Group Project 2
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Flow Visualization
https://vimeo.com/144427693

Purpose:

The purpose of this project was to demonstrate and capture fluid dynamics with a high-speed camera. We hung up balloons filled with water and food dye and shot the balloons with a BB gun. We captured this moment with a high-speed camera. After preforming a few experiments with one and two balloons we decided to add a third balloon with the middle balloon filled with air rather than the water and food dye combination. This arrangement of balloons showed a unique and interesting chain reaction.

Flow Setup:

Setting up the balloons in the manner we chose required an intricate setup. The basics included suspending the desired latex balloons by a string or wire and then puncturing the balloons with a high speed small ball bearing from a bb gun. We needed to capture the action with a high-speed camera. For best results with the Olympus I-Speed (the camera we used), we needed to conduct the experiment in a well-lit area. We conducted the experiment in direct sunlight with the addition of two hand held portable led lights. We placed the Olympus I-Speed approximately 5 ft from the subject. The background was a wooden fence that faced direct sunlight. The balloons were held approximately 1 foot from the fence by a hanger and left to settle until they were completely motionless. With the balloons in place, we were able to shoot them with a bb gun at a perpendicular angle from 10-15 ft away. According to the specs the BB left the Daisy Red Ryder BB gun and travelled at a rate of 350 ft/second as it entered the side of the first balloon. We began recording 20 seconds before the shot was taken and ended when all the liquid left the image frame. A schematic of this set up is shown in figure 1 below.

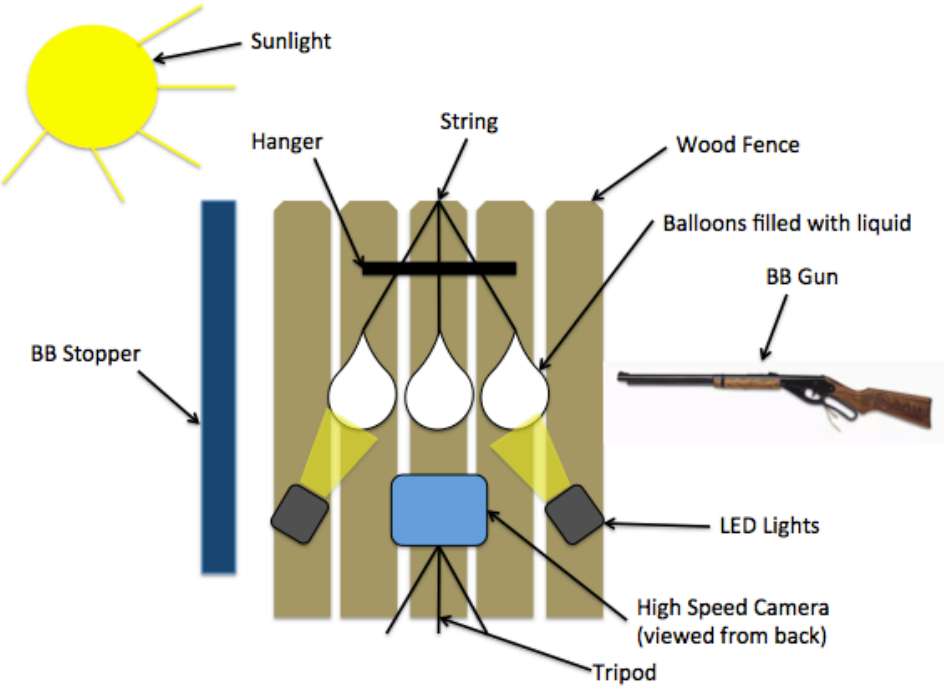

Figure 1: Experimental Set Up

Visualization technique:

Although the lighting was important, it was also important to find a way to further add color to the liquid to accentuate the action. The use of food coloring inside the balloons made it easier to capture the flow following the rupture of the pressurized balloon. With food coloring, there was minimal transparency in the liquid allowing us to capture all the reactions of the liquids following the shot from the metal BB. When the BB initially punctured the balloon, the latex fibers of the balloon that were originally in tension contracted in all directions away from the hole. At first, the water maintains the shape of the balloon after the pop, but as gravity pulls the water downwards the air resistance separates the water due to friction [1]; additionally, as the latex contracts and pulls away from the water, it creates a void, which causes the water to splash out to try and fill their air space created.

When the balloon pops initially, the retracting latex applies a force called skin friction to the liquid. Skin friction is a type of parasitic drag caused by viscous drag within the boundary layer. The boundary layer from skin friction usually starts out as laminar, but eventually turns turbulent. [2] Although it is very difficult to see enough detail in the video taken of this action, if the boundary layers were examined it would be expected to see an originally laminar flow that turns turbulent.

In the video you can see all the physics stated above with the right balloon but with the left you see something much different. The water in the balloon almost looks like it is exploding from the inside. My guess is that as the bb punctures the rubber latex of the balloon its speed is educed. Since it is going through two balloons first before the last one the speed is greatly reduced. It then looks like it does not puncture through a little piece of latex from the middle balloon and carries it through the last balloon as it pops. This then pushes the liquid in the balloon outward, which explains why it looks like the water in the balloon is exploding from the inside.

Photographic Technique:

The following camera settings were used when taking this video:

- Field of View: about 15x15 inches
- Exposure Time: 1 microsecond
- ISO: 1600-12,800
- Distance from lens to object: 3 feet
- Original image dimensions: 1280x1224 pixels
- Frame rate: 600 frames/second
- Played back at: 30 frames/second

After capturing the video we used iMovie to edit. Unfortunately we took the video at the end of the day when the sun was going down so it came out darker than we had wanted. We tried to play with the brightness in iMovie but decided to use the original video with no post-processing. You can see the video at this link: https://vimeo.com/144427693

Safety:

When working with a BB gun such as the Daisy Red Ryder it is important to take safety precautions to ensure nobody gets hit with a BB. To do this, before cocking the gun we always made sure everyone maintained a safe distance from the balloon setup. We designed a setup that allowed the balloon to be suspended without the use of a team member holding it. The balloon was held by a string that was attached to the top of a fence with a clothes hanger placed between the fence and string to separate the balloon from the wall. To eliminate any chance of ricochet from the BB a thick comforter was placed as a backdrop for the BB.

Summary:

The final image reveals the beauty of liquid when put in a violent environment. We accomplished the goal of our experiment by capturing this action with a high-speed camera. Not only did we capture the physics of one balloon filled with water, we produced a unique combination of balloons that prompted an exciting chain reaction. There are a couple things we could have improved upon to make resulting video clearer. One would be conducting this experiment in brighter sunlight. This would allow us to use a much higher frame rate, which would make the video less grainy. This would result in a clearer video that makes the physics components of the experiment more obvious.

Sources:

[1] http://science360.gov/obj/video/ef933250-6e76-4b2e-b653-99ce6394ca63/physics-popping-water-balloon

[2] https://en.wikipedia.org/wiki/Parasitic_drag#Skin_friction