. They are called meteorites. When one such rock, with diameter less than one meter, say, comes within the gravitational influence of the Earth, it is attracted towards the Earth. It is heated up by friction as it falls through the atmosphere and so it shines. It looks like a shooting star or a broken star falling on the Earth. Often it burns up entirely in the atmosphere, but occasionally, a few pieces reach the surface of the Earth. They are studied extensively by scientists, (*see Question 23*) however; they are not stars: they are very tiny objects!
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Q.7 When we study or photograph a distant star, is it really there?

If the star is at a distance of 10 light years, say, (that is approximately 100 million million kilometers) then, it takes 10 years for its light to reach us. So what we see there was really there ten years ago.

In those ten years, the star may have moved a little and in very rare cases, the star may even have exploded. This uncertainty is of course more in the cases of stars, which are very far away. Some galaxies are seen many billions of years after the light bringing their pictures left them on its long journeys.
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Q.8 How can we prove that the Earth revolves around the Sun?

It is possible to prove this with the help of two observations. In comparison with the stars, which are far away, the location of the Earth now and after six months will be different. The Earth takes twelve months to complete its orbit. So, the direction of a nearby star will be a little different in comparison with the Sun after six months and that can be measured. (When traveling in a train you notice that the nearby trees flash back in relation to the more distant ones.)

Another way is to measure the difference in the star's direction due to a different effect called aberration. We observe a distant star from the moving Earth and not a stationary Earth. So, the direction of the star depends on the speed and direction of light (the light which comes from the star) and the speed as well as the direction of the Earth's motion. As the Earth moves in its orbit, the direction of its motion changes and the resulting minute changes in the direction of the star can be measured. (*If you are stationary in falling rain, the direction of the falling raindrops is different from when you are moving through it*.)

The Greek astronomer Aristarcus (310-230 BC) had stated that the Earth is not stationary and that it revolves around the Sun. To check his statement, he had suggested the first method described above. But the observational devices at those times were not as advanced and sensitive, as they are today. So his prediction could not be confirmed and his view was taken as disproved. Indeed, it was widely believed that the Earth is stationary. The methods described above became usable only in the last two centuries. So, at the times of Copernicus and Galileo, there was no observational proof that the Earth revolves around the Sun.
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Q. 9 How are the orbits of the planets determined? Why are they elliptical?

The planets revolve around the Sun due to its gravitational force. The three laws of motion formulated by Newton and the law of gravitation determine the orbits of the planets. The force of gravitation attracts the planet towards the Sun. So the orbit of the planet is such that the acceleration is in proportion to the force of gravitation and in the direction of the Sun. Such an orbit of as, planet was proved to be elliptical by Newton in the second half of the seventeenth century. The mathematical proof is now a part of undergraduate mathematics. In the first part of that century, by analyzing a lot of observational data Kepler had already discovered that the planets move in elliptical paths.
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Q.10 How is the distance between the Earth and the Sun measured?

The Sun is at S, Venus at V lad the Earth at E. The triangle SEV is constructed from observation.

To measure this distance, astronomers in the early times used Kepler's laws and trigonometry. Suppose, we choose two places A and B on the longitude where the plane of the Venus and the axis of rotation of the Earth intersects the surface of the Earth. We can measure the distance *AB* on the Earth. We observe the direction of the Venus from *A* as well as *B*. Thus, if Venus is at *V*, we can draw the triangle *ABV* in proportion and thus measure the distance of Venus from the center of the Earth.

Now, if the Sun is at *S*, we can draw the triangle *SEV*. We can determine the angle between *SE* and *VE* by observation. From the first part described above, we know the distance *VE*. Now use Kepler's third law. This states that if the period of rotation of Venus around the Sun is T_1, and the same for the Earth is T_2 we have

$$T_1 / T_2 = [SV / ES]^3$$

Since we measure T_1, and T_2, by observation, we know the proportion SV/ES. Thus we can measure all the sides of the triangle *SEV* and find out *ES* or the distance between the Earth and the Sun.

Today we can use the radar and measure this distance directly and accurately to be 149597870.61 kilometers!

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Q.11 What effects will be observed if the mass of the Earth is suddenly increased?

In such an imaginary situation, the following effects will be noticed.

The angular velocity of the Earth will reduce and the day night cycle will be longer than 24 hours.

