Get Wet Assignment

Dry Ice Fog

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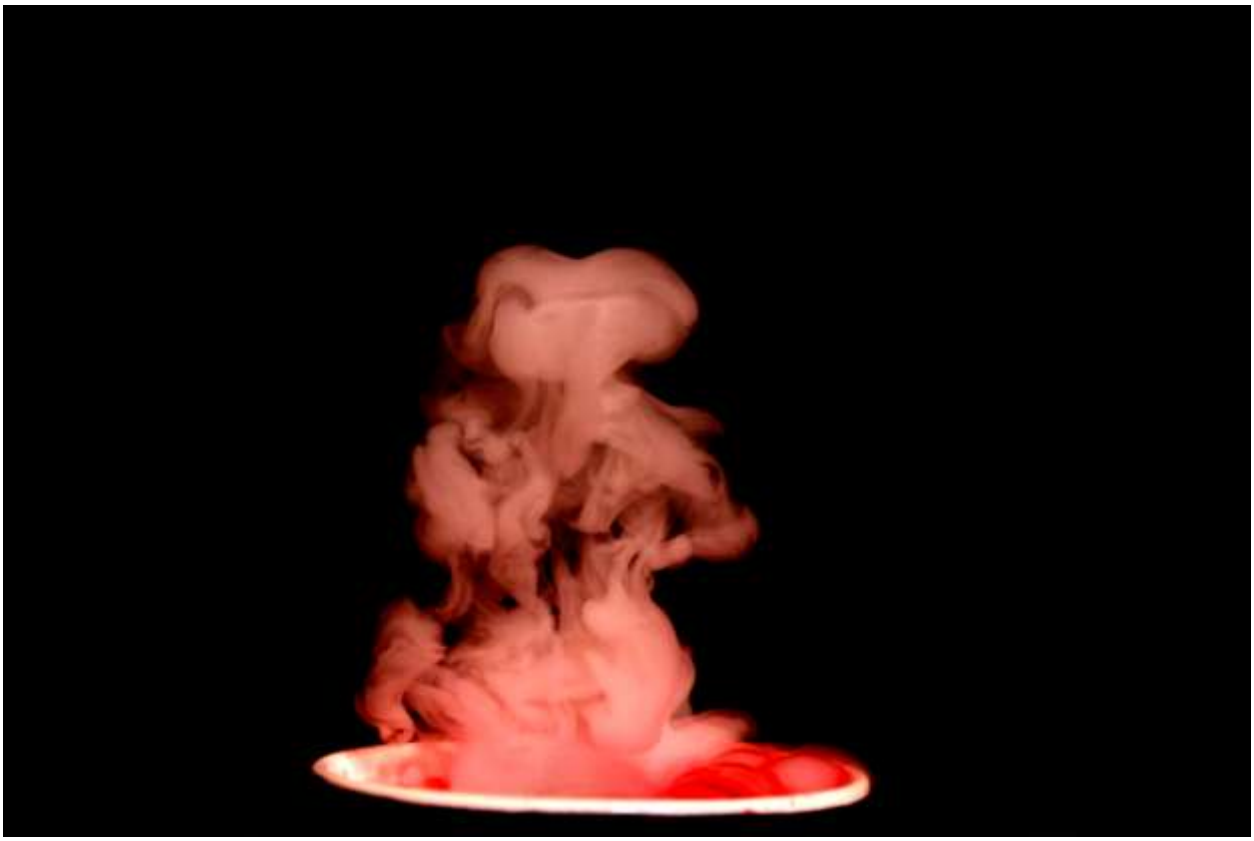

This photograph was taken as part of a fluid flow project for the spring 2011 Flow Visualization class at the University of Colorado. The intent was to explore the physics involved when a fog bubble created by frozen carbon dioxide (dry ice) interacting with water ruptures. The image shows the fog burst traveling upward immediately following the failure of the bubble. Fog forms when dry ice comes in contact with water because the cold temperatures of the dry ice quickly cool the water and cause it to condense, forming a vapor cloud immediately surrounding the dry ice. The vapor, in this case formed underwater, rises to the surface of the water and begins to form a bubble. When the pressure of the vapor on the inside of the bubble exceeds the surface tension of the water, the bubble bursts and the built up pressure forces the fog up from the surface of the water.

The setup for the project is shown in figure 1. Two dry ice chunks approximately 3cm in diameter were placed inside of a small dish that was 9.5cm in diameter and 3.8cm deep. The dish was placed on top of a small table covered by a black sheet which extended to the background. Three 500W type t halogen lights were set up 1m away from the table, 40cm above, and 30cm behind the camera.

