Starlight closes loophole

2017 Phys. World 30 (3) 4

(http://iopscience.iop.org/2058-7058/30/3/6)

Frontiers

In brief

New integrated circuits may survive Venus
Integrated circuits, which could withstand the harsh conditions on Venus for a record-breaking time, have been built by researchers at NASA. Operating a lander on the surface of Venus is very difficult because the temperatures can reach 460°C and the pressure (about 100 times that on Earth) quickly destroys electronic circuits – the best systems only survive for a few hours. The team has now created new integrated circuits from silicon carbide – an extremely tough, chemically inert and heat-resistant semiconductor – and tested them in the Glenn Extreme Environments Rig, which can simulate conditions on Venus. The chips survived for more than 500 hours with no cooling or protective chip packaging (*AIP Adv.* **6** 125119).

Stomach acid powers electronic capsule
A new ingestible electronic device can harvest energy inside the gastrointestinal (GI) tract, allowing it to monitor temperature over several days. Ingestible electronics are useful because they can take live images of the GI tract, deliver drugs and measure conditions such as pH and temperature. But powering such devices is challenging. Now, researchers in the US have developed a capsule that uses biocompatible galvanic (electromechanical) cells that harvest energy from the GI tract by transferring electrons between metallic electrodes and the gastric or intestinal fluid. The process can power the device for several days, allowing it to monitor temperature and send data wirelessly to the researchers (*Nature Biomed. Eng.* **1** 0022).

3D printed structure mimics plant porosity
A new 3D printed material (inspired by plant structures) has been developed by researchers in the US. Using ceramic foam ink, they developed a method of printing 3D structures with both macro- and microscale structures. In nature, grass has a hollow tubular macrostructure with a porous microstructure, helping it to recover after compression and to support its own weight. Using a ceramic foam ink containing alumina particles, water and air, the team mimicked this architecture by printing a triangular honeycomb structure that had microporous walls. The ink and printed structure were both tested and tuned to optimize density and stiffness. The resulting lightweight material could be used for thermal insulation or tissue scaffolds (*PNAS* 10.1073/pnas.1616769114).

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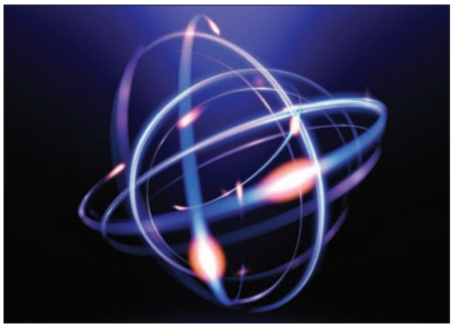
Decaying atoms feel friction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It's all relative Atoms could be subject to friction.

An excited atom decaying in a vacuum experiences a force very similar to friction, according to calculations done by physicists in the UK. At first sight, the result appears to violate Einstein's equivalence principle. Indeed, physicists Matthias Sonnleitner, Nils Trautmann and Stephen Barnett at the University of Glasgow noticed an apparent contradiction when considering a textbook quantum-mechanics problem. They calculated that the mass lost from the atom as it decays to the ground state allows it to lose momentum without slowing down.

According to quantum mechanics, an excited atom in a vacuum decays to a lower energy state, emitting a photon in a random direction. This phenomenon is normally described in the atom's rest frame, in which the magnitude of the photon's momentum is independent of its direction. Therefore, a photon is equally likely to be emitted in any direction and the expectation values of the photon's momentum and the atom's recoil momentum remain constant at zero.

However, consider a frame in which the atom is moving: because of the Doppler effect, a photon emitted in the same direction of travel as the atom would be blue-shifted – its frequency, and therefore its momentum, is increased. The opposite applies for a photon emitted in the opposite direction. The atom would therefore experience a net force proportional to its momentum but in the opposite direction – effectively, it would experience friction from the vacuum. This appears to violate the principle of relativity because an observer could use the atom's changing velocity to determine the absolute motion of their own frame of reference.

The Glasgow researchers realized that the answer lay with relativity after all: when an atom emits a photon and decays to a lower energy state, the classic equation $E = mc^2$ shows that its mass must also decrease. Although the decrease is tiny, it is enough to compensate for the decrease in momentum, allowing its velocity to stay constant.

This only works when a small, often-neglected correction proposed in 1888 by the physicist Wilhelm Röntgen is included to accommodate the interaction between the moving atom's electric dipole and a magnetic field. In this latest research, the magnetic field is associated with quantum vacuum fluctuations (*arXiv*:1204.6646). Although the phenomenon is, in principle, applicable whenever an atom absorbs or emits a photon, in practice, other influences are much larger, so the effect is not significant.

Starlight closes loophole

A Bell test of quantum entanglement that claims to use starlight to close the "freedom of choice" loophole has been performed by an international team of physicists. Entanglement is observed as correlations between measurements made on two particles and in 1964 John Bell proposed a test of whether such correlations are stronger than those allowed by classical physics. Although many Bell-test experiments confirm entanglement, no experiment is perfect and there are still a number of "loopholes" that could allow purely classical phenomena to affect the outcome.

In 2015 physicists were able to simultaneously close two important loopholes called "fair sampling" and "locality". The third is "freedom of choice". In a Bell test, a large number of measurements are made on different entangled pairs in which the direction of the polarization measurement is randomly selected. If, for some reason, the polarization is not random but correlated to other aspects of the experiment, then the outcome could be affected.

Now, Johannes Handsteiner and Anton Zeilinger of the University of Vienna and colleagues have used the randomly changing colour of starlight to decide how to set Bell-test polarization detectors. The stars were chosen so that their light arrives at two separate telescopes, before reaching other parts of the experiment. This, and the fact that the starlight light was created hundreds of years ago and very far from Earth, allowed the physicists to conclude that there is no correlation between the polarization measurement and the rest of the experiment. However, their experiment does not close the fair sampling loophole (*Phys. Rev. Lett.* **118** 060401).