The moon will come nearer due to the larger force of the Earth's gravitation and the tides in the seas will be more forceful.
Our weights will increase and if the mass of the Earth were much bigger, we may not be able to move easily.

The atmosphere would be more strongly attracted to the Earth and will become denser, and this will affect the climate conditions.
The orbit of the Earth around the Sun however will not change.
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Q.12 Who was the first to find the radius of the Earth and how did he measure it?

Eratosthenes (276-195 BC) was a Greek observer who found the radius of the Earth by the following method. This can be considered, historically, the first attempt to measure the Earth's radius.

The rays coming from the Sun to Syene (S) are perpendicular to the Earth and there is no shadow of the stick. At Alexandria (A), the shadow is AC curd the stick AB makes an angle of 7.5^0 with the Sun's rays. The triangle ABC can be drawn. Now, LABC = LAOS. The distance AS is known. Hence the circumference of the Earth is given by AS : Circumference = $7.5^0 : 360^0$ Thus, the circumference and the radius of the Earth can be measured.

The cities of Alexandria and Syene are 500 miles apart on the same longitude. Eratosthenes placed a stick perpendicular to the Earth at each place and arranged to measure at the same time the length of the shadow of the stick. Be observed that when the Sun is at the zenith, the shadow at Syene is almost shrunk to the base whereas it was a little bigger at Alexandria. By comparison of the shadows, he surmised that the Sun at Alexandria makes an angle of 7.5^0 with the zenith. Then using geometry, he first determined the circumference of the Earth as 2466.2 miles and then divided it by 2(pi) to get the radius as 3927 miles. The difference between this and the radius determined by modern, more accurate measurements is less than 32 miles. So the error in Eratosthenes's measurement was less than 1 percent!

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Q.13 Has the 10th planet been found?

No, so far, no tenth planet is found. If there is a planet beyond Pluto, it will be very difficult to view it, as it will be very faint. It will also be difficult to notice the effect of its gravitational force on the known planets. Moreover, according to Kepler's laws of motion, a very distant planet would move very slowly in relation to the star background, and so it would be hard to detect.

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Q.14 Why does the Sun shine?

The Sun is a ball of hot gases. The temperature of its surface is about 5500^0C. But its temperature nearer the center increases. The temperature at the center could be around $1{,}25{,}00{,}000^0$ C.

In such a hot gaseous form, the nuclei of the atoms are separated from the electrons and they also collide against each other and undergo nuclear fusion to produce a lot of energy For example, four nuclei of hydrogen come together to form one nucleus of helium. But the mass of one helium nucleus is less than that of four hydrogen nuclei. This difference in the mass is expressed in the form of energy emitted. This nuclear energy causes the Sun to shine and give heat. The process works at very high temperature and hence is called 'thermonuclear' process.

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Q.15 How was the Sun formed? How are the planets formed around the Sun?

In the vast space in the Milky Way, interspersed with the stars, there are large clouds of gas. One such cloud started contracting and started forming into a dense ball. When this happened, the heavier central part formed a star and began to shine by producing thermo-nuclear energy.

The Sun is believed to have formed in this way. The original cloud must have been rotating around its axis. Rotation generates centrifugal force. Because of this, while contracting, a flat disc of matter must have formed around the central star perpendicular to the axis of rotation. The disc rotated around the central star.

The Sun was thus formed at the center and the planets and their satellites condensed out of the disc. It is conjectured that the Sun and the planets were formed about five billion years ago. The size of the solar system, the number of planets in it etc, cannot be determined through this theory. It is conjectured however, that most stars would have planetary systems around them, formed in this way.

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Q. 16 What is meant by the statement "the Sun will eventually become a giant star?"

Suppose the radius of the Sun increases by more than 200-250 times! Then it will swallow not only the inner planets Mercury and Venus but also the Earth, and perhaps even Mars! If that happens, the Sun must be called a "giant" star. But when and how can this happen?

In the interior of the Sun, energy is produced through nuclear reactions. But then at sometime in the future, the fuel for this furnace will run out. Then the inner part of the Sun will collapse inwards due to its own force of gravity and will heat up. In this newly heated state, there will start a different nuclear reaction in which helium will be turned into carbon. Again, energy will be produced which will cause the outer envelope to expand. This is the giant state.

But it will be 6×10^9 years *(6 billion years*) before the Sun becomes a giant star! We find some stars, which have attained that stage. They are huge in size and because by expansion their surface cools down, their color looks reddish; so they are called red giants. The star called Betelgeuse in the Orion constellation is a giant star of this type. It is 700 times as big in radial extent as the Sun.

