Question Everything

132 science questions – and their unexpected answers

NewScientist

Question Everything

132 science questions – and their unexpected answers

More questions and answers
from the popular 'Last Word' column

edited by Mick O'Hare

P
PROFILE BOOKS

First published in Great Britain in 2014 by
Profile Books Ltd
3A Exmouth House
Pine Street
Exmouth Market
London EC1R 0JH
www.profilebooks.com

10 9 8 7 6 5 4 3 2 1

A CIP catalogue record for this book is available from the British Library.

ISBN (paperback): 978 1 78125 164 5
ISBN (book club hardback): 978 1 78125 468 4
eISBN: 978 1 84765 984 2

Text design by Sue Lamble
Typeset in Palatino by MacGuru Ltd
info@macguru.org.uk

Printed and bound in Great Britain by
CPI Group (UK) Ltd, Chatham, ME5 8TD

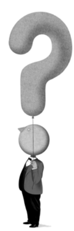
Contents

Introduction

The Last Word column in *New Scientist* magazine – the publication in which most of the questions and answers in this book began life – has traditionally devoted itself to the trivial. That's why we know why hair turns grey, why snot is green, and how fat you need to be in order to be bulletproof. And it's why this book's predecessors have proved to be such a hit with readers. It's our stock-in-trade: finding out how and why the things surrounding our everyday lives do what they do.

But every so often we look at the bigger picture. We'll get a question about stuff in the sky, stuff in the outer reaches of the universe or stuff at the atomic level. Not so much trivia as the stories behind why our planet, our solar system and our universe are like they are. Just why is the night sky black even though it's full of stars pumping out more light than our sun? Why does Earth rotate? And why is the Large Hadron Collider so, er, large? You can find out all about these and other mega-quandaries in the pages that follow.

Obviously, we also have lots of the usual stuff in here about our bodies, our dinners and the various living things we share the planet with, to keep regular readers happy. You can find out why your legs feel wobbly when you are standing on the top of a cliff or how flies can fly into a window pane without damaging themselves. And there's a lot about booze, of course. Why does ice in whisky create such lovely swirling patterns? Does drinking absinthe make you hallucinate? As we say on the cover: 'Question Everything'.



But this time we set out to make people think a little more about our universe and what's in it, and the physics, chemistry and biology that keep it all on the move.

So, with a big bang, here we go… and remember, you can follow the Last Word online at www.newscientist.com/lastword or in print by buying the weekly *New Scientist* magazine. Questions (and answers) always welcome!

Mick O'Hare

Special thanks – in no particular order – to the following: Melanie Green, the *New Scientist* subs and art teams, Jeremy Webb, Beverley De Valmency, Paul Forty, Andrew Franklin, Eleanor Harris, Drew Jerrison, Nick Heidfeld, Harold Wagstaff, Felipe Massa, Sally and Thomas.

1 Earth

In a spin

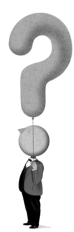
What makes Earth rotate?

R. J. Isaacs
Barnet, Hertfordshire, UK

Earth rotates simply because it has not yet stopped moving. The solar system, and indeed the galaxy, were formed by the condensation of a rotating mass of gas. Conservation of angular momentum meant that any bodies formed from the gas would themselves be rotating. As frictional and other forces in space are very small, rotating bodies, including Earth, slow only very gradually. The moon, a much smaller and lighter body, has effectively already stopped rotating because of the gravitational drag exerted by Earth, and now always keeps the same face turned towards us.

Glyn Williams
Derby, UK

Although Glyn Williams's explanation of Earth's rotation is correct, his assertion that 'the moon … has effectively already stopped rotating' could be misleading. The moon does rotate. The reason why it presents the same face to us is that its period of rotation is the same as its period of revolution around Earth. This equality is the result of tidal friction. If the moon did not rotate, any line through it, parallel to the orbital plane, would keep the same direction in space and the moon



would show us its far side during a complete revolution, as one can easily convince oneself by a simple drawing on paper.

D. S. Paransis
Department of Geophysics
Luleå University of Technology
Sweden

Early days

The shortest day of the year in the northern hemisphere occurs on 21 or 22 December, yet the earliest sunset is on 13 or 14 December and the latest sunrise occurs a similar number of days after the shortest day. Why is this?

John Walker and Alan Whittle
Manchester, UK

Two properties of Earth's orbital motion around the sun give rise to the curious disparity between the dates of earliest sunset, shortest day (winter solstice) and latest sunrise. These are the eccentricity of Earth's orbit, and the tilt of its equator to its orbital plane.

The combined effect of these is to vary the length of the day throughout the year. In some months, the interval between noons on successive days is slightly greater than 24 hours, while in other months it is slightly less. The differences cancel one another out over the course of a year.

In December, near the northern winter solstice, the interval between successive noons is about 30 seconds less than 24 hours. Because this difference is greater than the daily change in sunrise and sunset times, it becomes the dominant effect, causing the observed separation of the dates of earliest sunset and latest sunrise.

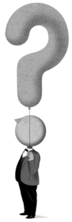
Fred Watson
Coonabarabran, New South Wales, Australia

The main effect of this shifting of latest sunrise to several days after the winter solstice (the shortest day of the year) is an oscillation of the time of day when the sun reaches its highest elevation. The time oscillates about noon in a sine wave with an amplitude of 8.8 minutes at latitude 45° and with a period of 6 months. At the solstices and equinoxes, highest elevation is at noon.

Each day, sunrises and sunsets occur equally before and after the time of the sun's highest elevation. If we call those intervals morning and afternoon, then at the winter solstice, the length of morning is at its minimum and so changes very little for a few days. But although the time of the sun's highest elevation is noon at the solstice, that time gets later quite quickly and shifts the sunrise so that it falls later for a few days. After those few days, morning begins to get longer and overwhelm the 8.8-minute sine wave so we get earlier sunrises again.

