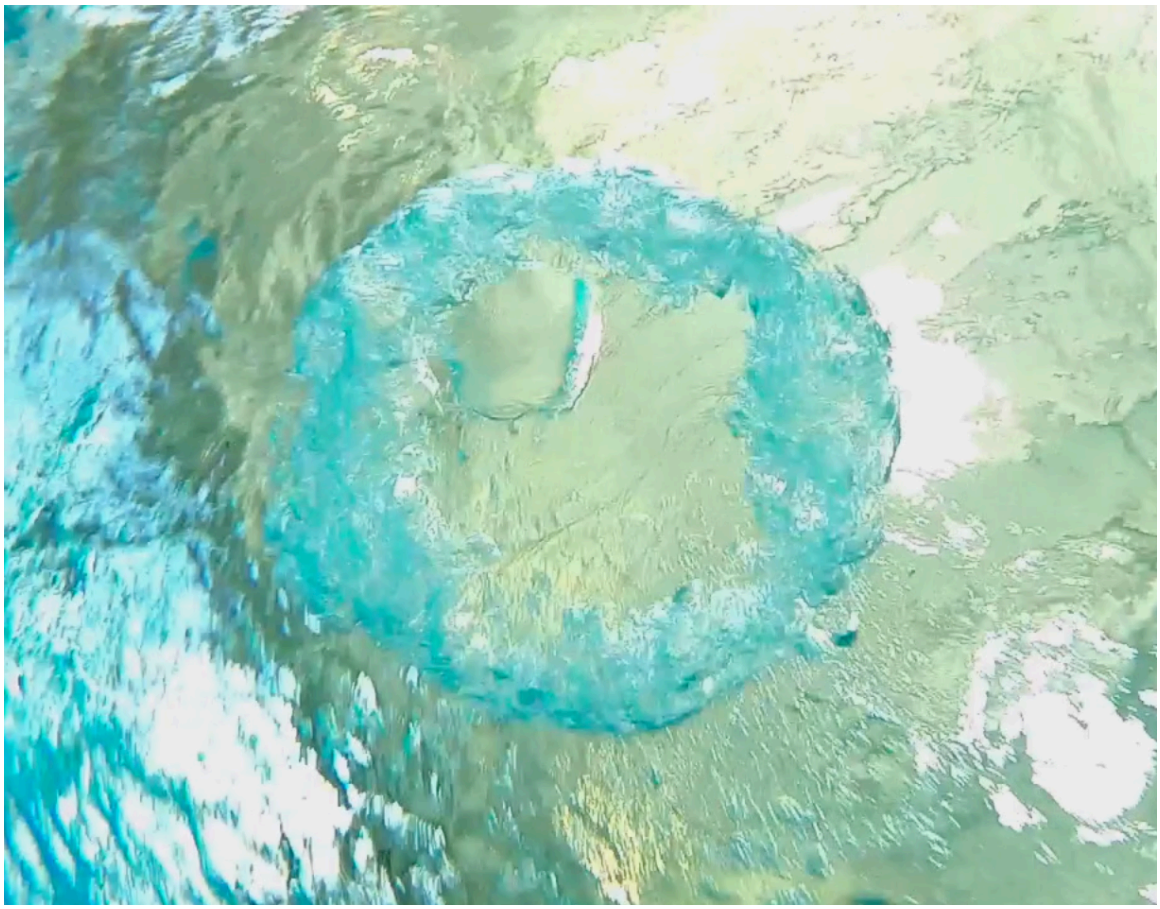
# Group Image 1



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MCEN 4151: Flow Visualization
11/4/15

**Introduction:**

The goal of this project was to capture toroidal bubbles. This underwater bubble ring effect was captured in the University of Colorado Boulder Recreation Center diving well using two GoPro cameras. The following report outlines the experimental setup, physics behind the flow phenomenon, and the photographic techniques used to achieve the video.

