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Q. If the Sun was the size of a basketball at St Stephen’s Green in Dublin where would the nearest star be?

Eiffel Tower, Paris
The Spire, Dublin
Taj Mahal, India

Answer – Taj Mahal, India

The radius of the Sun is 696000km. ie $6.96\text{x}10^5$ km The radius of a standard basketball is 12cm – ie $1.2\text{x}10^{-4}$km

The next nearest star to the Sun is Proxima Centauri at a distance of 4.07×10^{13} km

So the answer is (Radius of Basketball) x (Distance to Star)/(Radius of Sun)

Ie $1.2\text{x}10^{-4}$km x 4.07×10^{13} km/$6.96\text{x}10^5$ km = 7017 km

Distance from Dublin to the Taj Mahal, at Agra India is 7252km

Incidentally in astronomy because distances are so large it is more usual to give distance measurement in terms of ‘light years’. A light year is the distance which light travels in one year at a speed of 299,792 km per second. Proxima Centauri is 4.3 light years from the Sun. The average distance of the Earth from the Sun is 149 million km or 8 light minutes. This distance is also known as 1 Astronomical Unit (1AU)

Q. If you are skating along in roller blades in a frictionless environment will you ever stop moving?

Yes
No
Need more information

Answer – Need more information

In physics there are three laws which govern motion in our every day environment– Newton's Laws.

The first of these states that a body at rest will stay at rest and a moving body will keep moving in a straight line until a force acts on the body. A skater moving on roller blades will eventually come to rest because of friction between the skates and the ground or friction between the skater and the air or bumping into an object. Friction is a force which arises from electromagnetic forces between charged particles on surfaces in contact with each other.

So far so understandable.

So can a skater be in a frictionless environment? If so It would seem that they would never stop moving, but does such a frictionless environment exist? This question raises some more questions.

Is the frictionless environment flat? Is there a coastline to it? Does it depend on the perturbing effects of solar and lunar gravity as you drift along? Are you equipped with an airtight suit and compressed air bottle for the necessarily atmosphere-free surroundings?

Probably our most basic understanding of things we see around us is that energy is neither created nor destroyed. If a person is moving on roller blades, we say the person has an associated kinetic energy. To stop, the person must somehow lose this energy. This requires a force to act on the person which can come in many forms. However, in real life we eventually expect the skater to stop, even on a flat surface, because of the push of friction. There is always a little friction between things that rub together like skates and ice, or like air passing by the person, and this slows the person down. However, if the frictionless environment posed in the question were possible, such as is very nearly the case in outer space, then the skater could in principle carry on indefinitely. Recently, some near-frictionless graphite material has been produced using nano-technology; a property termed superlubricity. So we are at least getting close to the idealised limit of a frictionless surface.

However, what if the skater was going uphill? In this case, even in a frictionless environment (some ideal surface and a vacuum), the skater would still come to a stop because the kinetic energy is converted to gravitational potential energy due to the pull of gravity acting on the skater. So in order to answer this question, even in principle, we need to know information about the incline of the surface.

Q. In which of the following places would a pendulum swing at the slowest rate?
Barrow, Alaska
Singapore
Buenos Aires

Answer Singapore (if pendulums are at sea level at each locations)

A pendulum will swing slowest when closest to the equator. Why is this?
The time period, T, of the swing of a pendulum is given by:

$T=2\pi\sqrt{(l/g)}$

where l is the length of the pendulum and g is acceleration due to gravity.

Because the Earth is spinning, there is a bulge at the equator and the poles are slightly flattened. Hence on the equator the radius to the centre of the earth is greater than the radius at the poles.

