The Effect of Spin on Wetting Angle During Water-Entry

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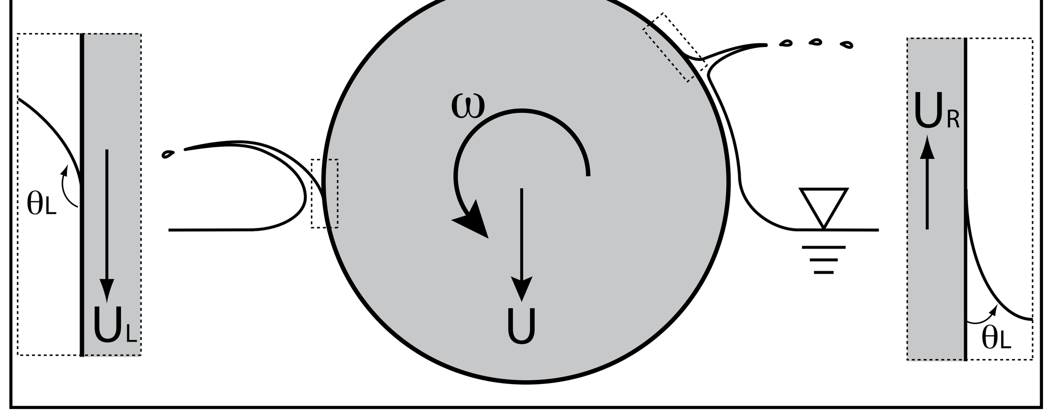
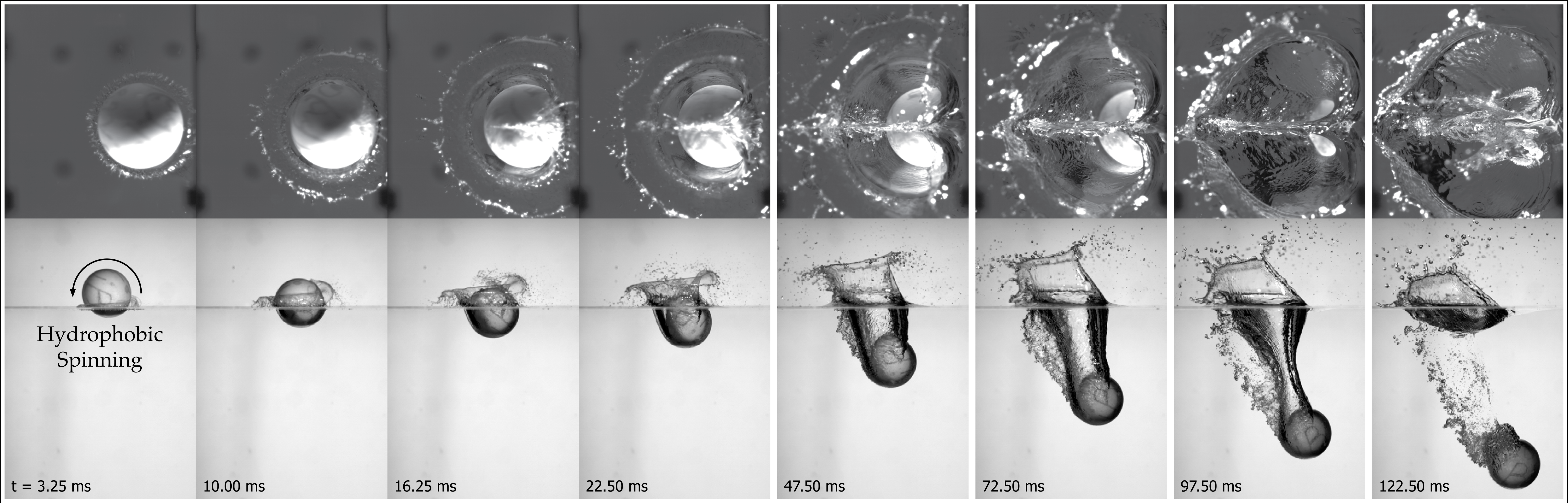
Case I: The water-entry of a hydrophobic billiard ball impacting at V_i = 1.72 m/s. The sphere is completely encased in a thin layer of air, and the splash crown is uniquely vertical.

