Air Bubbles in Water

Get Wet

Wangyang Wang

Introduction

The purpose of this assignment is to get us starting thinking and observing the fluids flow and the scientific reason behind the phenomenon. Starting with try different camera set-up and different photograph set-up, we will able to capture the best image. Since the purpose of "Get Wet" is intended to let your start, we were able to use any kinds of fluids and flow. I decided to capture the water poured into the glass with tea leaves in it, so the bubbles and tea leaves motion could be observed. That was the ideal but in reality I didn't know how to capture this, so a stationary image was captured instead.

Physical Analysis

The phenomenon in the figure 2 can be explained by surface tension and Reynolds number. Water has surface tension, when filling water into the glass quickly enough, water has all kinds of geometries and at some point water will become droplets. Water droplets with a high speed will create a gap on the surface of the water. Some air doesn't have enough time to get out so they get caught inside the water by the surface tension which creates the bubbles. In this case, kettle was lifted about 70cm away from the glass, when pouring water to the glass, the potential energy of the water changed to the kinetic energy which gave high speed of the water. According to Newton's second Law, the force on the air bubble should be 0, assuming the air bubbles are in spherical shape [1]:

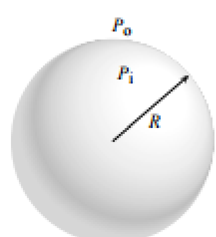

Figure 1: Spherical air bubble, the inner and outer pressures on the bubble are Pi and Po.

$$\sum F = 0 \qquad (1)$$

$$-2\gamma(2\pi R) + P_i(\pi R^2) = 0 \qquad (2)$$

The first term in equation (2) stands force due to the surface tension and the second term stands force due to pressure inside bubble. By simplify equation (2), we can get the pressure difference between the inside and outside pressure:

$$P_i - P_0 = \frac{4\gamma}{R} \qquad (3)$$

This result tells that the difference in pressure depends on the surface tension and the radius of the air bubble. Tiny air bubbles will have a big pressure difference compare with large air bubbles.

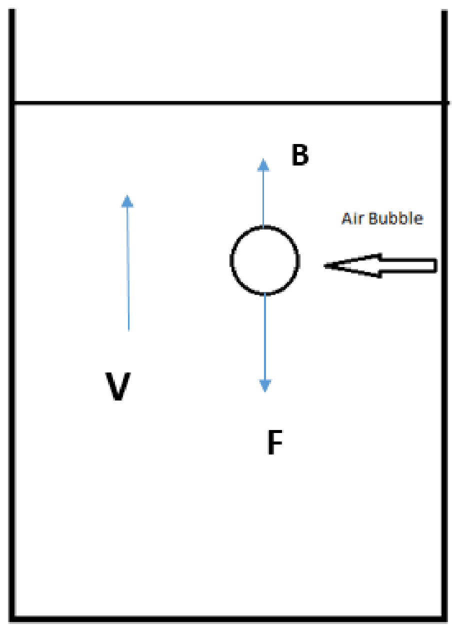

Figure 2. Forces acting on an air bubble

Fig 2 shows that forces acting on an air bubble, F is the friction and B is the buoyance. In this case the weight of the bubble is sufficiently small so we can neglect the weight. By the force balance, we have: [2]

$$B = F \qquad (4)$$

According the Stokes's Law, we can write equ (4) as:

$$\rho\left(\frac{4}{3}\right)\pi r^3 g = 6\pi\eta r v_T \qquad (5)$$

From equ (5), we got the terminal velocity of the bubble:

$$v_T = \left(\frac{2\rho g}{9\eta}\right) r^2 \qquad (6)$$

And from equation (6), we can explain why the large bubbles rise faster than small ones.

The water stream was observed as laminar flow but the water inside the glass observed as turbulent flow and it can be checked by calculating Reynolds number, figure 3.