**Experimental Setup:**

To capture the fluid phenomenon in this experiment the bubbles were produced at a depth of 12ft to allow time for the bubble to develop as they traveled upwards. Team member Andriy Wybaczynsky created all the bubbles seen in the video. Creating these bubbles is a special skill and is not as easy as it looks. As seen in Figure 1 two GoPros were used to capture the video. One camera was positioned looking down at Andriy and a second looking directly up. Due to the GoPro cameras extreme wide-angle lens the second camera was placed about 6 inches away from the subject in order to fill the frame.

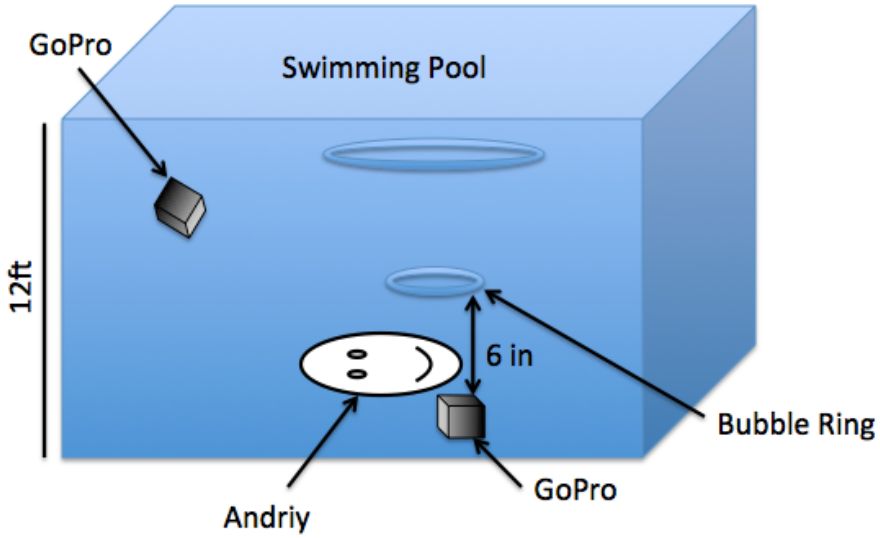


Figure 1: Experimental Setup

**Flow Phenomenon:**

The underlying physics behind toroidal bubbles are similar to that of other types of vortex rings. In this case the medium is air in water and the bubbles are driven upwards by buoyant forces. In this case the bubble ring is formed when a large spherical bubble, diameter greater than two centimeters, rises through the water. The ring is formed due to the pressure difference between the top and bottom of the bubble. The higher pressure on the bottom of the bubble pushes up creating a fluid

jet that is pushed through the bubble [1]. The ring formation can be seen bellow in Figure 2.