The equatorial radius is 6378.1km while the polar radius is 6356.8 km

The value of g at the Earth's surface relates to the values of the Earth's radius, r, at that point using an inverse square law ie g is proportional to $1/r^2$

At the North Pole, **g** is about 9.83m/s^2, while at the equator, **g** is smaller, at only 9.79m/s^2 .
So the period of a pendulum will be longer (i.e. slowest) at the equator than at the pole

Singapore is closest to the equator. - Latitude 2.1° North
Buenos Aires – Latitude 34.5.° South
Barrow, Alaska – Latitude 71.5° North

(An interesting side issue for pendulums relates to temperature. A pendulum should be kept in a temperature controlled environment as on a warm day the pendulum rod will expand and the pendulum will run a little slower. However as Singapore is considerably warmer than Alaska, this adds even more to the effect of the pendulum swinging at a slower rate in Singapore.)

Q. In what conditions would a match burn with a spherical flame?

zero gravity
vacuum
sealed container

Answer zero gravity

A match heats the air immediately around it and causes it to expand to be less dense than the other air in the room. This air rises due to gravity pulling on it less than the other cooler air, as is also the case for a hot air balloon. This results in upward air currents around the match, which sweep out the flame in an upwards direction. In zero gravity, there is no pull on air, dense or not, and the flame would therefore be symmetrical.

Another effect of the zero gravity is that the match will go out rapidly as there is no flow of air around it to keep renewing the oxygen supply.

With regards to a sealed container, a typical room can be considered one. Unless the container is of the size of the flame itself, it doesn't affect the air currents immediately around the flame.

In a vacuum, a match would not burn at all, as there would be no oxygen available.

To find out more about other effects of zero/microgravity see:
http://www.physics.org/explorelink.asp?id=5182&q=zero%20gravity&currentpage=1&age=0&knowledge=0&item=1

Have you ever wondered what fire is? For a great explanation using animation in under two minutes see http://www.boreme.com/posting.php?id=30746

Q. The amount of energy poured onto the Earth by the Sun every 10 minutes is equivalent to the world's electricity needs for how long?

month?
year?
decade?

Answer: Year

Based on 2007, global Electricity consumption is 17.9 trillion KW Hours or 1.8×10^{13} KWhours (from World Bank Indicators)
Power stations often express their energy output in KWatt Hours. This can be converted to the more usual SI energy unit of Joules by:

1Watt=1 Joule per sec
1KWatt hour =1000x60x60 Joules = 3.6×10^{6}Joules

Sol global electrical consumption is
$1.8\times10^{13} \times 3.6 \times10^{6} = 6.48 \times 10^{19}$ Joules

From suntrek.org website the Solar energy received on Earth is 10^{17} Joules per sec.

So 10 mins of solar energy received on earth is $600\times 10^{17} = 6 \times 10^{19}$ Joules which is approximately equal to the 2007 global electricity consumption figure.

Q. How many planets the size of Earth would fit into the Sun?
Hundred?
Thousand?
Million?

Answer: Million

The Earth has a radius of about 6350 kilometers. The sun has a radius (r) of about 695,000 kilometers so the sun's radius (R) is about 109 times the radius of earth.
The formula for volume of a sphere is V=(4/3) ðr3

So the Sun's volume is approximately 1,300,000 times that of Earth.

This would suggest that the number of Earth's which can fit into the Sun is 1,300,000.

But when it comes to the actual filling of the available space, the number will be smaller since spheres always leave some free space around them, even when tightly packed together.

The tightest possible packing of spheres will fill around 74% of the available space. 74% of 1,300,000 is 962,000. So, assuming that both the Sun and the Earth are perfect spheres, around 962,000 of Earths would fit in the Sun - hence the answer 1,000,000 is the closest approximation.

Q. How many times would you have to cut the long side of a piece of A4 paper in half before it's the width of an atom?

31?
310?
3100?

Answer: 31

The size of a carbon atom = 10^{-10}m
2^{10} = 1024 so 10 cuts reduces the length of the side by a factor of 1024

The side of an A4 sheet of paper is 0.297m

Cut Length in metres
0 cuts 0.297
1 cut 1.485 x 10^{-1}
11 cuts 1.450 x 10^{-4}
21 cuts 1.416 x 10^{-7}

31 cuts 1.383 x 10^{-10}

32 cuts should cut into a carbon atom 0.6915 x 10^{-10}

This is equivalent of dividing the length in half 32 times ie dividing by 2^{32}

Q. A clock on the equator runs slower, faster or identical than one on the North pole?
Slower?
Faster?
Identical?

Answer: Identical

The answer is identical for the purposes of timescales which directly affect mankind.

