The Inveterate Tinkerer

3. Experiments with Vortex Rings

In this series of articles, the authors discuss various phenomena in fluid dynamics, which may be investigated via tabletop experiments using low-cost or home-made instruments. The third article in this series is about vortex rings and some interesting experiments based on them.

Vortex rings are produced by the impulsive ejection of a slug of fluid from an orifice into a quiescent fluid. The reader may refer [1, 2] for an elementary discussion on vortex rings.

Materials and Methods

We used a plastic pipette to form vortex rings in water inside a glass container. The glass container had a square cross section of length 15 cm and height 30 cm (a water height of 20 cm). Alternatively, one may use a measuring cylinder made of glass. However, note that the curved edges result in a distorted image. The pipette was filled with the desired liquid (from the list below), and a drop was squeezed out from a height of ~1 inch above the water surface. It is essential that the water be very still without any convection currents, to avoid deformation of the vortex ring. The vortex ring descends and breaks up into a beautiful cascading ‘temple’ of smaller vortex rings, which undergo further

Keywords

Vortex rings, smoke ring, bubble ring.
Figure 1. A vortex ring descending in water.

Figure 2. Breakup of a vortex ring into a cascade of smaller vortex rings in water.

breakdown into yet smaller vortex rings (Figures 1 and 2).

We tested the following liquids in water and observed the formation of distinct vortex rings: Luxor Hi-Tecpoint black ink, Shiny black stamp ink, Camlin fountain pen ink – blue, red, and black, Parker Quink blue ink, potassium permanganate solution, vinegar with red food dye, fluorescein dye in water, Taral Alta dye (Rose Bengal), cyan printer ink from ASR Resin and Chemicals Co., water with red food dye, aqueous sugar solution with red food
When the vortex ring approaches the bottom of the beaker, its diameter abruptly increases and its speed of descent decreases.

We recommend the use of Parker Quink blue ink to obtain the most vivid results against a white backdrop placed behind the glass container. However, using Parker ink, the water in the glass container required frequent replacement, while the experiment could be repeated several times without staining the water using vinegar and red food dye. One may also generate vortex rings by releasing dyed vinegar below the surface of the water using a submerged pipette. The production and instability of vortex rings in water may be seen in the video:

https://www.youtube.com/watch?v=zdKX9q09BpQ

Suggestions

We now suggest a few experiments which the reader may wish to attempt.

*Experiment 1: Interaction of a Vortex Ring With a Wall*

The experiment discussed above may be repeated in a shallow glass beaker. When the vortex ring approaches the bottom of the beaker, its diameter abruptly increases and its speed of descent decreases. Watch:

https://www.youtube.com/watch?v=1QTfAlep2HU

*Experiment 2: Half-Ring Vortex*

A half-ring vortex can be produced by dipping the edge of a dinner plate or tablespoon into a large tub filled with water. A flapping motion of the wrist produces a submerged half-ring vortex with its ends on the surface of the water. A video of submerged half-ring vortices illuminated using a halogen lamp (500 W) may be seen at:

https://www.youtube.com/watch?v=Gv2ulsa_zHY

*Experiment 3: Smoke Rings*

In this experiment, we used a cardboard box with an orifice on one face made using a hole saw. A burning incense stick was placed inside the box, which was sealed with tape. After waiting
for a few minutes to allow the smoke to fill the box, we opened and rapidly closed the top flap of the box. This sends a puff of air into the box, which causes the formation of a smoke ring (Figures 3 and 4). The smoke ring propagates for a considerable distance before diffusing into the air. For better viewing, one may place a black backdrop behind the cardboard box. For photographing the ring, we had set the camera exposure to a minimum, and used a 500 W halogen lamp for illumination. The smoke particles show quite clearly, the circulating motion of air within the ring.

If the flap of the box is opened and closed twice in quick succession, one may observe ‘leap-frogging’ of vortex rings. The trailing vortex ring speeds up and shrinks in diameter, passing through the leading vortex ring. However, it is difficult to observe more
than one leapfrog event with smoke rings. If the smoke ring is directed towards a wall, we observe the same effect as discussed in Experiment 1 above. On placing a fine mesh in front of the orifice on the box, we did not observe any change in the structure of the vortex rings. Watch the generation of smoke rings at: https://www.youtube.com/watch?v=OJ9vR4950FE

Suggested Reading


See the video: youtube.com/watch?v=S93R6tmulZI

Also see the video: youtube.com/watch?v=qX7GkbAohbBg

[6] Try producing a half-ring vortex (Experiment 2) in a quiescent swimming pool. See the video: youtube.com/watch?v=pnbJEG9r1o8

[7] Dolphins have been observed producing ‘bubble rings’ (vortex rings with air bubbles occupying their core) and playing with them. Can you think of a method to produce bubble rings in the laboratory?

See the videos: youtube.com/watch?v=bT-fctr32pE and youtube.com/watch?v=GbmTFa-h8Ts


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