Spin alters the effective wetting angle of an object impacting on a liquid surface. As a sphere rotates, the relative surface velocity changes around the sphere, and thus creates a dynamic wetting angle that affects whether or not a cavity is formed when the sphere enters the water. In the case of the spinning sphere, the relative velocity on one side is significantly higher than on the other, often causing cavity formation only around half of the sphere. In this poster we present four distinct cases where cavity formation is clearly dependant on the dynamic wetting angle. Cases I and IV are non-spinning, and Cases II and III are spinning with initial spin rates of S = ωr/U = 3.6 and 3.2. In Cases I and II the sphere has a hydrophobic coating with an initial static wetting angle of θ = 120º, and in Case III the sphere is cleaned such that it is hydrophyllic with static wetting angle of 68º. Case IV has two different wetting angles split down the sphere's vertical axis, half-hydrophobic (θ = 120º) and half-hydrophilic (θ = 68º). The spheres used in this study are billiard balls with a diameter of 5.72 cm.

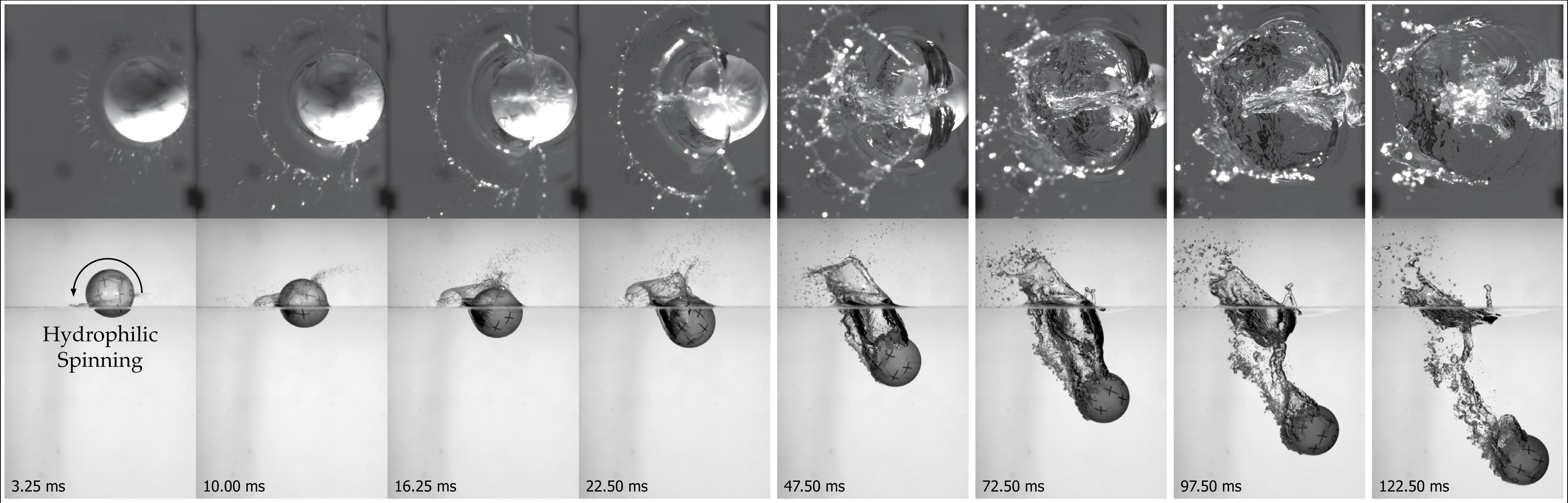
The illustration below shows a cutaway view of how the water is affected by the surface of the sphere. On the left, the increased relative velocity creates an advancing contact line, increasing the dynamic wetting angle, thus, allowing air entrainment and cavity formation. On the right, the relative velocity is actually in the upward direction creating a receding contact line, thus, keeping the fluid in contact with the sphere's surface.



