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New Quantum Weirdness: Balls That Don't Roll Off Cliffs

Quantum particles continue to behave in ways traditional particles do not

By George Musser

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A good working definition of quantum mechanics is that things are the exact opposite of what you thought they were. Empty space is full, particles are waves, and cats can be both alive and dead at the same time. Recently a group of physicists studied another quantum head spinner. You might innocently think that when a particle rolls across a tabletop and reaches the edge, it will fall off. Sorry. In fact, a quantum particle under the right conditions stays on the table and rolls back.

This effect is the converse of the well-known (if no less astounding) phenomenon of quantum tunneling. If you kick a soccer ball up a hill too slowly, it will come back down. But if you kick a quantum particle up a hill at the same speed, it can make it up and over. The particle will have “tunneled” across (although no actual tunnel is involved). This process explains how particles can escape atomic nuclei, causing radioactive alpha decay. And it is the basis of many electronic devices.

In tunneling, the particle can do something the ball never does. Conversely, the particle might not do something the ball always does. If you kick a soccer ball toward the edge of a cliff, it will always fall off. But if you kick a particle toward the edge, it can bounce back to you. The particle is like one of those little toy robots that senses the edge of a table or staircase and reverses course, except that the particle has no internal mechanism to pull off its stunt. It naturally does the exact opposite of what the forces acting on it would indicate. The researchers behind the analysis—Pedro L. Garrido of the University of Granada in Spain, Jani Lukkarinen of the University of Helsinki, and Sheldon Goldstein and Roderich Tumulka, both at Rutgers University—call this phenomenon “antitunneling.”

In both cases, the explanation lies in the wave nature of particles, which in turn reflects the fact that a quantum particle generally has an ambiguous location. The wave describes the range of locations where it could be found. This wave behaves much like ordinary waves such as sound. Whenever any wave encounters a barrier that is not absolutely rigid, some of the wave will penetrate into the barrier, albeit with diminishing intensity. If the barrier is not too thick, the wave can reemerge on the other side. That is analogous to tunneling.

For antitunneling, the analogy is that whenever any wave encounters any abrupt change of conditions—even ones more favorable to its propagation—some of it will reflect back. Something similar happens when a scuba diver looks up and sees the sea surface acting as a mirror. To be sufficiently abrupt, the distance over which conditions change must be shorter than the wavelength (which for a particle is related to momentum). If the change is too gradual, the wave will simply go along, and the particle will act like a soccer ball after all.

Garrido and his colleagues undertook a numerical analysis to rule out the possibility that the phenomenon was an artifact of idealized assumptions. They also calculated how long a particle will tend to roll around the table before going over the edge; it gets longer the higher the table is. David Griffiths of Reed College, author of a widely used introductory quantum mechanics textbook (the second edition of which gives a version of antitunneling as a student exercise), calls it “a very sweet paradox.” Physicist Frank Wilczek of the Massachusetts Institute of Technology says, “It’s a solid analysis, and it points out an interesting phenomenon I hadn’t been consciously aware of.”

Antitunneling might have applications for building laboratory particle traps, describing nuclear decay or exploring the foundations of quantum mechanics, but its main appeal is to remind physicists how a nearly century-old theory has lost none of its capacity to surprise.

Note: This article was originally published with the title, "Quantum Brinkmanship".

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- tharriss at 08:29 AM on 11/20/08

Very cool!

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Assegai at 01:03 PM on 11/20/08

how will this affect philosophy and how we think of the universe, incredible

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ChrisJones at 03:46 PM on 11/20/08

Why would I automatically assume that a particle rolled to the edge of a table would "fall off?" From the particle's "point of view" what, exactly, would constitute "off" or "fall?" Looking upon all things as residing within our very limited perceptual framework is hardly "innocent." At best it is arrogant, at worst, ignorant. Quantum mechanics IS strange and bizarre, but it isn't precisely the "opposite" of every thing one, in his or her narrow perception, assumes to be the absolute truth. The cat is neither both dead and alive at the same time, nor alive and dead a the same time. We can't even be sure there even IS a cat in the box, or what color it is...this amazing cat is dead and alive and present and not present AND every possible color... male and female.... so the reality is very much stranger than a simple 'black is white' dichotomy. Opposite would be easy! Sesame Street plays 'one of these things doesn't belong here.' The same game with QM is much more complicated.... and, of course, simpler at the same time. Interesting article though... poor start... but interesting.

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H at 04:19 PM on 11/20/08

The following is a direct response to this comment.

Thanks DeCarte.