However there is more to this than meets the eye.

Firstly, it depends on the type of clock used as any time measuring device may also have its measurement affected by local conditions such as gravity.

Pendulum Clock

For a pendulum clock, time is kept by noting the period, T, of the swing of the pendulum.

The equation for this is

T=2ðv(l/g)
Where l is the length of the pendulum and g is acceleration due to gravity.

Because the Earth is spinning, there is a bulge at the equator. This was predicted by Newtonian mechanics.

Equatorial radius 6378.1km
Polar radius 6356.8 km

The value of g at the Earth's surface relates to the values of the Earth's radius, r, at that point using an inverse square law ie

g is proportional to $1/r^2$

At the North Pole, **g** is about $9.83 m/s^2$, while at the equator, **g** is smaller, at only $9.79 m/s^2$

So the period of a pendulum clock will be longer at the equator than at the pole. Hence a pendulum clock at the equator runs slower than one on the North Pole.

However modern day time keeping uses atomic clocks – read on

Atomic Clock

An atomic clock uses the natural frequencies of electronic transitions in atoms. This is the signal that electrons in atoms emit when they change energy levels. These provide the most stable form of a clock with an accuracy of at least 10^{-9} seconds per day.

However, even with such clocks there was a query until recently as to whether their position on earth would affect their accuracy.

In his 1905 Special Relativity paper Einstein predicted a clock at the pole would run faster than at the equator because the velocity of the surface is less at the pole.

However a hundred years later Dr. Alex Harvey of Queens College in New York and Dr. Engelbert Schucking of New York University pointed out that Einstein had not taken account of an effect of general relativity, which says that clocks run slower the more deeply in a gravitational field they sit. This effect was first predicted 10 years after Einstein's original paper.

The rotation of the Earth causes it to bulge at the Equator, hence a clock at the pole is closer to the centre of the Earth than at the equator and so sits in a stronger gravitational field and Harvey and Schucking claim that it runs more slowly by just the right amount to offset the time dilation predicted by Einstein.

See:
1) A Small Puzzle from 1905 by Alex Harvey and Engelbert Schucking, PHYSICS TODAY, March 2005, [27] page 34. Publication of the American Institute of Physics.
2) American Association of Physics Teachers
http://www.aapt.org/doorway/TGRUTalks/Ashby/AshbyTalk6of6.htm#geoid

GPS and Relativity

GPS satellites have atomic clocks on board to keep accurate time. General and Special Relativity however predict that differences will appear between these clocks and an identical clock on Earth.

General Relativity predicts that time will appear to run slower under stronger gravitational pull – the clocks on board the satellites will therefore seem to run faster than a clock on Earth.

Furthermore, Special Relativity predicts that because the satellites' clocks are moving relative to a clock on Earth, they will appear to run slower.

The whole GPS network has to make allowances for these effects – showing that Relativity can have a real impact.

Q. If a pingpong ball had the same kinetic energy as two colliding protons in the LHC how fast would the ping pong ball move?

4 cm/s?
4 m/s?
4 km/s?

Answer: 4cm/s

How fast would the ping pong ball move?

If a ping pong ball had the same kinetic energy as two colliding protons in the Large Hadron Collider at CERN, it would be moving at about 4 cm/s, which is about 14.5 km/h or 9 mph.

The LHC will accelerate protons up to energies of 7 TeV each, which is about 1.1 microJoules (1eV is the energy of an electron accelerating through a potential difference of one Volt, hence E=qV and 1eV = $1.6x10^{-19}$J). Remember that since the protons will be moving at very near the speed of light, this is a relativistic energy, according to $E^2=p^2c^2 + m_0^2c^4$, which includes both the kinetic energy and the rest mass energy $E=m_0c^2$ (remember that $p=??m_0v= m_0v/????-v^2/c^2$)). For a proton rest mass of $m_0 = 1.67x10^{-27}$kg, the energy equivalence is about 938 MeV, in other words very small compared to the total energy once accelerated. For the purpose of the comparison in this question we have neglected the rest mass energy. The energy available when two moving protons collide head on is hence 14 TeV, which is about 2.2 microJoules (the beam energies simply add, as opposed to the case of a stationary target).

