“Slow Motion Balloon-Popping”

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Flow Visualization MCEN 4228
Professor Jean Hertzberg
Due March 15, 2006

Context and Purpose

Students in Flow Visualization class have grouped into teams to collaborate and create a flow original to the class. As a group of 5, we have come up with the idea of capturing the image of a liquid filled balloon being popped and releasing the liquid. We recorded the action with a high speed camera so that we could capture as many still images possible of the liquid's reaction to an almost instantaneous release into free space. By supporting a liquid filled water balloon that is under a considerable amount of pressure due to the stretching of the balloon rubber, and creating a tear in the rubber that will cause the rubber to shed from the liquid body rapidly, we simulated the effects of a liquid loosing a defined shape from a given point in time. We were hoping to capture different liquids and how each response would be in similar situations. In the end we were able to capture images and video of a honey filled balloon being popped and allowed to fall under Earth's gravity.

Apparatus and Theory

The flow apparatus used in this visualization was designed to support the water balloon. The first step was to create a situation that would minimize the mess usually found in fluid flow experiments. A plastic tub was used to eliminate the need for mopping after the experiments were completed. The next step was to create a support system that allowed the team to have access to the balloon without obscuring the image. A wire frame shelf was used as a table to support the balloon. To prop the balloon in the up-right position a roll of tape was put on top of the wire table. A visual demonstration if found in Figure 1. To pop the balloon without obscuring the image, a custom popping device was fabricated out of a wooden spoon and a needle. The intent of the image was to capture the natural form of honey in the balloon before gravity had any effect on the shape. The purpose of this experiment was to capture a fluid in minimal motion, thus we could assume since the desired result has little to no velocity, the Reynolds number and other non-dimensional constants are negligible.

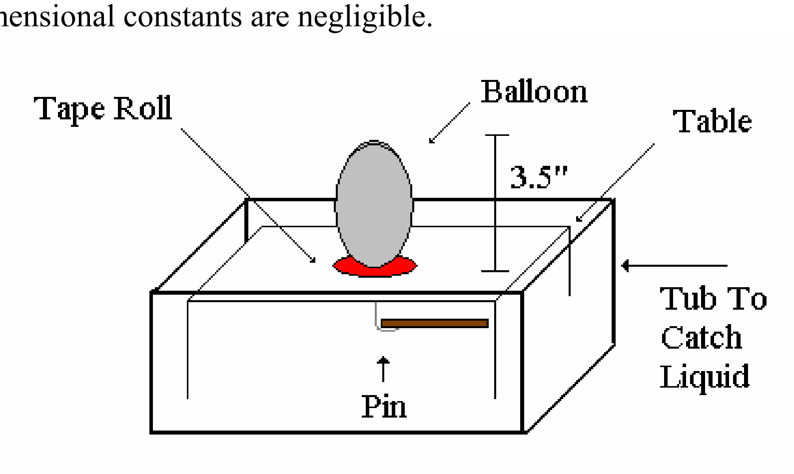

Figure 1: Balloon Platform

The video of the honey filled balloon shows how the honey was reacting to being released into a free environment. Fractions of a second before rupture the balloon created boundaries holding the honey in a specific shape. Balloons that were being used were approximately 3.5 – 4 inches in diameter, laterally, and approximately 6 inches tall. The balloon was held up by a roll of electrical tape that had a hole in the middle to allow liquid to fall through. The tape was set on a grate over a tank that was used to collect all the dropped liquid. Lighting was a high priority on this set because of the amount of wattage needed to take a bright enough image. 3000 watts of lighting was used to take this video. Notice in the video how the honey is exceptionally smooth over the surface. The viscosity of Honey is 10,000 cP @ 20°C. Compare this to water's viscosity that is .2848 cP @ 99°C. The high viscosity means that the fluid has a high resistance to change in its shape; the honey is trying to retain the same shape that it was in when in the balloon. Gravity brings the honey mass downwards and causes it to spread out over the tape base. The time for each shot was approximately 2-3 seconds, but the most interesting effects happened in a time space of less than a second.

