Puzzles – suggested answers

Why does our Moon not have a name? Can we call it Eeyore?

Moons around other planets in our Solar System are named by the International Astronomical Union. A working group on planetary nomenclature decides on the names, which the IAU's General Assembly must verify. The next time this body meets will be in Sydney in 2003.

Themes have been established for naming celestial bodies and features on them. For example, new moons of Uranus are named after characters in Shakespeare's plays, notably *The Tempest*. Caliban and Sycorax are among the latest characters honoured. Craters on the asteroid Eros are given suitably erotic names, such as Lolita. But there have been no plans to rename our moon, *the* Moon. A different IAU body would be responsible for naming the planets that have been discovered orbiting stars outside our Solar System.

Although all the planets of the Solar System travel around the Sun in the same direction, Venus actually rotates on its axis in the opposite direction to all the other planets. My son wants to know why this is and I'm ashamed to admit that I couldn't explain it to him. Can anyone help?

Astronomers assume that Venus started out spinning in the same direction as the other planets in the Solar System, which is the same way that all the planets rotate about the Sun. So somehow its spin must have been reversed. One early idea was that, billions of years ago, Venus was hit by a massive object that turned it upside down. This theory could still be true, but recent research suggests that there are less violent ways to give Venus its backspin. The Sun raises bulges in Venus's dense atmosphere, much like the tides in the Earth's oceans, and the heat of the Sun also creates bulges in the atmosphere.

As these high-pressure bulges rotate around the planet, they exert a gentle twisting force which could have gradually tilted Venus over until it was upside down and spinning in its present direction. But this could only happen if Venus started off with a high tilt; it would have had to be nearly on its side to begin with. That, at least, has been the assumption until recently.

Now, the researchers Alexandre Correia and Jacques Laskar (*Nature*, vol 411, p 767) have shown that this needn't be so. Again, the atmospheric bulges come into play, and so do occasional gentle tugs from the gravity of passing planets such as Earth. The messy combination of tugs from the atmosphere and other planets makes the whole system chaotic. The forces acting on Venus add up in unpredictable ways. Models show that these forces could flip the axis. Or, if Venus was never a planet that spun quickly, they could have acted to slow the rotation and start it spinning in the other direction.

Venus's unique combination of a thick atmosphere and being close to the Sun make it much more likely to reverse than any other planet. Because these changes are chaotic, the researchers can't say that it was inevitable, only that there was always a good chance.

How long will astronauts' footprints on the Moon's surface remain there?

Footprints in sand on the surface of the Earth will not last long at all because of the action of wind. But because the Moon has no atmosphere it might be expected that the footprints would last indefinitely--unless they are disturbed by a moonquake produced by a meteorite impact. However, this is not the case.

In the mid-1970s I worked in the Lunar Physics Group at Birmingham University, where my speciality was fission track analysis. Fission tracks are produced in crystal material, such as that found on the lunar surface. On the Moon, uranium is present as a trace element and some of this undergoes spontaneous fission, producing fission fragments. The damage that these cause to the crystalline structure can be revealed by etching the crystal and examining the fragments' tracks under an optical microscope. The older a specimen is the more tracks should be revealed, as it has had more time to accumulate damage.

Research on materials recovered from the Moon's surface by the Apollo astronauts and the Soviet robot missions revealed that the crystals contained fewer fission tracks than would have been expected, given the age of the material. This could be explained as an annealing effect. The high surface temperatures produced during the solar day tend to "heal" the damage in the crystals. This is similar to processes used in the semiconductor industry, in which crystals of silicon are heated in ovens under controlled conditions to remove defects.

The big surprise, though, was that this annealing process seemed to have affected the top metre or so of the lunar surface. Because of the poor thermal conductivity of the surface layers, one would not expect more than the first couple of centimetres to be affected. That the effect is felt much deeper than this implies that the surface material is constantly circulated. This has become known as the "lunar gardening effect". It is thought that expansion and contraction in the surface layers, caused by the extreme temperature changes between lunar day and lunar night, lead to a complete turnover of the top metre every 10 000 years or so.