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Q.17 Why do stars twinkle? Why don't the planets twinkle?

We see the stars or take their photographs with the help of the light rays coming from them. When these rays travel through the, atmosphere around the Earth, their directions change a little due to the fluctuations of density, temperature, etc. of the atmosphere. As the layers of the atmosphere through which starlight passes undergo these changes, the image of the star seems to vibrate or wobble. The stars are very far and appear point-like. The light from them travels a very long distance so this effect is noticeable.

The planets are nearer and are seen as discs of light rather than point sources. The points on the planetary disc also dance or wobble, but their combined effect is incoherent and is not noticed. In a crowd people move in random directions and there is no overall coherent motion. The dancing of individual points on a planetary disc is similar. Which is why the planets don't twinkle.

When viewed from above the atmosphere the images of stars appear steady, as witnessed by the Hubble Space Telescope.

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Q. 18 Can the man made satellites remain stationary in the sky?

No, they move in fixed orbits around the Earth. If they were stationary, they would have been attracted to the Earth due to gravitation and would have hit the Earth. The so called geo-stationary satellites are moving in orbits but their angular velocity is the same as the angular velocity of the Earth, so they seem to be stationary when viewed from the Earth. They are sited above the equatorial belt of the Earth.

The Moon (M) comes between the Earth and the Sun (S). Then in the shadow (AB) of the Moon on the Earth, we can see the total solar eclipse and from the surface of the Moon facing the Earth, a partial eclipse of the Earth will be seen on the area covered by AB.

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Q.19 Like the eclipses of the Moon and the Sun, is the Earth also eclipsed and can we observe it from the Moon?

If we are on the Moon and want to see the eclipse of the Earth, the Earth should be in the shadow of the Moon. But the Moon is much smaller than the Earth and its shadow too small to cover the Earth. Thus the eclipse will be partial and the area on the Earth where the Moon's shadow falls will look dark. Thus, on the new Moon day, we can see the partial eclipse of the Earth at the time when from the eclipsed part of the Earth, a total solar eclipse will be seen.

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Q. 20 What do we mean by moonlight? Can we see the Earth rise and set from the Moon?

The Sun's light falls on the Moon and gets scattered and reflected; that is how we get the light from the Moon. The Moon does not have its own light.

When the Moon rotates around the Earth, it also revolves around itself and the velocity is such that we see the same surface of the Moon all the time. So, from the other part of the surface, the Earth will never be seen. Also, from the part where the Earth is visible, the Earth will seem stationary in the sky; it will neither rise nor set. But it will be seen to rotate around its axis.

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Q.21 Did the Moon originate out of Earth? Why is there no atmosphere and life on the Moon?

Although the Earth and the Moon are formed out of a proto-solar gas cloud, the Moon is not formed out of the Earth. (*See Question 15*) This has been verified by examining the rock samples from the Moon. Their composition is different from the rocks and minerals on the Earth. So, the Moon formed separately and must have wandered into the gravitational field of the Earth and got trapped as its satellite.

The gravitational pull of the Moon is much less than that of the Earth and was probably not strong enough to retain an atmosphere. Hence there are no gases around it. Since the Moon does not have atmosphere and life supporting gases, there is no life on the Moon.

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Q.22 How are comets formed?

An exact answer to this question is not known. The theory explained by the scientist Jan Oort is generally accepted. It says that at a distance of about one light year (*approximately 60,000 times the Earth-Sun distance*) there is a shell of clouds around the Sun. That cloud-shell is formed of frozen gases and occasionally, due to some perturbations; clots of these gases get thrown towards the Sun. Because of the gravitational pull of the Sun they start traveling in an orbit towards it. When they come near the Sun, their frozen gases on the surface take a gaseous form. By the pressure of the Sun's light and the solar winds, the gaseous parts spread out away from the Sun and this forms the tail of the comet. This is made of dust and gases.

The comet traveling towards the Sun rarely hits it. It moves in a very long elliptical orbit, goes around the Sun and keeps coming near it periodically. When it comes near the Sun, it can be seen from the Earth. Halley's comet reappears after every 76 years and its earlier visits have been documented. But the period of some comets is thousands of years. Their older records are not available.