Visualization Technique

The technique behind the photograph was quite simple for this project in that it only required basic camera operation and simple lighting. The high speed camera used required high quantities of light to image the desired object, in this case a balloon filled with honey. To supply ample light 3000 watts were supplied through the use of three construction stand lights shown in Figure 2. The balloon was elevated over a bin to catch the honey after it was popped. The elevated position also allowed for the balloon to be punctured from underneath preventing the popping mechanism from being photographed. White cardboard was placed behind the balloon to help amplify the light through reflection and allow for the colors within the balloon to be highlighted.

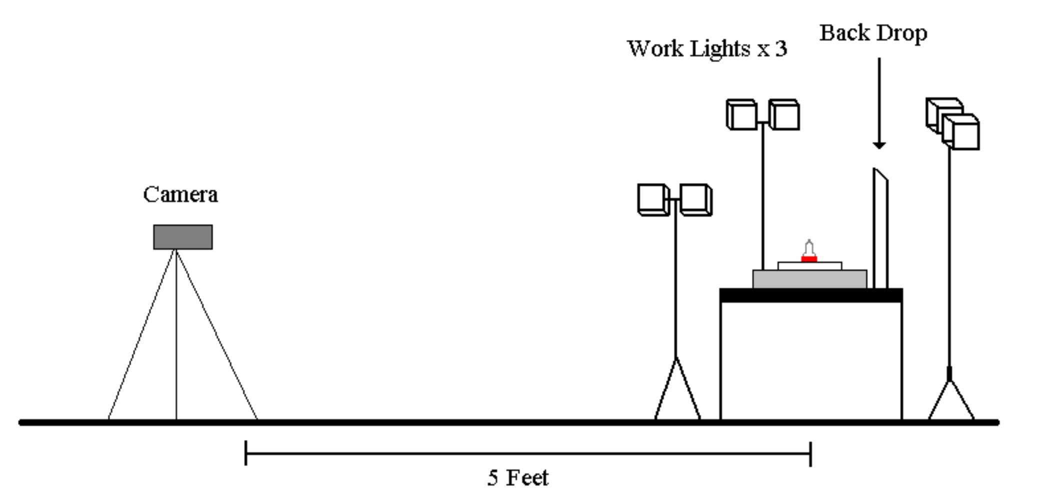

Figure 2: Camera and Lighting Setup

Photographic Technique

As stated earlier, three work lights at 1000 watts each were used to counteract the natural lighting deficiency that is normally seen in applications using the high-speed camera. The camera was located approximately five (5) feet away from the balloon. A sheet of white foam board was used to serve as a back drop to our image. The camera settings used to photograph the image are given below.

- Field of view: 4 x 6 inches
- Distance from object to lens: 5 feet
- Lens: 50 mm, Nikon
- Camera: Digital, High Speed
- Exposure: Aperture F3.4, Exposure 1/400 sec
- Resolution: 720 x 480

Image Context and Conclusion

Until more recent discoveries it was thought that water could not hold the form of a solid object once that object was removed. With the assistance of high speed camera, it is proven that for a brief second liquid water can hold its shape. Honey, with its much higher viscosity than water was hypothesized to hold the shape of a solid for a longer time period than water before submitting to the effects of gravity. The longer duration was desirable for the intent to capture the form of the solid made of just honey. However, the tackiness of the surface on the honey in contact with the balloon slowed the balloon peeling process preventing the actual shape to be held in this experiment.

The video provides a good representation of the fluidity of honey due to gravity. The slight bond between the rubber and the honey made it difficult for the form of the balloon to be held by the honey once the balloon was popped, which was the original desired result. It would have been ideal for the balloon to instantaneously unwrap from the honey much like it did with water, however all attempts failed. Surface tension forces are accurately demonstrated and help show the motion of a viscous fluid, so the experiment was not looked upon as a failure.

For the next go around, different procedures should be taken to capture the form of the honey once the balloon ruptures, but before it has a chance to react to gravity. One solution would be to coat the inside of the balloon with a thin film of oil or lubricant to help prevent the bond between the honey and the rubber. Because of the lack of lubrication in this experiment the intent of capturing the honey in the exact form as the balloon was not accomplished, but the motion of honey after rupture was. Another suggestion for further experiments using viscous fluids and high speed photography would be to commence the experiments outside where there is ample light from the sun, and reflectors can be optimized. More light would allow for the speed of the camera to be increased. This increased speed, or frame rate, would allow for the fluid of choice to be captured more times is succession and might reveal a better still image. Other viscous fluids should also be experimented with; examples would include: automobile oils, syrups, gak, etc.