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Galileo's Paradox

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Thomas B. Greenslade Jr.

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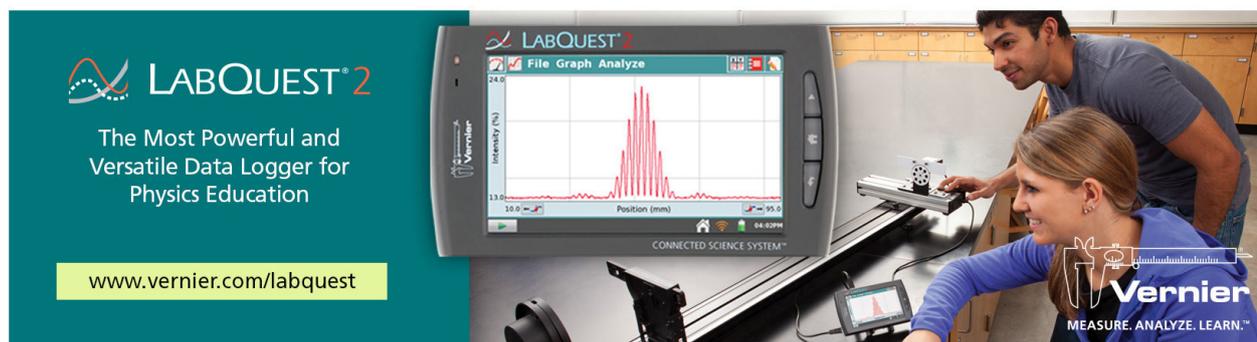
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Galileo's Paradox

Thomas B. Greenslade Jr., Kenyon College, Gambier, OH

The paradox is a wonderful teaching tool. The sleepy student in the back row is surprised and wakes up, and the student with the instantly memorized answer is forced into the analytical mode. The diagram in Fig. 1 has the following paradox: A body sliding freely down a chord from the edge of the circle reaches the lowest point on the circle at the same time as a body released simultaneously from the top. This result was first mentioned in a 1602 letter from Galileo Galilei to Guidobaldo dal Monte.¹

To show that this seemingly strange result has a firm basis in theory, assume that the diameter of the circle is D , the length of the chord is L , and that the angle between the chord and the horizontal is θ . The acceleration of the body sliding down the chord is $a = g \sin \theta$, and the time t for the trip down the chord is found using $L = \frac{1}{2}at^2$. Putting in the expression for the acceleration and solving for t^2 gives $t^2 = 2L/(g \sin \theta)$. We know that the triangle bounded by the chord and the diameter of the circle is a right triangle, so $\sin \theta = L/D$, and $t^2 = 2D/g$. But this is just what we would expect for a body falling freely through a vertical distance D , and the paradox is resolved.

Apart from the invaluable *Demonstration Experiments in Physics*, edited by Sutton,² I have found this demonstration only in an 1864 French apparatus catalogue, in which balls rolled down a pair of inclined troughs. For my annual lecture demonstration seminar presentation at Kenyon College in May 2007, I built a modern version using a bicycle rim left over from an earlier piece of apparatus that used the hub.³ The upright rim was fastened to a block of wood by a pair of screws. Wires ran from the bottommost spoke hole to the topmost hole and also to a hole about at the three o'clock position. Metal beads sliding on the

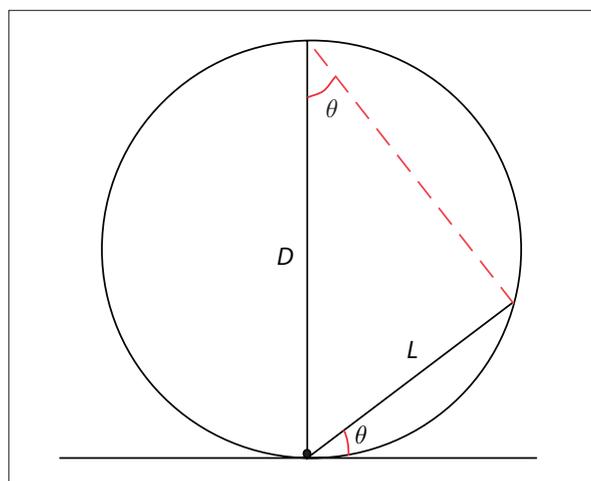


Fig. 1. Under the influence of gravity, the transit time across the chord of a vertical circle is equal to the free-fall time across the circle.

wires met at the bottom with a satisfying single click when they were released simultaneously. The construction time was about an hour.

References

1. Domenico Bertolini Meli, *Thinking with Objects* (Johns Hopkins University Press, Baltimore, 2006) p. 71.
2. Richard M. Sutton, *Demonstration Experiments in Physics* (McGraw-Hill Book Company, London, 1938), pp. 42-43.
3. Thomas B. Greenslade Jr., "All about lissajous figures," *Phys. Teach.* **31**, 364-370 (Sept. 1993).

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