Apart from the Sun, the planets also affect the comet by their gravitational forces. In particular, Jupiter being the largest planet, exercises more effect on the comets and can change their orbits as well as their periods. The comet Shoemaker-Levy was caught in the gravitational field of Jupiter and hit it and got destroyed. But such an event takes places very rarely, perhaps once in a thousand years. The chance of a comet hitting the Earth is rarer still, perhaps once in a million years - because the Earth is not as massive as Jupiter to pull in comets towards it.

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Q.23 What is a meteor shower?

During the passage of a comet, some particles from its tail are left behind and when the Earth passes near that region, some of the debris comes under the gravitational field of the Earth and travels towards it. The pieces of this debris shine due to the friction of atmosphere when they come towards the Earth. This is known as the meteor shower. From a distance, a group of such shining meteors looks like shooting stars, but they are tiny pieces. Such debris is accumulated in certain places in the orbit of the Earth. Whenever the Earth passes those regions, meteor showers are seen. Normally between 1- 20 August (*in the constellation of Perseus*), 11- 20 November (*in Leo*), 20-22 April (*in Lyra*), 24-27 November (*in Andromeda*), 9-14 December (*in Gemini*) and 30 May - 14 June (*in Gemini*) such meteor showers are seen.

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Q. 24 Will the comet Swift-Tuttle hit the Earth? It so, what will happen on the Earth? Can this danger be averted? Is ther similar danger from other comets or small meteoroids?

The comet Swift-Tuttle has passed by the Earth recently and will come again on the 14th August 2126. According to the original calculations it was predicted that it would hit the Earth. But later on, it was realized that the Sun's light and the solar wind could affect the comet and change its orbit slightly. So we cannot accurately predict its orbit so much in advance. Taking into consideration all the factors, it is very unlikely that it will hit the Earth.

When the comet is again approaching the Sun (*and the Earth*) more accurate calculations can be made. If it is found that the crash is imminent, the orbit of the comet can be changed slightly. To achieve this, a spaceship can be sent near the comet with a nuclear payload to explode in its vicinity. A nuclear explosion near the comet can change its direction and it will pass by the Earth at a safe distance instead of crashing on it. (*In my Science Fiction story. The Comet: a similar plot was described.*)

If a comet does crash on the Earth, the life on the Earth will be destroyed. In the place of the crash, a huge crater is formed. The fire caused by the friction and the loss of life at that place is inevitable and the Life in nearby regions will also be endangered. In fact if the atmosphere is severely damaged all life may become extinct. Such a crash of a large meteorite may have been responsible for the destruction of large animals like dinosaurs.

Fortunately, such impacts are very infrequent, once in about a million of years. There are a lot asteroids and minor planets revolving around the Sun. Most of them are in the region between Mars and Jupiter, but some, however, do pass by the Earth due to changes in their orbits. A large asteroid if it crashes on the Earth, can cause a lot of destruction. So astronomers are keeping a record of all such asteroids - so that the danger of such a crash can be predicted in advance and can be adverted.

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Q.25 What are white dwarfs and Neutron stars? What is the contribution of the Indian scientist S. Chandrashekhar in this field?

A star like the Sun shines because of the nuclear energy in it. (*See question 14*). The pressure created by the emission of nuclear energy helps maintain the size of the Sun. When the nuclear fuel finishes, the gravitational force will cause the mass of the Sun to collapse inward.

Due to this contraction, the density of the Sun will increase. Increased density implies the particles of mass packing more densely. The quantum theory, which describes the properties of micro particles, states that the electrons cannot be packed more closely than a certain limit. This prohibits the growth of density. These forces known as 'degeneracy forces' can stop the farther contraction of the; Sun. But by then, the density of the Sun will be increased about a million times and the size of the Sun will be smaller, its radius being the 100^{th} part of the present radius. Such a star is called a white dwarf. Dwarf because it is smaller in size and white, because it emanates a very pale light.

During 1930-35 Chandrasekhar proved that if the mass of the star exceeds by more than 40% of the Sun's mass, that is if the star's mass is about one and a half times the Sun's mass, then these gravity-opposing forces cannot come into action and then the contraction of the star continues unhindered. This limit on the mass of the star is called the Chandrasekhar limit. Stars with mass less than this limit transform into white dwarfs and remain in that state for very long time.