Figure 3: Flow observation

For turbulent flow, the Re >4000.

$$Re = \frac{VD\rho}{\eta} = \frac{VD}{\nu} \qquad (4)$$

Where V – velocity of flow (m/s), D – diameter of pipe (m), ν – kinematic viscosity (m^2/s)

$$Re = \frac{VD}{\nu} = \frac{(\frac{0.4m}{s}) * 0.04m}{0.3 * \frac{10^{-6}m^2}{s}} = 53333$$

During this calculation, I approximate my velocity to be V = 0.4m/s, because I calculated the volume of my glass and count the time used to get the glass filled, so I found $\dot{Q}$, volume flow rate. With know the area of the glass, I can calculate the velocity of the water. The kinematic viscosity of water $\nu = 0.3 * 10^{-6} m^2/s$, because I was using boiled water for tea, so the temperature of water was approximately 95℃. After calculation, Re is greater than 4000 which approved that the flow inside the glass was turbulent flow. [3]

Image Set – up

Picture was taken on a table with a piece of white paper and a plastic sheet lain on top of the paper for protection from the liquid. A piece of white paper was used as background, the picture was taken in the dark environment, and so light source was needed. A floor lamp used behind the background as the light source. The idea of using the light behind the white paper was trying to avoid the light reflection on the glass, and the paper would diffuse the light which create even light.

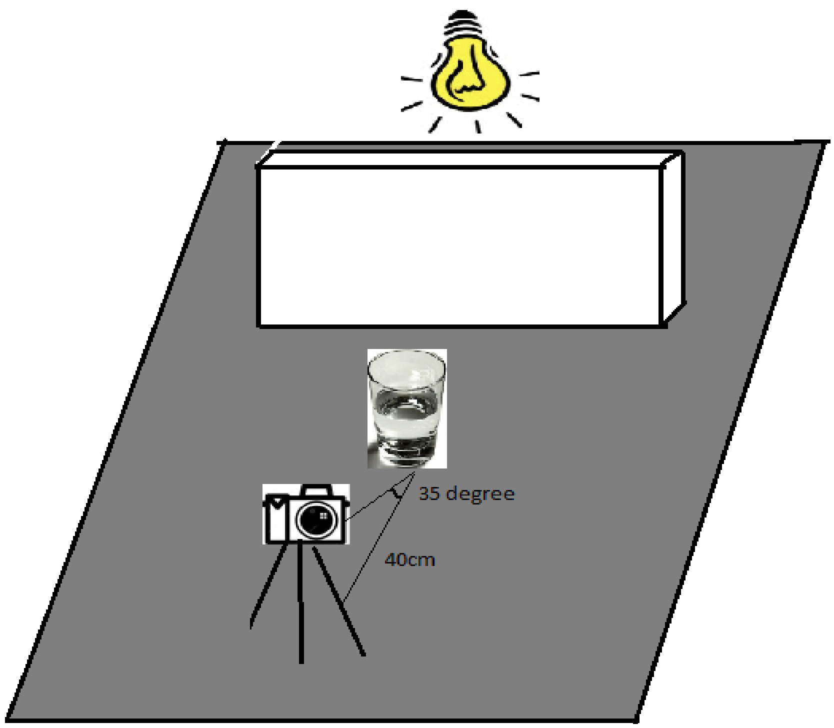

Figure 4: Setup

Camera was sitting approximately 40cm away from the glass with 35 degree angle. Figure 3. The glass was heated by hot water before started, by doing so we could avoid the steam appearing on the glass which affect the visibility. The type of camera used to capture the image was Canon EOS REBEL T2i and the camera set-up is shown in table 1. After the nice picture been captured, some image properties had been changed in the Photoshop.

Table1

Camera	Canon EOS REBLE T2i
Focal Length	55mm
Exposure	1/800sec; f/5.6; ISO 1600
Image Size	2170 x 3060

Figure 5: Original

Figure 6: Edited

Comparing the two images shown in figure 2&3, the original picture has a sharper background, its little bit over exposure and edited picture is smoother with better contrast. By playing with the contrast curves and clone stamps, a better image could be achieved.

Conclusion

Overall, the first assignment was more challenging and took much more time than I expected but I was very pleased with the image that I captured. It has all the information that I want and the detail that I would like to show could be observed, like the bubbles, the water stream and the leaves inside the glass. For the future reference, I would use better light sources to create more evenly light.

Reference:

[1]. Surface Tension
http://scipp.ucsc.edu/~haber/ph5B/bubble.pdf

[2]. Metin Yersel, *A simple Demonstration of Terminal Velocity*
http://isites.harvard.edu/fs/docs/icb.topic1032465.files/Final%20Projects/Fluids%20Drag/Terminal%20Velocity.pdf

[3]. Laminar & Turbulent flows
http://udel.edu/~inamdar/EGTE215/Laminar_turbulent.pdf