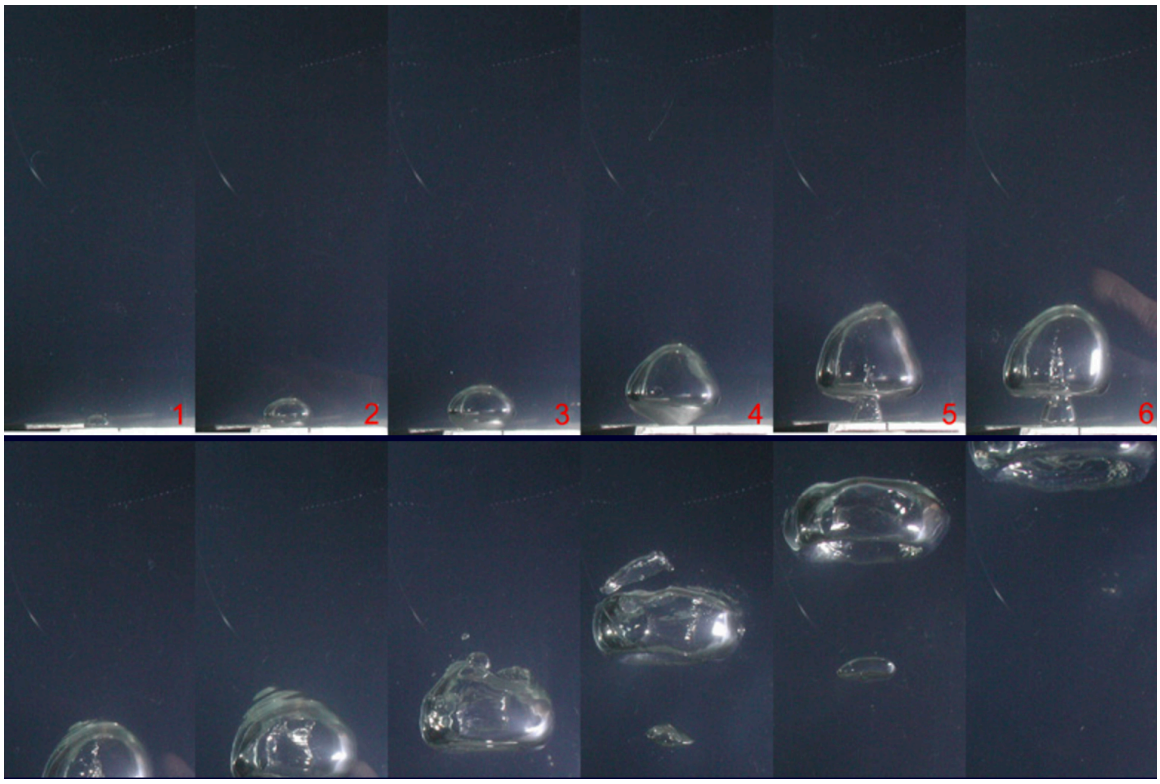

Figure 2: Evolution form spherical air bubble to toroidal bubble ring [2]

Because of the motion of the fluid jet and the interaction between the air-water boundary layer the bubble begins to rotate around the axis of torus [3]. This creates the classic vortex shape shown in Figure 3.

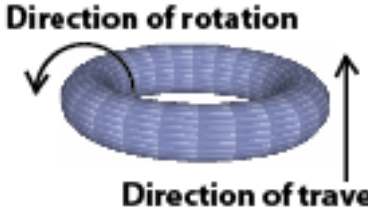

Figure 3: Motion of a bubble ring [1]

By taking a closer look at the video footage of the bubble ring an estimated velocity can calculated. The bubble ring took about 4 seconds to reach the top of the water. Given that the diver was at a depth of 12 feet the bubble was created at a depth of about 10 feet.

$$Velocity = \frac{Distance}{Time} = \frac{10\ feet}{4\ seconds} = \ 2.5\ ft/sec$$

**Video Technique:**

Two GoPro Hero 3+ cameras were used in the making of this short video. Both equipped with 130$^{o}$ wide-angle lenses with a fixed aperture of f2.8 and ISO of 400. The field of view for the shot is about 4feet by 4feet. The video was shot at 1080p with 60 fps and slowed down in editing to 30 fps. Video editing was done using iMovie. The only editing done was reducing the frame rate, removing unwanted footage, and adding transitions.

**Conclusion:**

The bubble rings created and captured in the video demonstrate a fascinating fluid phenomenon while also creating a cool visual effect. In the future finding a way to create more consistent bubble rings would help to capture better video. In addition diving to a depth of 12ft was difficult. Using a shallow pool would make producing the bubbles easier. Another factor that affected the team's success was the pool water was constantly moving; using still water would help create more stable bubbles.

References:

[1] (Poloidal rotation)
http://upload.wikimedia.org/wikipedia/commons/6/67/Bubble-ringspin.png

[2] (Deep Ocean Diving's)
http://www.deepocean.net/deepocean/index.php?science09.php

[3] Zhidov, I. G., E. E. Meshkov, V. V. Popov, V. G. Rogachev, and A. I. Tolshmyakov. "Formation of a Vortex Ring during Ascent of a Large Air Bubble in Water." *J Appl Mech Tech Phys Journal of Applied Mechanics and Technical Physics* 18.3 (1978): 341-43. Web.