Then the existence of stars more than a billion times denser than white dwarfs was surmised. These very dense "Neutron Stars" have an abundance of neutrons and their close packing generates new pressures similar to those worked on by Chandrasekhar for white dwarfs. For these stars the mass must be less than twice that of the Sun. These pressures can stop the contraction of the star.

Neutron stars do not have visible light but many of them emit regular radio pulses and are found in the form of 'pulsars'.

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Q.26 What are black holes? Are black holes found in the universe? Can the Sun turn into a black hole?

When we throw up a ball, it eventually falls on the ground due to the gravitational force of the Earth. But according to Newton's law of gravitation, the force of the Earth's gravitation decreases as an object goes away from the Earth. So, if an object is thrown up with a velocity greater than a critical limit, the object does not come back to the Earth. The force of the Earth's gravitation is too weak to pull back the object. This critical limit is the velocity of 11.2 kilometers per second and is called the 'escape velocity'.

The stronger the force of gravitation, the higher is the escape velocity. The escape velocity on the Sun is about 640 kilometers per second. Now, what if the escape velocity on some star is more than the velocity of light... that is more than 300 thousand kilometers per second? Then even the light rays cannot escape from that massive object! How can this object be seen? Because it cannot be visible, it is called a 'black hole'. Just as an object thrown into a deep well sinks in it, all small objects around a black hole are attracted by it and sink into it.

Are there such black holes in the universe? How can one look for an object which is invisible? What is the proof that such an object is found?' The black hole is invisible, but its strong gravitational force exists and its effects on nearby objects can be seen. So, from the observation of objects in the vicinity, the existence of a black hole can be deduced. For example, if out of two rotating binary stars, one of them is a black hole, its existence can be deduced from the behavior of the other ordinary companion star. It is conjectured that at the x-ray source Cygnus X- 1 there is a binary star system, which contains such a black hole.

Can the Sun turn into a black hole? The present radius of the Sun is 700 thousand kilometers. If it is shrunk to 3 kilometers, the Sun will turn into a black hole. However, this cannot happen in fact. The gravitational force of the Sun causes its contraction but the internal forces oppose it. Today's physics tells us that if the energy required to shine in the star is over, then the mass of the star determines its fate. If it is more than twice of the Sun's mass, then the internal forces cannot stop the star's contraction due to the gravitation, and it turns into a black hole. If the mass is less than that the internal forces win over gravitation and the star turns into a Neutron star or a white dwarf and remains in that state, (*see question 25*).

Thus, the Sun will eventually become a white dwarf and not a black hole.

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Q.27 What is a quasar?

A Quasi Stellar Source' is known as a quasar. The word is made of the letters from the above words. These objects were first mistaken for stars, but the astronomers later discovered that they are billion times brighter than stars. Apart from visual lights, most quasars emit X-rays and many also emit radio waves. On the whole, the energy of a quasar is more than that of our Milky Way galaxy, containing 100-200 billion stars.

Quasars have another important property. The spectrum of a quasar shows the shift of its lines towards the red color (*see question 34*). If we apply Hubble's law, then this red shift helps us determine the distance of the quasar. This distance is usually very large of the order of millions to billions of light years. So, quasars are considered to be most distant visible objects. The very first quasars, known by their catalogue numbers a 3C273 and 3C48 were discovered in 1963.

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Q. 28 What are binary stars?

When two stars are found to be revolving around each other under their mutual gravitational force of attraction, the pair is called a binary system. Many such binaries are found. Sirius A, the brightest star in Orion and its faint companion Sirius B revolve around each other. To human eye, they seem as one bright star.

Detailed observations of binaries and the changes in their brightness, help the astronomers find out more about them, like their masses, distance etc. If one of the binary system happens to be a black hole (*see question 26*) then its mass can be determined by observing the other visible star revolving around it. Sometimes there is a flow of gases, dust particles etc. from one star to the other. If such an ejection is strong, it emits X-rays. X-rays telescopes are useful in such cases to find out more about the binary stars.

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Q.29 What happens to objects collapsing in a black hole?

A black hole attracts objects in its vicinity by its gravitational force. Let us imagine that an unfortunate man is falling into a black hole. If his head is towards the hole, and legs away from it, then the gravitational force is more on the head, less on the legs. Because, the force is less for an object that is farther from the black hole. Thus, the unfortunate man will be pulled apart and extended in length. The gravitational force of the Moon also creates such a tension on the Earth. This is demonstrated by the tides in the oceans. So, such an effect of the gravitational force is called the 'tidal force'. When an object is attracted towards a black hole, this tidal force grows enormously and the object is broken up by it.

