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Early descriptions of Coriolis effect FREE

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LETTERS

Early descriptions of Coriolis effect

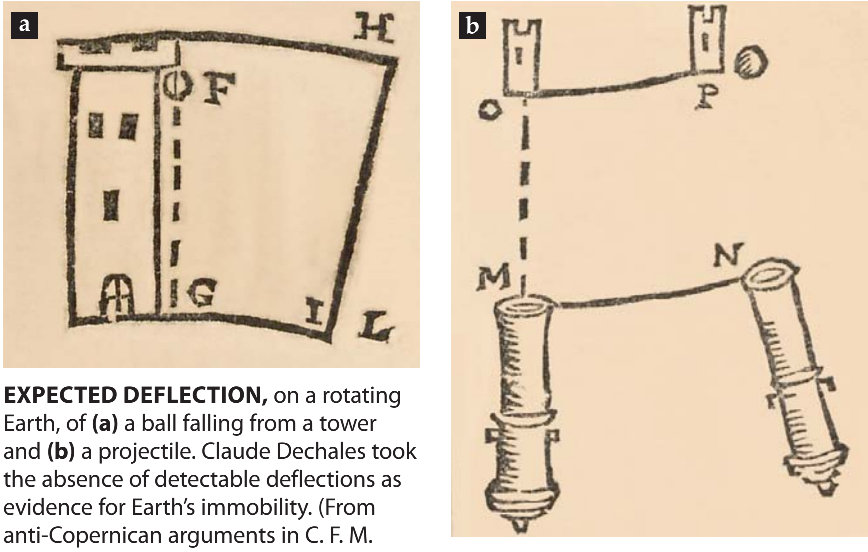
Earth's rotation deflects projectiles and bodies in free fall. That phenomenon is called the Coriolis effect, after Gaspard-Gustave Coriolis (1792–1843), who described it mathematically in 1835. In a previous letter to PHYSICS TODAY (August 2011, page 8), I noted how Jesuit astronomer Giovanni Battista Riccioli foresaw the effect, described it in his 1651 *Almagestum Novum*, and took the fact that it had not been detected as an indication of Earth's immobility. Riccioli's seems to be the earliest description of the effect, although Galileo hinted at it in his *Dialogue Concerning the Two Chief World Systems* of 1632 (see also PHYSICS TODAY, April 2015, page 10).

Riccioli's work might be presumed to be a historical anomaly—an insight published and forgotten. However, I recently discovered another discussion of the Coriolis effect in a Jesuit work, again as an argument against Earth's motion. It is in the 1674 *Cursus seu Mundus Mathematicus* of Claude François Milliet Dechales (1621–78). Dechales cited Riccioli repeatedly. In a section entitled "Objectiones contra Copernicum," Dechales noted that the "common" objections to the Copernican motion of Earth all fail—for example, the objection that a rotating Earth will leave behind birds in flight. Dechales illustrated why by using the example of a ball released from the yardarm of a steadily moving ship: On account of common motion, the ball falls to the same spot as it does if the ship is at rest.

But then Dechales included panel a of the figure (below), a diagram of a tower on a rotating Earth, and asks his reader to consider the following (my translation):

> A ball F, hanging from the top of a tower directly above point G, is dropped. While the ball descends, point G is carried [by Earth's rotation] into I. The ball F is shown to be unable to arrive at point G (now at I). This is because the ball when positioned at F has a momentum [*impetus*] requisite for passing through arc FH (through which the tower top moves while the ball descends) which is greater than that requisite for arc GI. Therefore, if the ball is dropped, it will not arrive at point I, but will advance forward farther [to L].

Similarly, Dechales says to consider a cannon discharged toward one of Earth's poles, as in panel b. The cannon is at M, its target is O. While the ball is in flight, the cannon is carried by Earth's rotation from M to N, and the target from O to P. Because of that same rotation, the ball has momentum corresponding to the cannon's motion from M to N—a motion greater than the target's motion from O to P. The flying ball, he says, "conserves



EXPECTED DEFLECTION, on a rotating Earth, of **(a)** a ball falling from a tower and **(b)** a projectile. Claude Dechales took the absence of detectable deflections as evidence for Earth's immobility. (From anti-Copernican arguments in C. F. M. Dechales, *Cursus seu Mundus Mathematicus*, vol. 4, 1690, p. 328.)

this momentum whole," and therefore should outrun, and not hit, the target. He illustrates the ball passing to the right of the target. A rotating Earth should produce detectable effects.

Thus Riccioli was not an anomaly. What we now call the Coriolis effect was being described and illustrated by different authors a century before Coriolis was born. The twist to the story is that the effect was first described by Riccioli, and then by Dechales, as part of an anti-Copernican argument. Nonetheless, if we grant honor to firsts in science, it seems the "Coriolis" effect might be due for a renaming.

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Hall sign reversal in certain metamaterials

The proliferation of electronic sensing and computer control has increased the importance of Hall-effect devices. Among their many applications are magnetometers, contactless position sensors, and magnetic-field-activated switches for ignition timing.

Hall-effect measurements in the simply connected (no voids), flat-plate Hall-bar geometry are widely used in the laboratory to characterize the carrier type—electrons or holes—in metals and semiconductors. In a typical measurement, a device-normal magnetic field, the applied current, and the Hall electric field lie in mutually orthogonal directions. Because negatively charged electrons and positively charged holes are deflected to the same side of the device by the magnetic field for a given orientation of the magnetic field and the current, sign-inverted Hall effects for electrons and holes are usually taken as direct evidence for sign-inverted Hall coefficients for the two types of carriers, and the sign uniquely determines carrier type in the material.

The cover story of the February 2017 issue of PHYSICS TODAY (page 21) highlights a paper that claims to report a novel sign reversal of the Hall coefficient in chain-mail-like three-dimensional metamaterials.[1] The experimental validation of a "mind-boggling prediction"[1] was cited as another example of "metamaterials with electromagnetic, acoustic, or mechanical properties that are qualitatively different from those of their constituents."

The reported sign inversion of the Hall effect in the metamaterial specimen should be attributed to a change in effective geometry rather than to a change in sign of the Hall coefficient. That's because the metamaterial specimen was not simply connected; its tori included voids. I and my colleague, in 1994, reported sign inversion of the Hall effect in specimens with voids or physical holes.[2] We were studying "anti-Hall bars," in which the current and voltage contacts are on the interior boundary of a void in a semiconducting plate. Such a configuration exhibits a sign-reversed Hall effect with respect to the standard Hall-bar geometry.

Because a change in geometry can change the sign of the Hall coefficient, geometry needs to be explicitly taken into account when determining the sign