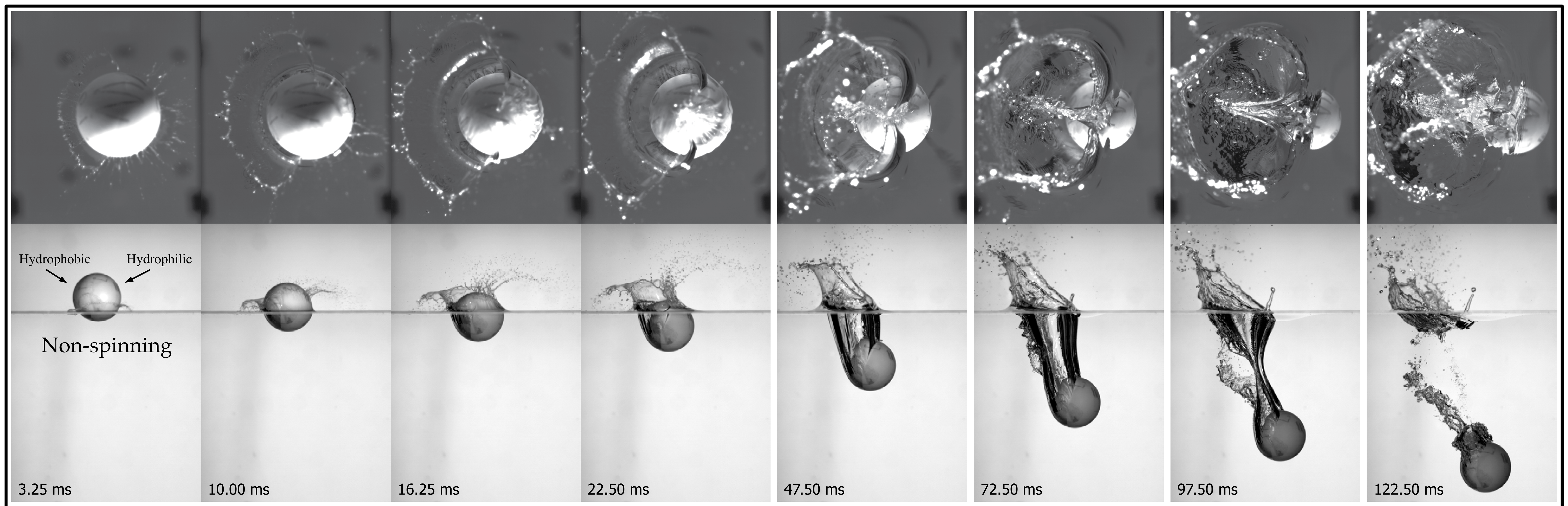
We would like to acknowledge Ashley Cantieny, Mike Smith-Bronstein and Gustav Truscott for their efforts in helping perform these experiments.



Case II (hydrophobic: θ = 120º, V_i = 1.72 m/s, ω = 218 rad/s.): Top and side views of a spinning billiard ball with hydrophobic coating. Viewed from above, the sphere creates a cardiod shaped splash curtain and subsurface air cavity as it descends in the fluid. The dynamic wetting angle is high on the left side of the sphere due to an advancing contact line and a large outward splash forms. On the right, the relative velocity is upward, thus creating a receeding contact line which inhibits splash growth, and helps to draw a wedge of fluid across the cavity, bisecting it into two separate cavities. Note that the first four images are spaced by t = 6.25 ms while the next four are spaced by 25 ms for Cases II - IV.



Case III (hydrophilic: θ = 68º, V_i = 1.72 m/s, ω = 192 rad/s): Top and side views of a spinning billiard ball cleaned with an acetone/isopropyl alcohol/ethanol cleaning process to ensure a hydrophilic surface. This case has the same impact speed as Case II, however the top view reveals a less pronounced cardiod cavity shape. Due to the lower wetting angle of the hydrophilic sphere, the splash radiates outward only from the left half of the sphere. In contrast, the splash forms around almost two-thirds of the sphere in Case I. As in Cases II and IV, the cavity is split into two halves by the wedge formation before pinch-off.



Case IV (half and half: θ_{left} = 120, θ_{right} = 68, V_i = 120m/s, ω = 0 rad/s): Top and side views of a non-spinning billiard ball half coated with a hydrophobic coating and cleaned to be half hydrophilic as in Case III. The relative velocities on the left and right are equal and both sides experience an advancing contact line, however the contrasting surface treatments on each half of the sphere result in significant differences in splash and cavity formation on either side. The fluid driven up the right side wraps around the sphere and is funneled left and inward, toward the sphere's equator forming a fluid wedge, instead of being forced to radiate outward and form a splash curtain as occurs on the left side. Amazingly, a cardioid shaped cavity, similar to the spinning cases, also forms for this non-spinning case and the sphere moves to the right as it descends despite having no initial horizontal velocity or spin.