The mass of a standard tournament ping pong ball is 2.7 grams. Hence to reach an energy of 2.2 microJoules, the speed of the ball, calculated from ½mv^2, would be about 0.04 m/s.

This is of course a rather slow speed; the ball would move much faster in a game (although the 4 km/s option given on the mat is rather extreme – the ball would likely disintegrate and/or burst into flames at such speeds…). Given the "high" energies reached at the LHC, one might expect the ball to move faster, but the key difference is of course the macroscopic size of the ball compared to the microscopic size of a subatomic particle. The same amount of energy as a slowly moving ping pong ball is concentrated into a tiny space. 7 TeV is higher than any previously achieved energy for accelerating protons and corresponds to a speed very close to the speed of light.

Each beam at the LHC will consist of up to 2808 bunches and $1.1x10^{11}$ protons in each bunch. Therefore the total beam energy will be about 360 MJ, which is roughly the equivalent of the kinetic energy of a high speed train. This sounds more impressive even by macroscopic standards, however the comparisons made in this question are not that useful in trying to comprehend how powerful the LHC is. It reminds us to be careful when comparing relativistic particle physics with common everyday macroscopic physics.

Incidentally, a good indication of the level of energies reached is the equivalent temperature of the particles accelerated in the LHC. From E=kT, this is around 10^{17}K (in comparison the temperature of the Sun’s core is around 16 million degrees, and at the surface it is only about 6000 degrees), which corresponds to the conditions in the universe about 10^{-12} seconds after the Big Bang.

For more information about the LHC and the experiments that will be carried out at CERN, see www.cern.ch.

Q. Two filled cola cans one liquid one frozen roll down a short smooth slope. Which one gets to the bottom first?

Liquid?
Frozen?
Same?

Answer: Liquid

If two filled cola cans, one frozen, one liquid, rolled down a short smooth slope, starting from the same point, the can filled with liquid would reach the bottom first. You can actually try this experiment at home if you freeze a can (beware – it might burst).

One might be tempted to say that the two cans will either reach the bottom at the same time, since both are “filled” cylinders, however the contents behave differently. While the frozen cola is attached to the insides of the can and rotates with it, the liquid does not rotate appreciably (if the viscosity is not too high). This means that only the can is rotating in the case of the liquid contents. Hence less of the initial gravitational potential energy (mgh) is converted into rotational kinetic energy (½I?^{2}, where I is the moment of inertia and ??the angular velocity), and more translational kinetic energy (½mv^2) is available. Essentially the combined moment of inertia I of the can filled with liquid is lower, since the contents are not rotating.

If one used a fluid with a high viscosity this would affect the result, as more rotation will occur. Other factors like the surface and length of the slope may also affect the amount of rotation.

Q. What happens if you try to light a candle in an orbiting space station (weightlessness)? Would the candle:

not light at all?
burn dimly for a while?
briefly burn very brightly, then go out?

Answer: burn dimly for a while

If one attempts to light a candle inside an orbiting space station, it would burn dimly for an extended period of time. This experiment has actually been done by NASA scientists on the Mir space station.

One might have expected that the flame would go out shortly after lighting, due to lack of oxygen. On Earth a candle tends to burn continuously until the fuel is used up. As the hot air around the flame rises, this sets up a convection current and cooler, oxygen rich air moves to the candle wick. Thus a continuous supply of oxygen to the wick is guaranteed.

