

LETTERS TO THE EDITOR

Letters are selected for their expected interest for our readers. Some letters are sent to reviewers for advice; some are accepted or declined by the editor without review. Letters must be brief and may be edited, subject to the author's approval of significant changes. Although some comments on published articles and notes may be appropriate as letters, most such comments are reviewed according to a special procedure and appear, if accepted, in the Notes and Discussions section. (See the "Statement of Editorial Policy" in the January issue.) Running controversies among letter writers will not be published.

CORIOLIS MYTHS AND DRAINING BATHTUBS

Here is an answer to your sample question #137, from "Paul R. Sherwood," contained in your June editorial introducing the new "Questions and Answers" section [Am. J. Phys. **62** (6), 488 (1994)].

Controlled experiments to demonstrate the Coriolis effect on the bathtub vortex have been performed in the northern hemisphere by Shapiro¹ (Cambridge, MA: 42.4° N latitude) and Binnie² (Cambridge, England: 52.2° N latitude). Experiments in the southern hemisphere have been conducted by Trefethen, *et al.*³ (Sydney, Australia: 33.9° S latitude) and by Cope⁴ (South Pole: 90° S latitude). In all of these experiments, the initial direction of rotation of the bathtub vortex was consistent with the expectations based on the Coriolis effect. The occasional vortex reversal as the liquid level approaches the bottom of the tub has been observed by Shapiro,¹ Binnie,² Trefethen, *et al.*,³ Sibulkin,⁵ and Kelly, *et al.*⁶ Explanations of this phenomenon have been discussed in articles on the theory of the bathtub vortex by Marris,⁷ Sibulkin,⁸ and von Flotow.⁹ In addition, a film of Shapiro's experiments is also available.^{10,11} I am not aware of any similar experiments performed at the equator where the Coriolis force is zero.

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¹Ascher H. Shapiro, "Bath-tub vortex," Nature **196**(4859), 1080–1081 (1962).

²A. M. Binnie, "Some experiments on the bathtub vortex," J. Mech. Eng. Sci. **6**(3), 256–257 (1964).

³Lloyd M. Trefethen, R. W. Bilger, P. T. Fink, R. E. Luxton, and R. I. Tanner, "The bath-tub vortex in the southern hemisphere," Nature **207**(5001), 1084–1085 (1965).

⁴Winston Cope, "The bathtub vortex," Am. Sci. **71**(6), 566 (1983).

⁵Merwin Sibulkin, "A note on the bathtub vortex," J. Fluid Mech. **14**(1), 21–24 (1962).

⁶D. L. Kelly, B. W. Martin, and E. S. Taylor, "A further note on the bathtub vortex," J. Fluid Mech. **19**(4), 539–542 (1964).

⁷A. W. Marris, "Theory of the bathtub vortex,"

J. Appl. Mech. **34**(1), 11–15 (1967).

⁸Merwin Sibulkin, "A note on the bathtub vortex and the earth's rotation," Am. Sci. **71**(4), 352–353 (1983).

⁹Andy von Flotow, "The bathtub vortex," Am. Sci. **71**(6), 566 (1983).

¹⁰Ascher H. Shapiro, Film "Vorticity" (Educational Services, Inc., Watertown, MA, 1961).

¹¹Ascher H. Shapiro, Four-minute Film Loop No. FM-15, "The bath-tub vortex" (Educational Services, Inc., Watertown, MA, 1963).

MORE ON CORIOLIS MYTHS AND DRAINING BATHTUBS

Water draining from a bathtub in the northern-hemisphere was consistently observed to rotate *counterclockwise* (as observed from above) by Shapiro¹ at MIT, as expected if the rotation is determined by the Coriolis force. Contrary to Sherwood's belief that "the experiments were only done in the northern hemisphere and so were less than convincing," water draining from a bathtub in the southern-hemisphere was consistently observed to rotate *clockwise* by Trefethen *et al.*² at the University of Sydney, again in harmony with the Coriolis-force interpretation. The heroic efforts required for these bathtub-vortex observations are summarized by Walker³ but are well worth reading in the original. For the less heroic or those averse to the splinters of wooden bathtubs,² a plastic-pail bathtub may be placed on a merry-go-round with an angular velocity ω about 10^4 greater than that of the Earth. Rotations simulating northern and southern hemispheres then result in water vortices around the drain which are, respectively, counterclockwise and clockwise. This experiment can easily be performed by introductory-course students.⁴

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13 June 1994

¹A. H. Shapiro, "Bath-tub vortex," Nature **196**, 1080–1081 (1962); Film "Vorticity" (Educational Services, Inc., Watertown, MA, 1961); Film Loop No. FM-15, "The bath-tub vortex" (Educational Services, Inc., Watertown, MA, 1963).

²L. M. Trefethen, R. W. Bilger, P. T. Fink, R. E. Luxton, and R. I. Tanner, Nature **207**, 1084–1085 (1965).

³J. Walker, *The Flying Circus of Physics (with answers)* (Wiley, New York, 1975), p. 95. Walker gives other references germane to the experiments.

⁴R. R. Hake, "A Socratic Dialogue Inducing Lab on Angular Momentum," AAPT Announcer **20**(4), 53 (1990).

STILL MORE ON CORIOLIS MYTHS AND DRAINING BATHTUBS—FILMS AND VIDEO TAPES

I have a book entitled *Illustrated Experiments in Fluid Mechanics* which was published by the National Committee for Fluid Mechanics and copyrighted in 1972 by the Educational Development Center, Inc. The portion on vorticity was written by Ascher H. Shapiro of MIT. The book contains text and photographic material related to a series of films which "cover nearly all of the fundamental phenomena of fluid motions." One of the films, "The Sink Vorticity," shows the experiment and Professor Shapiro explains the theory in the book. Mr. Sherwood is correct in that the circulation developed in the tank was in the expected direction and, in order of magnitude, of the expected numerical value. The experiment was done in Boston. No mention was made of the experiment being done in the southern hemisphere. The film, on VHS video tape, is available from Encyclopedia Britannica Educational Corporation, 310 S. Michigan Ave., Chicago, IL 60604.

I remember that David Fultz at the University of Chicago also did something along these lines. He published a series of articles in the *Journal of Meteorology* and *Tellus* in 1949 and 1950. Then, in 1960, he co-authored with R. J. Donnelly articles in the *Proceedings of the Royal Society, A*. I did not read these articles but the titles and abstracts indicate that this question might be addressed.

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