Assuming the footprints left on the Moon to be approximately 1 centimetre deep, if the turnover of the top metre takes 10 000 years, it will take 100 years for the footprints to disappear completely.

How large will the International Space Station have to be before it can be seen with the naked eye? And when built, how significant will it appear to an observer on Earth?

WAIT no longer! The station is already visible, and was from the time that the first module, Zarya, was launched. It currently appears as a bright "star" of about 0 magnitude, slightly less bright than Mir, which is also regularly visible. When completed, the ISS is likely to rival Venus for brightness at about magnitude -4.

To discover when the station is visible from your location you need to enlist the help of NASA via the Marshall Space Flight Center by accessing its excellent website at liftoff.msfc.nasa.gov/realtime.

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This will show you the current orbit and position of the station and will also allow you to check pass times for your latitude and longitude. As an alternative I would recommend using the equally excellent STS-Orbit Plus program available as shareware at tie.jpl.nasa.gov/dransom/stsplus.html. You will also need regularly updated orbit parameters (or elements), which are available from a number of sources, including www.celestrak.com/NORAD/elements/index.html.

The STS-Orbit Plus program will run on all PCs using DOS or Windows (all versions) and will display, on your home computer, satellite tracks of the type seen on television from NASA Mission Control. Times of visibility will be correct to within seconds as long as the orbital elements are up to date.

I've heard that the Moon is moving away from the Earth by about 4 centimetres every year. What mechanism leads to this shift and how is such a tiny amount calculated?

The Earth and Moon exert tidal forces on each other. The Moon's tidal influence raises the ocean tides on Earth, while the Earth causes body tides on the Moon effectively stretching and squeezing it. This tidal activity dissipates enormous amounts of the Earth's rotational energy.

Because the Earth rotates faster than the Moon goes round it, the tidal bulges of the oceans don't point exactly along the Earth-Moon line but are dragged slightly ahead. The gravity from these leading and trailing bulges tugs the Moon forward and transfers angular momentum from the Earth's rotation to the Moon's orbit, increasing the total energy of the Moon.

The tidal friction between the oceans and the Earth's surface causes the Earth's rotation to slow by approximately 0.002 seconds every century. However, ignoring energy lost to heat generated by the tides, the angular momentum of the Earth-Moon system must remain constant. The Earth's angular momentum is decreasing, so the Moon's must increase. The only way it can do this is by moving into a higher orbit around the Earth. Thus, the distance to the farthest point of the lunar orbit is increasing by about 3.8 centimetres per year.

This change is measured by a method called laser ranging. In 1969, the Apollo 11 astronauts placed a reflector array in the Sea of Tranquility on the Moon. Additional reflectors were left on later missions. Scientists fire a laser beam through an optical telescope pointed at one of these reflectors and the beam bounces directly back towards the telescope, where sensitive filtering and amplification equipment detects the faint return signal. The time taken for the laser pulse's round trip gives the distance between the Earth and the Moon.

Having survived a ride at a local funfair, I was struck by the violence of the accelerations and decelerations on the waltzer-type rides, particularly those with the new stellate patterns. How do these forces compare to those experienced by fighter pilots and astronauts?

I am researching amusement ride dynamics and the implications for the design of passenger vehicles.

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The main difference between amusement rides and aeroplanes or spacecraft is that pilots and astronauts experience sustained *g* forces which can last long enough for physiological effects (such as a loss of consciousness) to occur. On most amusement rides, the accelerations change constantly with each peak lasting less than a second. It is often the rate of change of acceleration, known as jerk, which gives the ride its thrill.

One other difference is that pilot and astronaut vehicles are not refitted and adjusted every five minutes or so and do not have to accommodate passengers ranging from adults to small children. However, if you want to experience something approaching jet fighter manoeuvres, try some of the modern roller coasters.