Around a black hole is a 'horizon'. When an object enters that region, its contact with objects 'outside' is lost. So an observer away from the black hole cannot find out what happened to it, as there is no communication of any kind. The gravitation theory of Einstein tells us that when an object reaches the center of a black hole, it reaches the limit of space-time and has no future thereafter! This final state where no laws of physics work is called a state of "singularity".

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Q.30 What is a white hole? How can it be observed in space?

Suppose one takes a movie of an object contracting under gravitation and on the verge of becoming a black hole and then that movie is shown backwards. Then we will see in it an object exploding out of a small hole. A white hole is similar to this situation.

From a white hole, energy and mass emerge on a large scale. At first, the velocity of the mass thus thrown out is the same as the velocity of light and later it slows down. Due to the explosion of energy, a white hole is very bright and visible from a distance.

One claim is that wherever we see a large explosion of light and mass, a white hole may be present. Thus, explosions at the centers of some galaxies or the bright quasars may be due to white holes. But these explosions may also be due to other reasons. For example, a majority of astronomers would argue that such phenomena are due to the presence of a large black hole. It is speculated that a black hole attracts matter in its vicinity and some of it after circulating goes out with tremendous speed.

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Q.31 What are the special features of space telescopes?

The Earth is surrounded by atmosphere. When we observe stars from the Earth, the light from the stars travels through the layers of atmosphere. Some of the light gets absorbed or scattered in the atmosphere and its direction too fluctuates in a small scale. So the images appear pale and seem to wobble (*See Question 17*).

To get steadier and brighter pictures it is better to observe from above the atmosphere. To achieve this, man has started making space telescopes. In 1990, the first space telescope was sent in space to observe from a height of about 600 km. It is named after Edwin Hubble, a leading astronomer of the 20th century (*see Question 34*). The Hubble Space Telescope (HST) is certainly far more efficient than telescopes on the Earth. It can observe very faint stars and take their clear and steady pictures. It is of course controlled from the Earth as it orbits around the

Earth.

Before the HST, telescopes making observations of ultraviolet rays and
X-rays were sent into space through satellites. The HST, however, is much bigger, in fact, as big as a space shuttle can carry. Its main mirror has diameter of about two and a half meters.

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Q.32 How are the stars in our Galaxy counted?

The angular velocity of the outer stars when they revolve around the center of a galaxy can be used to determine the total mass of the galaxy. Newton's law of gravitation is used in determining the mass of the galaxy. If the average mass of a star is assumed to be a solar mass, then one can estimate the number of stars in a galaxy. Thus, in the Milky Way there are approximately hundred and fifty thousand million stars!

If we manually keep counting the stars, and if we count a hundred stars per minute (*that is, fifty million stars in one year*) it will take us 3000 years to count so many stars! Today computers are used to do the counting of stellar or galactic images on the photo- graphic plates.

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Q.33 Is the universe finite or infinite? How can this be ascertained?

The universe is extended as far as our telescopes can observe. Groups of galaxies are found everywhere. So, if the universe has a finite limit, it has not yet been observed.

Current theories of the formation of the universe assume that the universe has no boundary. This does not necessarily imply that the volume of the universe is infinite. For example, the surface of a sphere has no boundary but its surface area is finite. This may be true in ease of the universe in three dimensions: it may have a finite volume but no boundary.

Today's observations are not enough to determine whether the universe is finite or infinite. To determine if a particular theory is right or wrong, we need to have very distant observations including the density, geometry, etc. Such observations at present are in elementary stages.

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Q.34 What is meant by the expansion of the universe? What is it expanding into?

The sun and the solar system are members of a large galaxy. We call this galaxy the Milky Way. There are 10^{11} to 2×10^{11}stars in it.

Observation shows that there are many such galaxies in the universe. If we examine the spectrum of a galaxy, we find some dark lines in them. These are lines of absorption and their wavelengths are determined by the particles, which absorb them. In the case of most galaxies the wavelengths of the absorption lines are more than expected. That is, they are shifted towards the red color of the spectrum. What does this wavelength indicate? According to laws of physics, when a source of light is receding from the observer, the lines in its spectrum are shifted toward the red color and this shift depends on the speed of recession.