In weightlessness there is no reason for hot air to rise or colder air to correspondingly sink, thus convection currents are absent. However, oxygen molecules still travel by diffusion mechanisms, and it turns out that this is a fast enough process to sustain a dim blue flame around the wick for quite a while. As the oxygen near to the flame is used up and levels of combustion products (carbon dioxide and water) rise, the latter diffuse away from the flame and oxygen molecules move towards it from regions of higher concentration.

The flame is hemispherical in shape, since there is no preferred direction in weightlessness. Since the rate of oxygen supply is much lower than on Earth the temperature of the flame is lower, and the colour is a very dim blue. Candles in microgravity can in fact burn for a significantly longer time than the same candles would on Earth, given the low power burning. The flame also extends over a larger area than on Earth, and burning can be soot-free as combustion can be more efficient.

Interestingly, it was not possible to light a second candle in very close proximity to the first lit one.

For some images of flames in microgravity see http://spaceflight.nasa.gov/history/shuttle-mir/science/mg/sc-mg-cfm.htm
and for more information visit
http://microgravity.grc.nasa.gov/fcarchive/combustion/edmps/cfmedmp.html.

The results from these experiments can incidentally be useful for understanding more about combustion physics.

Q. What is the maximum distance from the sun's centre of mass of our solar system?
(This question does not feature online as it has a similar answer to the 'how many earts fit into the sun' question and hence is not suitable for the auto text replies)

1.3 km?
1300 km?
1.3 million km?

Answer: 1.3 Million Km

The maximum distance between the Sun's centre and the centre of mass (barycenter) of the solar system is roughly 1.3 million kilometres, which is a bit less than the diameter of the Sun (1.4 million km). Hence this is not an insignificant distance. The Sun will come very close to its maximum distance from the barycenter on 3 December 2022.

This might be a bit surprising as we usually consider the Sun to be the centre of the solar system. However gravity of course acts between all masses, and hence the orbiting planets pull on the Sun in the same way that the Sun pulls on them. Given that the Sun is so much more massive the centre of mass is naturally much closer to it than to any of the planets.

A quick indication of how much the Sun might move by can be obtained by working out the centre of mass between the Sun and its largest satellite, Jupiter. The position vector of the centre of mass of a system of two bodies is defined as $\mathbf{R} = (m_1\mathbf{r}_1 + m_2\mathbf{r}_2) / (m_1 + m_2)$, where m_1 and m_2 are the respective masses, and $\mathbf{r}_1$ and $\mathbf{r}_2$ the respective position vectors. If we have two bodies orbiting a common centre of mass, as is the case for the Sun and one of its planets, we can set the origin of the system at the centre of mass, so $\mathbf{R}=0$. Hence, if $a = r_2-r_1$ is the distance between the two bodies (remember, the position vectors both point away from the centre of mass in opposite directions), then the distance between the centre of one of the bodies, in this case the Sun, and the centre of mass is $r_1 = am_2/(m_1+m_2)$.

The mass of the Sun is about $2x10^{30}$ kg, the mass of Jupiter about $1.9x10^{27}$ kg, and the distance between them is roughly $7.8x10^{8}$ km. Putting these numbers into the equation gives a common centre of mass roughly 700,000 km away from the Sun's centre.

The actual barycenter of the solar system of course depends on the interactions between all the planets (and other bodies), but from above we can see that Jupiter is responsible for a fair amount of the total gravitational pull on the Sun, as expected. In comparison the common centre of mass of the Sun-Earth system is only about 450 km from the centre of the Sun, producing a barely noticeable movement.

Given the complicated interactions of the bodies in the solar system, the Sun doesn't move around in a smooth little orbit, but follows a rather irregular trajectory, producing a measurable "wobble". Detecting such a star wobble is one of the main current methods of finding exosolar planets in other solar systems. While we cannot image the planets directly, we can measure the effect they have on the stars they orbit. The planets discovered so far tend to be large ones, since the wobble is too small to be measured for smaller planets.

An interesting website showing the effects of the planets on the movement of the Sun is www.orbitsimulator.com/gravity/articles/ssbarycenter.html. This uses n-body simulations to model the movement of bodies in the solar system (amongst other things).