

Manu with a Ball: Water Entry of Two Tandem Spheres

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A popular diving maneuver known as the “manu bomb” has long been a hallmark of recreational water activities in New Zealand. This cannonball-like dive generates a large splash and produces a pronounced air cavity beneath the water surface. As the cavity collapses, it generates a loud noise and focuses the surrounding fluid into a vertex where a vertical jet, known as the Worthington jet, is formed. If a diver performs the maneuver while holding a ball (e.g., a football), the ball is propelled upward by the Worthington jet, which we refer to as the “manu ball”. As interesting as this dive with a ball is to witness, there are no existing studies on this phenomenon yet.

In this work, we study the mechanism of the manu ball and provide a theoretical framework for maximizing the height, and thus the “fun”, of launching the ball. We model the manu ball as the tandem water entry of two spheres: the bottom sphere representing the diver, and the top sphere representing the ball. Our theoretical model quantifies the rebound of the top sphere as a momentum transfer ratio, comparing the initial and final momentum of the top ball over the initial and final momentum of the bottom ball. This ratio is a function of the Froude number, a dimensionless number that can physically be interpreted as the spacing between the top and bottom ball at water entry. This momentum transfer ratio is also parameterized by key factors such as the mass ratio between the top and bottom balls and jet strength.

Our model was then validated by experiments, where the two spheres were positioned at a set initial separation and released with prescribed time delays. The process of water entry and rebound of the balls was recorded at 2000 frames per second using a high-speed camera. The bottom ball was varied across four sizes and a range of weights to achieve different types of water entry-induced cavities, including both quasi-static and deep seal.

Our experimentally validated framework provides a quantitative basis for understanding and optimizing the manu ball. By modeling the system as a two-sphere water-entry problem and identifying the governing nondimensional parameters, we capture the essential physics of jet formation and jet–ball coupling. The resulting scaling laws enable the prediction and enhancement of the top ball’s rebound, and establish a foundation for future investigations of recreational water-entry phenomena and related jet-driven propulsion mechanisms.