In 1929, Edwin Hubble formulated this law based on such observations: If a galaxy is further away from us, its red shift is more. According to Hubble's law the distant galaxies are receding from us faster than he near ones, the speed of recession being proportional to distance of the galaxy. This large-scale motion is interpreted as the expansion of the universe. It may be better to say that the space, which contains these galaxies, is itself expanding. An analogy is the galaxies are like dots on a balloon; as the balloon is inflated, the dots move away from one another.

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Q.35 Is there life beyond the Earth? Are there any life forms on other planets in the solar system? How can other, possib more advanced life forms be detected?

There are huge clouds of gas and dust in the space between the stars. With the help of telescopes observing with microwaves and millimeter wavelength waves, evidence is found of the existence of organic molecules in those clouds. At the base of the life forms on the Earth are the DNA molecules and all the components of these DNA molecules are made up of such organic molecules. So, it is quite possible to imagine that DNA-based life forms may exist on some planets in some other solar systems.

However, as yet there is no evidence of any other life in our Galaxy and it is very difficult to estimate how many more advanced civilizations may be there in the universe. Scientists however, like to make guesses about this number. A general such estimate is that in our Galaxy of 100-200 billion stars, a few millions of advanced civilizations may exist.

To detect such civilizations, an effective way would be to erect huge radio antennas and to try to intercept any messages between nearby stars. The science of detecting messages through the general chaos of noises is progressing. What will be the language of such messages if they do come? Which wavelength will be used to transmit them?

Let us assume that the physical laws are the same at all places. Then it is probable that the more advanced civilizations will use a language of mathematics and physics. The mathematics used is likely to be binary as it is the most basic one and is used in the computers. Astrophysicists believe that the waves of 21-centimeter wavelengths atoms of neutral hydrogen, and which can travel far, will be known to all civilizations, as the hydrogen atoms are omnipresent.

So, work is in progress to install many channels in the band of 21-centimeters in detectors attached to the radio telescopes used for detecting any messages. Some messages have also been sent from the Earth. So far, no contact with another neighboring civilization has been established.

In our own solar system, some life forms may exist on Mars. When Viking I and II reached Mars, they were unable to find any life forms. But their investigations may not be thorough. The possibility of finding life on other planets of our solar system is much less. May be in the 21st century, man may be able to explore the surface of Mars further and settle the question as to whether life exists on Mars.

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Q.36 What are UFO s or flying saucers? Have they come from other planets? Do extraterrestrial beings come to the Eart

through such spaceships? Where do UFO s come from?

On June 24, 1947, an amateur pilot in the United States named Kenneth Arnold found some flying saucer like objects following his plane near Mount Ranier in Washington State. This was probably the first recorded incident of flying saucers, which was highly publicized. Afterwards, many people have claimed to see such flying objects.

Any unidentified flying object is called UFO. If the object is identified later, it is no longer a UFO. Before identification, it is clearly wrong to assume that it is a spaceship from some extraterrestrial civilization.

After Arnold's report many such incidents were reported in newspapers. When their numbers grew the U.S. Air Force examined them under Projects like Project Sign, Project Blue Book etc., in the United States. Some incidents were studied separately. From various such investigations, the following facts emerged:
The planet Venus, while rising or setting, is sometimes mistaken for a spaceship.
Like mirages in deserts, even in the sky, some illusions take place and people believe they actually see something, which is not there. The experience of Arnold was probably of this type.
Manmade satellites or spaceships can be mistaken for UFOs.
Some people who claimed to have sighted UFOs were examined by psychiatrists and it was discovered that those people habitually had illusions or had fabricated stories of UFOs.
The photographic proofs of UFO's have often been faked. In short, so far, there is no credible scientific evidence of a spaceship from some other planet.

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Q.37 Sometimes there are reports of flying saucers in newspapers. Are they not true?

Any unidentified flying object is called a UFO and is announced as such. When it is finally identified, it is no longer a UFO. (*see question 36*) But just from newspaper reports, it is wrong to suppose that the UFO was a spaceship from another planet.

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Q.38 Many airplanes crash, boats sink and clocks stop in the Bermuda Triangle - what could be the power behind such mysterious events? Could there be some supernatural or extraterrestrial power active there?

The book 'Bermuda Triangle' written by Charles Berlitz made this triangle notorious. It is in the Atlantic Ocean. The three vertices are Florida, Puerto Rico and Bermuda.