Why does the time of the sun's highest elevation oscillate around noon? Mainly because Earth's axis is tilted with respect to its orbit around the sun. Fix a frame of reference at the centre of Earth, aligned with the axis of Earth, but rotating uniformly around that axis only once per year, not once per day. In that frame, the sun generally goes up and down by 23 degrees. But it also goes side to side a little, and this gives the oscillation in time of the sun's highest elevation each day around noon.

Terry Watts
New Jersey, US



? Midsummer misnomer

In the northern hemisphere the sun reaches its highest point in the sky on (or very close to) 21 June every year. Yet the warmest months tend to be July or August. Why is that? Similarly, on 21 December the sun reaches its lowest point but the coldest months are usually January and February. Can somebody explain this?

Wolfgang Wild
Granada, Spain

Earth has a certain heat capacity, which leads to a thermal time lag. Therefore, when a hemisphere is experiencing its longest day it is still warming up, and will not reach its warmest until a few weeks later. Similarly, on the shortest day it is still cooling down and will not reach its coolest until a few weeks later.

Aidan Westwood and Stephen Collins
University of Leeds, UK

Although the northern hemisphere receives most sunlight at the end of June, it is rather like heating up a room with a gas fire. The fire gets hot very quickly, but it takes a while for the air in the room to heat up. The same applies to the atmosphere of Earth. Likewise, the room does not get cold the instant the fire is turned off – the air gradually cools in the same way the air in Earth's atmosphere does.

Ian Hedley
Poole, Dorset, UK

Not early to rise

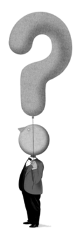
Being very keen to see the return of the sun after the northern hemisphere winter, I began checking the sunrise and sunset times to see how the interval between them increases each day. The sunset time increases by more than one minute per day but the sunrise time is getting earlier by considerably less than one minute each day. Why is there asymmetry? I suspect it has got something to do with London's latitude, but what?

Kate Lee
London, UK

Your correspondent has discovered a quirk of astronomy usually termed the 'equation of time'. I was wondering recently whether day length really changes faster at some times of the year and slower at others. I plugged sunrise and sunset times into a spreadsheet and the resulting graph shows that the day length stays briefly but depressingly static in midwinter, then changes rapidly through spring into another short period of near stasis in summer.

But then I noticed the oddly different behaviour of sunrise and sunset times: the two curves are not symmetrical. So I found the midpoint of the two, which gives the apparent (or true) solar time of noon. When you plot the difference between this time and the mean (or clock) time of noon across the year, you discover a complex curve in a second graph, which is a visual representation of the equation of time. Sunrise and sunset are symmetrical about this line.

Steve Head
Cholsey, Wallingford, Oxon, UK



The asymmetry in the rates of change of sunrise and sunset arises from the nature of Earth's orbit around the sun, and is caused by variations in the length of the solar day – the time between solar noons on successive days – throughout the year. Sunrise and sunset are essentially symmetrical about solar noon, but solar noon is not always at clock noon. The sources of this variation are, firstly, Earth's elliptical orbit around the sun, and, secondly, the 23.5-degree inclination of Earth's rotational axis to the axis of its orbit around the sun.

From solar noon one day to solar noon the next, Earth not only has to turn through 360 degrees, but also through about 1 more degree to compensate for the movement along its orbital path during that time. While Earth reliably turns through 360 degrees once every 23 hours 56 minutes, regardless of the time of year, it is the variation in how much further Earth has to turn to complete the solar day that gives rise to the varying solar day lengths.

Earth speeds up as it approaches the perihelion of its elliptical orbit, the point of closest approach to the sun, and slows down as it approaches the aphelion, the point furthest from the sun. The increased speed at the perihelion, together with the shorter distance to the sun, means the angle swept out by Earth about the sun every day is greater near the perihelion than near the aphelion. So more rotation is needed to complete a solar day near the perihelion, causing the solar day to lengthen. This factor generates a sine wave-like variation in the length of the solar day with a period of one year.

The second source of the variation is more difficult to visualise. At the summer and winter solstices, the plane joining Earth's rotational axis to the centre of the sun is perpendicular to the plane of Earth's orbit, and a point on the equator has the least distance to travel between one noon and the next, so the solar day is at its shortest. By contrast, at the equinoxes, Earth's axis is tilted towards or away from the orbital plane. Now, a point on the equator must travel further between consecutive noons, and a solar day is longer than a solar day at the solstice by about 22 seconds. This mechanism operates at other latitudes, which causes a variation in the solar day length with two peaks and two troughs a year.

These two sources of variation together create an intricate pattern of solar day length. While the changes from day to day are small, they are cumulative and can lead to marked differences between solar time and clock time during a year. They are the bane of sundial makers and are expressed in the equation of time, which shows a pattern resembling a sine wave of a six-month period superimposed on a sine wave of a one-year period. The time difference ranges from about 14 minutes negative to more than 16 minutes positive, with the steepest slope, of more than 20 seconds a day, occurring in December. It is the shifting solar noon added to what would otherwise be a symmetrical movement of sunrise and sunset that produces the asymmetry.

Ian Vickers
Mosman, New South Wales, Australia

There are several websites where you can find out more about this. Try: www.analemma.com and www.cso.caltech.edu/outreach/log/NIGHT%20and%20DAY.pdf – Ed.

Long hours

Do all points on Earth receive an equal number of daylight hours over the course of a year? I realise that the intensity of the sun's rays will differ considerably depending on your latitude, but does a person living in Alaska see the sun for as long as somebody living in Ecuador over the course of a year?

Tami Shinn
By email, no address supplied