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mrsaturn42 at 07:15 PM on 11/20/08

I am very disappointed in sci-am lately. First the "Nature breaks the second law of thermo" article adn now this!?
They are putting too much "weirdness" into quantum mechanics so that laypeople will never understand it.
I feel like sci-am makes philosophy/English grads read physics textbooks and write something interesting about very simple concepts.
The thing about a particle and a ball is that a particle has the wave/particle duality.
In this case the particle acts more like a wave of light. Where some will penetrate and go through the barrier(ie a piece of glass) and some will reflect (ie a piece of glass/mirror);

This article is reading way too much into a very elementary evaluation of Schrodinger equation.

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buddha_dust at 07:47 PM on 11/20/08

Dear mrsaturn42,

Don't you know the new paradigm yet? Magazines and television no longer share knowledge, they entrap readers/viewers just long enough for the advertisements to work. No one respects truth or rigorous exposition anymore, it is all about the advertising dollar. Like Pogo said long ago,

"We have met the enemy, and he is us."
buddha_dust@yahoo.com

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amoebadrew at 08:04 PM on 11/20/08

The analogy of a ball rolling off a cliff to a particle encountering a drop in potential energy is not right at all. As a ball moves off a cliff there is no discontinuity in the energy it has, it has to actually fall in order to gain any energy. In contrast, to demonstrate quantum tunneling, you need an abrupt or discontinuous spatial change in energy. Immediately after encountering the barrier/anti-barrier the energy of the particle must change. A better analogy might be to consider a ball rolling onto a moving walkway (like those in airports). As soon as the ball hits the walkway, it immediately gains kinetic energy. (This isn't quite right either, but the idea is better). David Griffith's exercise mentions this exact fallacy in reasoning, so I'm not sure why the article is incorrect.

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redfoxone at 08:06 PM on 11/20/08

Whoah! Now that is pretty cool isnt it.

Jess
http://www.privacy.mx.tc

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Tan Boon Tee at 11:13 PM on 11/20/08

Particles are particles. Objects are objects.

A particle is a theoretical concept (albeit an extremely useful one) in physics, it is supposed to be infinitely tiny and massless. What happens to an object of a given mass in real life could be entirely different (if not exactly the opposite) to what happens to a particle in the quantum arena. They are incompatible.

Where comes the weirdness? Where is the surprise?
(btt1943@yahoo.com)

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bunturbuff at 06:54 AM on 11/21/08

Amazing!

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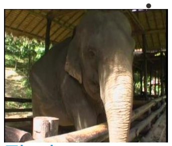
- 
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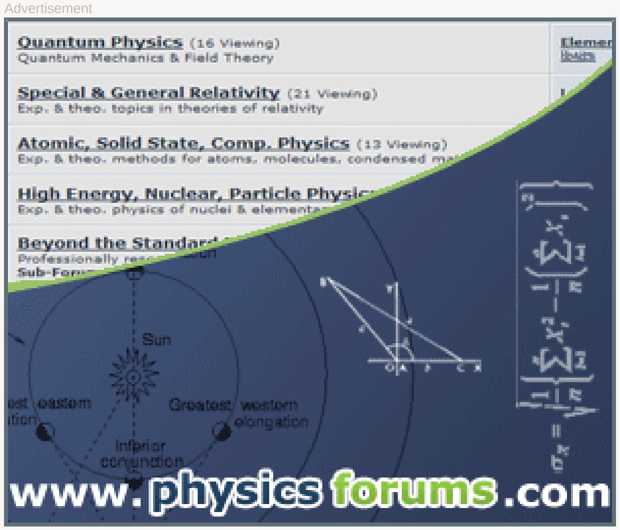
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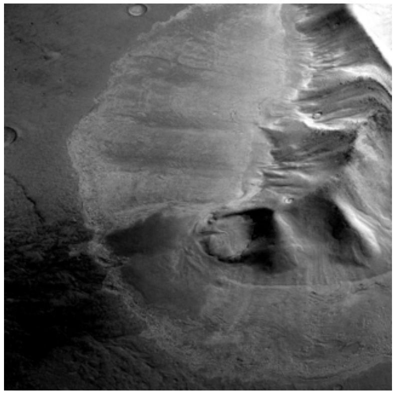
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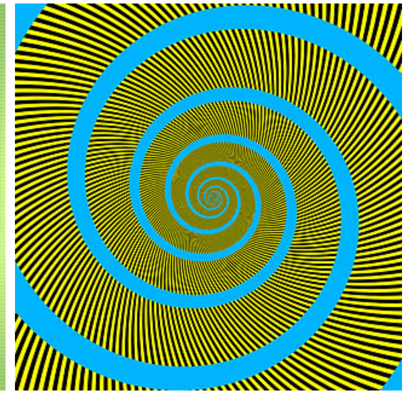
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