Topsy-Turvy Top

Revisiting the tumbling of a different kind of top

By IVARS PETERSON

The tippe top looks like a perfectly rounded, miniature apple with a stiff, straight stem. When spun, the toy revolves on its curved bottom. As the top whirls, however, its stem dips lower and lower to the ground. Suddenly the toy flips over and begins to rotate on its stem.

Such unexpected behavior has long delighted children of all ages. It has also fascinated a number of scientists, mathematicians, and engineers, who couldn't resist scrawling equations and diagrams on the proverbial back of an envelope to puzzle out the cause of the top's startling reversal.

The latest effort to decipher this toy comes from dynamicist Arthur C. Or, a research scientist at the Climate Dynamics Center at the University of California, Los Angeles. He describes his investigations of the tippe top's motion in the June SIAM JOURNAL OF APPLIED MATHEMATICS.

"One day, I saw my children playing with this toy, and I got interested in it," Or says.

At that time, Or was a control engineer at Hughes Aircraft, where he often had to analyze the motion of gyroscopes and other spinning bodies. He showed the top to his coworkers. "There were many different theories about how it worked," he says.

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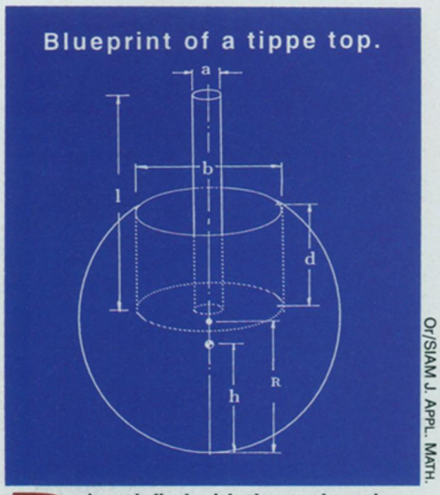
A spinning tippe top intrigues physicists Wolfgang Pauli and Niels Bohr.



Blueprint of a tippe top.

Or/SIAM J. APPL. MATH.

Dissatisfied with the explanations, Or wrote a computer program to simulate the top's movements. At first, the simulations failed to replicate the top's reversals. But by adding the effects of friction when the spinning top's stem dips enough to touch and slide across a flat surface, he finally succeeded in matching his observations.

"Without friction, it doesn't work," Or remarks.

Or wrote a paper describing his results. "At that time, I did not know there was already a huge pool of literature [on this topic]," he says.

He learned from one of the reviewers of his paper that interest in the tippe top could be traced back to the 19th century, with a major burst of topical cogitation in the early 1950s. Papers about the toy's perplexing movements had appeared in NATURE, PHYSICA, the AMERICAN JOURNAL OF PHYSICS, and elsewhere.

The problem of the top's motion had also caught the eye of such notables as Niels Bohr and William Thomson (Lord Kelvin). Thomson was once supposed to be studying for a major mathematics examination at the University of Cambridge in England but instead whiled away the hours spinning smooth stones gathered from a beach. These stones showed the same reversing behavior as the tippe top.

In its simplest form, a tippe top consists of a sphere with its upper portion sliced off and a rod planted in the middle of the flat side. With the top's center of mass somewhat lower than the sphere's center, the toy normally rests in a position with its rod, or stem, pointing vertically upward.

When spinning quickly enough, however, the top is more stable if its center of mass is higher than the sphere's geometric center. Given a chance, the spinning top changes its orientation.

Investigators realized early on that a variety of rounded objects having a similarly offset mass distribution would show the reversing effect. Indeed, the effect was observed with several tops, pebbles of certain shapes, and even rings set with large, heavy stones.

But despite a number of ingenious experiments aimed at tracking the tippe top's movements, researchers had difficulty sorting out whether the force responsible for flipping the top arose from rolling contact or sliding friction as the top moved over the surface on which it was spinning. The debate continued for decades.

A spinning tippe top inverts itself.

Or/SIAM J. APPL. MATH.

Or's calculations and computer simulations demonstrate that the friction produced as the top slides across a surface plays the predominant role in this phenomenon. "A transition from sliding to rolling never seems to occur," Or notes.

Now, Or has a new toy to ponder. The rattleback is an elongated, rounded piece of marble that rotates very smoothly in one direction and quite erratically in another direction.

"It's even more intriguing than the tippe top," Or says. □