It is found that the incidents described in the book are either exaggerated or imaginary. Laurence Bush has described the results of scientific investigations in his book. In it, it is shown that there does not seem to be any queer property associated with the Bermuda Triangle.

For example, consider the incident after the Second World War in 1945. Berlitz says that the five planes of trainee pilots (*including one of the trainer*) vanished in this triangle in broad daylight! They had sent a message to the plane coming after them, "we do not know where we are going. They are following us". In fact, it was evening time. It was getting dark. The radar instruments were not as advanced as they are today. Besides, the message received from these planes was: "We know where we are. There is no need to follow us." In fact, just as in the Bermuda triangle, in many other parts of the world, airplanes have crashed and boats have sunk. It is not true that a much bigger number of mishaps have taken place in the triangle area. So we have no reason to believe that there is some supernatural or extraterrestrial power in the Bermuda Triangle.

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Q.39 In ancient times, was there a highly advanced civilization on the Earth?

There are entertaining books on this subject, like the Chariots of God by Von Danken. But the evidence given in such books does not really stand up to scientific investigations.

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Q.40 How are radio waves formed?

When electric charges move with variable velocities, electro-magnetic waves are formed. The rate of change of velocity is known as acceleration. This comes from change in the magnitude or the direction of the velocity (*or in both*). For example, when an electric charge is having a circular motion, the direction of velocity is continuously changing (*while its magnitude is constant*), whereas when an object falls vertically down under the Earth's gravitation, the velocity changes in magnitude (*but not in direction*) and in both eases there is acceleration.

The electro-magnetic waves created in such situations have different wavelengths and properties. The waves of wavelengths longer than 10-20 centimeters are the radio waves. In a wireless transmitter, electric charge is vibrated with alternating current and such waves are created. In space, magnetic force is responsible for causing acceleration in electric charges to produce such waves. This process is known as synchrotron radiation.

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Q.41 What is meant by radioactivity?

In the nucleus of a large atom there are several neutrons and protons. These particles are attracted towards each other by the nuclear force, which keeps the nucleus bound. Some atomic nuclei are not stable and some of these constituent particles escape from them. This is called radioactivity.

The particles radiated are of three types. Until more investigations were made, they were called alpha, beta and gamma. Of them the alpha particles are the nuclei of helium atom, these have two protons and two neutrons bound together. Beta particles are negatively charged and are none other than electrons. They are much lighter (*about 7300th part*) than the alpha particles. Gamma rays are the light rays. But these rays have a much smaller wavelength than visible light and are much more energetic. These types of radiations are now studied in laboratories as well as in natural surroundings and a lot of information is obtained from them about the atomic nuclei.

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Q.42 The water does not turn into vapor until it is heated to 100^0 C or to the boiling point. How does the water vapor ris from the sea at temperatures around 30^0 C?

Keep some water in a plate. After some hours it will have vanished at room temperature. This takes place faster in hot summer and in dry weather. Even at temperatures much lower than 100^0 C, water does evaporate to some degree. Of the water molecules, some go up in the atmosphere whereas some molecules from the atmosphere condense and come back on the Earth. Both the processes take place and their speeds are determined by the temperature, the pressure in the atmosphere, the speed of any prevailing wind, the amount of water vapor in the atmosphere etc. Thus, part of the seawater does turn into vapors and go up into the atmosphere.

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Q.43 A block of iron sinks in water whereas a ship made of iron floats on the water Why?

The discovery of Archimedes explains this result. If an object is to float, it must displace the water equal to its own weight. This is the finding of Archimedes. The iron, of which the ship is made, is spread out in a sheet and given a particular shape. So that, when only a part of the ship is in water, it displaces water equal to its own weight, and he ship remains afloat by Archimedes's law. A block of iron cannot achieve this and so it sinks in water.

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Q.44 Who measured the speed of light first and how?

In 1676, the astronomer Romer made observations of the satellites of the Jupiter and their eclipses caused by the Jupiter. When Jupiter is between the Sun and its satellite, he satellite gets eclipsed. These satellites revolve fast around Jupiter and we can see many eclipses. When we see them from the Earth, however, they do not occur at the same time because the light from Jupiter takes some time to reach the Earth. As the Jupiter - Earth distance changes, so does this time lapse. Romer calculated all these and estimated the speed of light as 350,000 kilometers per second. Modem physics determines it as 299,792.458 kilometers per second.

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