A fundamental design consideration of an aircraft is its *g*/mach number envelope, which determines limits to its speed and manoeuvrability. Modern military aircraft typically have *g* limits of around +9·5 to -5·5*g*, although these boundaries are continually being pushed back. Sensors are fitted into most cockpits to allow the pilot to monitor *g* values to avoid overstressing the airframe. For additional safety and to cope with crash impacts, cockpit interiors are designed to withstand 20*g* in any direction.

Finally, ejection systems (ejector seats, escape pods) may generate instantaneous loads (for about one-tenth of a second) in excess of 30*g*. The requirement is that a seat lofts a pilot from an aircraft at zero forward speed and zero altitude (the so-called "zero-zero" seat) to an altitude at which the parachute can deploy safely. Alternatively, the seat must be able to clear the tail plane of an aircraft travelling at high speed.

I believe the record for a human experiencing *g*-loading is around 86*g* by the occupant of a rocket-sled. By comparison civilian airlines experience a modest 1·5*g* during take-off acceleration.

Spacecraft returning to Earth from orbit are subject to the intense heat that is generated by the friction from re-entry into the atmosphere. Why is it not possible for them to employ an opposing thrust to counteract the pull of Earth's gravity?

It is quite possible to employ an opposing thrust to counteract the pull of gravity.

However, in practice this would need an immense amount of fuel, only a little less than that needed to start the spacecraft from its launch pad. A spacecraft would have to carry this fuel for braking throughout its whole journey, and also a corresponding amount of additional fuel to launch it in the first place, because the fuel for braking would obviously have to be carried into space. The braking thrusters would also add extra weight.

Such a spacecraft would need roughly three or four times as much fuel as one that does classic atmosphere braking, making it much more expensive. The technical difficulties of how to transport such an amount of fuel up into space, and the huge mass to be manoeuvred around while the spacecraft carries out its mission, add to the problem. Compared with this, heatproof tiles are simple and cheap.

Some friends and I were watching TV footage of a Russian space walk and began to wonder what would happen to an unprotected human body ejected into space. Would it explode immediately, freeze quickly or a combination of both, depending on whether it was ejected into sunlight or shade? We are dying to know.

Many science-fiction films suggest that you would explode but this is not the case. As depicted in *2001: A Space Odyssey*, the surface tension of your skin is strong enough to hold you together. Evaporation in a vacuum is very quick, so space would feel cold and any cuts would also evaporate, forming a quick seal of dried blood.

Contrary to popular belief, a human body ejected into space would not explode. At 1 atmosphere (spacecraft are pressurised to even less), there is not enough pressure inside your body to turn it inside out. You must remember that a vacuum doesn't suck, it is pressure from the inside that pushes. Therefore, an infinite vacuum will not necessarily cause everything to explode.

One person's space suit began to leak during tests in a vacuum chamber at a NASA centre. He blacked out after 14 seconds but survived. Should you end up in empty space without a suit, the advice is don't try to hold your breath, because you could damage your lungs in the same way a rapidly ascending scuba diver might.

Why does lightning fork and what is the diameter of a bolt of lightning?

Lightning usually brings the negative charge from a thunderstorm down to the ground. A negatively charged leader precedes the visible lightning, moving downwards below the clouds and through air containing pockets of positive charge. These are caused by point discharge ions released from the ground by the thunderstorm's high electric field.

The leader branches in its attempt to find the path of least resistance. When one of these branches gets close to the ground, the negative charges attract positive ions from pointed objects, such as grass and trees, to form a conducting path between cloud and ground. The negative charges then drain to ground starting from the bottom of the leader channel. This is the visible "return stroke" whose luminosity travels upwards as the charges move down. Those branches of the leader that were not successful in reaching the ground become brighter when their charges drain into the main channel.

Photographs of lightning often overestimate the channel width because the film can be overexposed. Damaged objects that have been struck by lightning show channel diameters of between 2 and 100 millimetres.

Questions and answers from readers of www.newscientist.co.uk