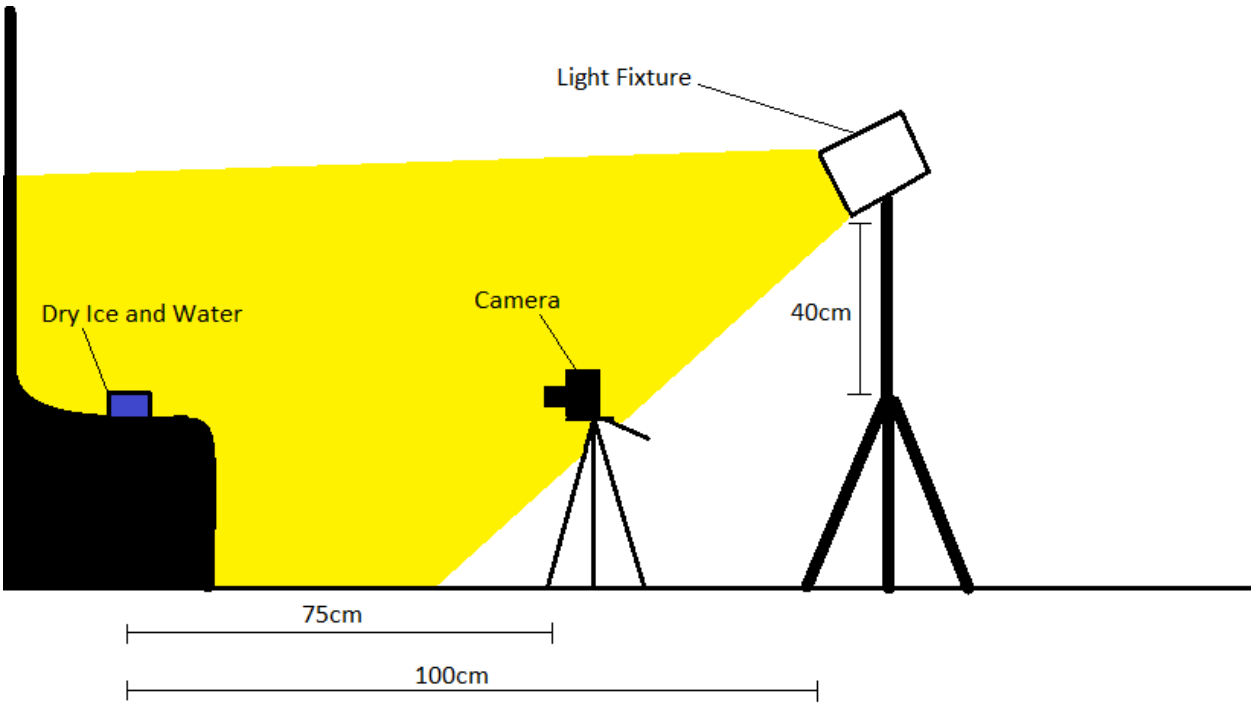

Figure 1: The configuration of the experimental equipment

The specifications of the camera and the image are in Figure 2.

Camera Type	Canon EOS Rebel Ti1 DSLR (15.1 Megapixel)
Focal Length	55mm
Aperture	f/5.6
Shutter Speed	1/500
Sensitivity	ISO 800
Field of View	approx. 22cm x 15cm (4752 x 3658 pixels)
Distance from camera to object	75cm

Figure 2: The specifications of the image

Six drops of food coloring were added before filling the dish with 120 ml of tap water that was approximately 40°C. The picture was captured between 30 seconds and a minute after pouring the water into the container, so the estimated temperature of the water at the time of the photo was between 20°C and 30°C. With an estimated velocity of 0.25m/s, the Reynolds number of the carbon dioxide flow can be calculated using equation:

$$Re = \frac{\rho VL}{\mu} = \frac{(1.977)(0.25)(0.09525)}{1.503 \times 10^{-5}} = 3132 \qquad (1)$$

Here ρ = the density of the fog taken to be the approximate density of carbon dioxide at 25°C (2), V is the estimated average velocity of the fog (estimated to be 0.25 m/s), L is the characteristic flow length of the fog, which was measured to be approximately 9.525 cm, and μ the absolute (dynamic) viscosity of carbon dioxide at 25°C (3). The calculated value of the Reynolds number of 3132 indicates that the flow is in the transition region between laminar and turbulent, which occurs between Re = 2300 and 4000 (3). This agrees with the image since both laminar properties such as the billowing top of the fog as well as turbulent properties such as the small eddy currents in the central region of the flow can be seen.

During post-production, the image was modified using Gimp ver. 2.6.11 photo editing software. The contrast and brightness levels were adjusted by changing the primary red, green and blue curves. This was done to eliminate the black sheet used for the background from the image and to enhance the contrast of the image. Additionally, it brightened the fog, highlighted the texture of the fog, and emphasized the red tones from the food coloring. The clone stamp feature was then used to eliminate any remaining traces of the background sheet from the image.

If the setup were to be repeated, setting the focus and not adjusting it during the experiment would enable the image to be focused more precisely. Also, a smaller aperture could be used so that the depth of field would be increased. Another consideration would be to find a way to make the experiment more repeatable, since it took hundreds of photos to capture the moment immediately following a bubble burst.

Figure 3: The original photograph taken before post-processing

References:

1. LMNO Engineering, Research, and Software, Ltd., Gas Viscosity Calculator. 2003. http://www.lmnoeng.com/Flow/GasViscosity.htm
2. Wikipedia, “Carbon Dioxide”. February 2, 2011. http://en.wikipedia.org/wiki/Carbon_dioxide
3. Wikipedia, “Reynolds Number”. January 26, 2011. http://en.wikipedia.org/wiki/Reynolds_number