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Two-ball bounce problem explained

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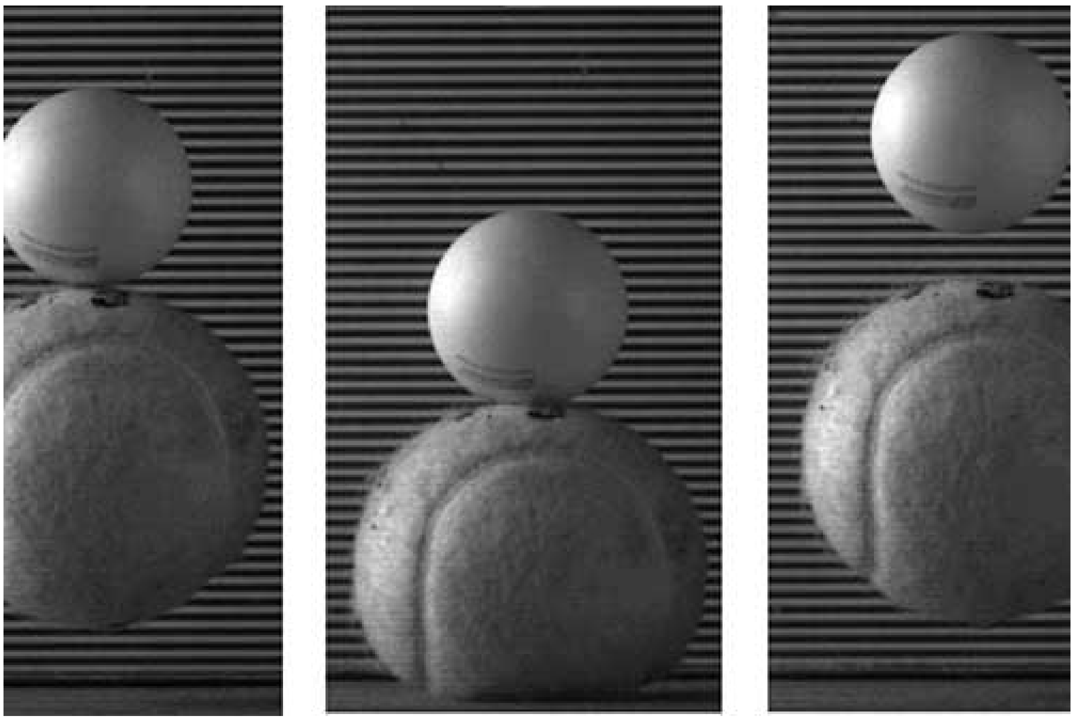

Stills from high-speed camera for an instance of the 'two-ball bounce problem', in this case a tennis ball and a table tennis ball impact

Researchers from the University of Bristol have revisited a well-known classroom demonstration where a lighter ball is dropped on top of a larger heavier ball and offer a model to explain the phenomenon.

The 'two-ball bounce problem' is often used to demonstrate that the rigorous rules of physics can produce counter-intuitive effects. When a tennis ball is placed on top of a basketball and the two dropped together the tennis ball bounces significantly higher than one would expect - around three to four times higher than where it was dropped from.

The research, led by PhD student Yani Berdeni from the Department of Engineering Mathematics, found that even such a simple experiment can offer further surprises. The success of this experiment depends on how far the two balls are placed from one another at the time of release. If the experimenter is very accurate and makes sure there is no gap between the two balls the effect of the top ball rising higher is diminished. The study published in the *Proceedings of the Royal Society A* offers a model to explain the phenomenon.

The researchers found that if you drop two balls close together they don't rebound as far as if you drop them further apart. Other recent research along the same lines - looking at the collisions of two spheres - has found a similar effect. If two spheres collide at lower velocities they will not rebound as far as expected.

The standard textbook explanation of the 'two-ball bounce problem' assumes two independent, instantaneous collisions - the lower ball impacts with the floor, rebounds and then collides with the upper ball. Newton's law of restitution is used along with the law of conservation of momentum to predict the final velocities of both balls.

This simple explanation was tested by using a drop-tower to align the balls vertically, synchronising their release using solenoids controlled by a computer. A high-speed camera was used to record the impacts at 20,000 frames per second. The researchers found that the assumed order of collisions was incorrect - unless the separation distance was extremely large the basketball was still in contact with the floor when it impacts with the tennis ball. As the separation distance between the balls became very small the simple explanation breaks down, over-predicting the velocity of the upper ball.

An alternative explanation was developed, modelling the lower ball as a spherical membrane. The deformation of the spherical membrane upon impact excites an elastic wave, which fires off the upper ball in a trampoline-like effect.

Yani Berdeni said: "Understanding how spherical bodies behave when they collide has important implications when modelling 'granular materials', such as sand, as these are can be treated as a collection of lots of tiny spheres."

Many basic products such as building materials, chemicals, pharmaceuticals and food are granular. Because granular materials are an unusual form of matter with properties that are poorly understood, many processing plants operate inefficiently and sometimes experience catastrophic failures. As a result even a small improvement in understanding how these materials work could have a profound impact on industry.

More information: "The two-ball bounce problem." *Proceedings of the Royal Society A*. DOI: 10.1098/rspa.2015.0286

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