Get Wet.
MCEN 4288
Hwapyong Ko

Water Tornado

This get wet assignment is motivated to get familiar with fluid flow observation and get visual image of the flow motion. The purpose of the image “Water Tornado” is taken to observe the denser fluid or an object’s movement starting from the surface of the water tornado. Such application could be a very simple model of objects near a black hole. When the black hole’s enormous of gravity pulls gases and particles and even other planet into its black center, the shape of the suction line that creates is decaying spiral. A simple mathematical model was created by MatLab. The model is the uniform dimension and the uniform density to make the model simple and applicable to others. Figure 1 shows the characteristics of what the flow is look like over time. The basic equations used for this model are shown below equations 1~3.

$$x(t) = e^{-a \cdot t} \cos bt \tag{1}$$

$$y(t) = e^{-a \cdot t} \sin bt \tag{2}$$

$$z(t) = e^{-a \cdot t} \tag{3}$$

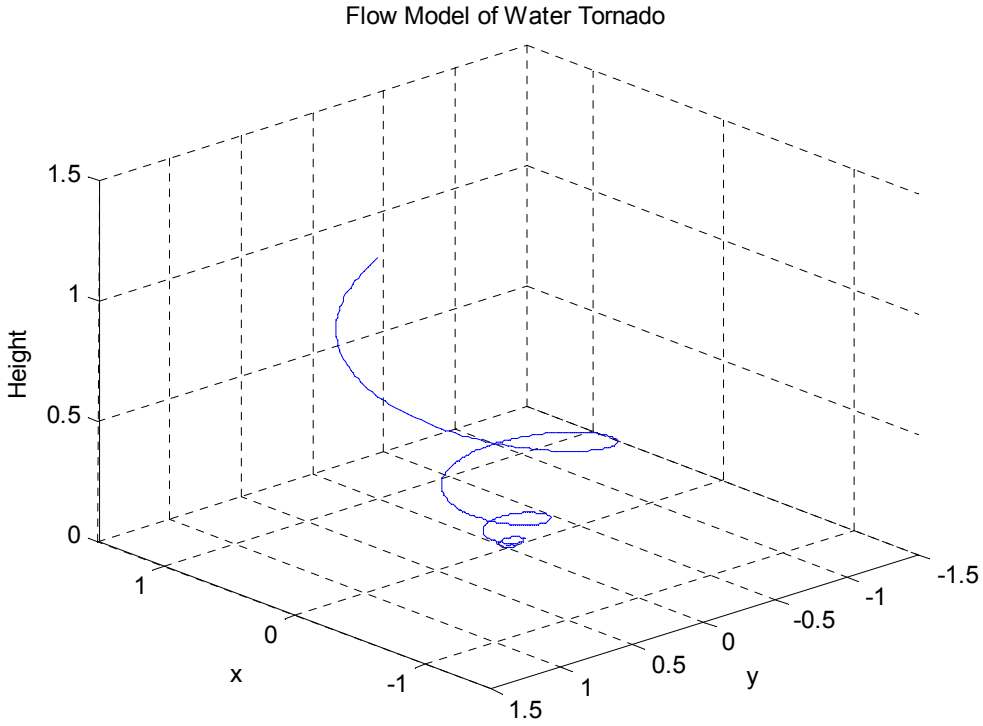


Figure 1: Flow Model

In the equation, ‘a’ term will control the centripetal force of the spiral. It is iterated according to the observation of the flow. There is no any special equation for calculating the force. Bigger number will give faster movement to the center of the spiral. ‘b’ term can be the density of the object or fluid. If the number is large, the circulation of the spiral will be short which means the fluid will decent rapidly. t is the unit time.

The apparatus for this flow visualization were a glass jar, soy sauce, water, spinning tool, kitchen light, built in flash light on camera, extra light source and 8 mega pixel Konica Minolta A2 camera. Figure 2 simply describes the set up of the apparatus. Water in the glass jar that is circulated by spinning tool. The spinning tool was used to create the water tornado. Figure 2 shows the set up of the apparatus.

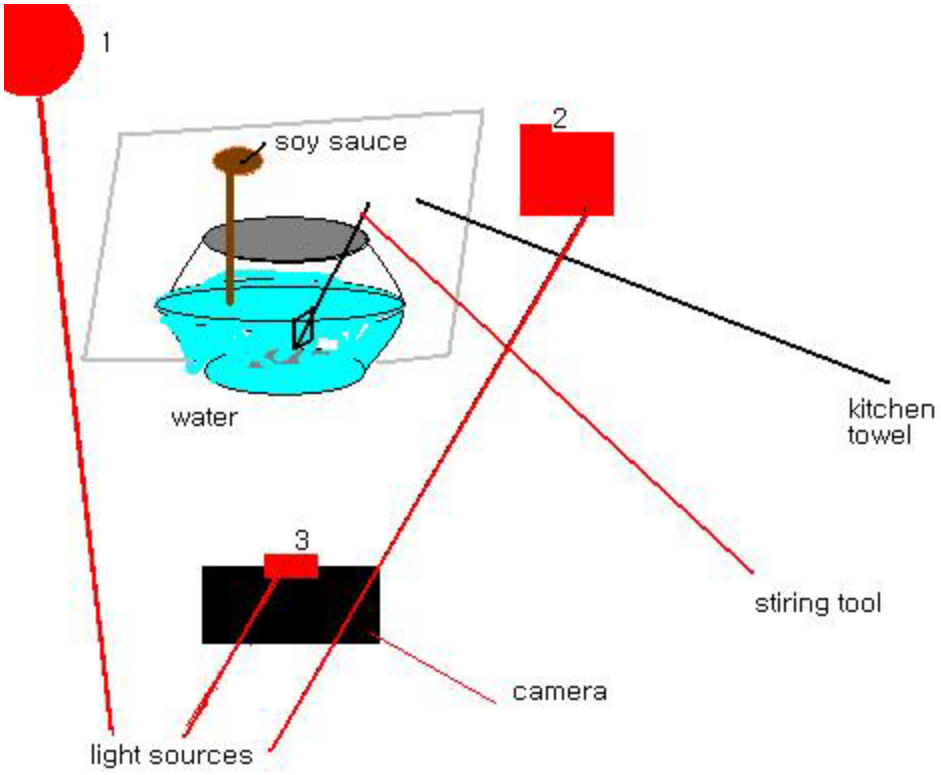


Figure 2: Set Up

The distance between camera and the target object was a foot and the soy sauce was placed and poured about a half foot above the water surface. The glass jar is about 5 inches diameter at maximum. The light source 1 is the kitchen light, 2 is the extra normal light stand, and the 3 is the camera flash light. There is no specific predicted number due to the human hand movement is not constant. However, the velocity of the soy sauce can be calculated right before it hits the surface of the water by making some assumptions. By using energy equation (Equation 4), the final velocity of the soy sauce was found to be approximately *5.67* [ft/s].

$$0.5mv_i^2 + mgh_i = 0.5mv_f^2 + mgh_f \quad (4)$$

The soy sauce does not have strong surface tension to hold the blobs it becomes turbulent when it his the surface of the water due to the water drag. The Reynolds number is roughly calculated by assuming the viscosity and density of soy sauce is slightly larger than the water (assumed 5% larger). This assumption gave the Reynolds number around ~10^6, which is fully turbulent flow in the water jar.

The Konica Minolta A2 8 Mega pixel camera was used for the imaging. Table 1 shows the

specification of the information of the imaging technique.

Table 1: Imaging Specs

Size of the field of View	4 inches / 1600 pixels
Distance from object to lens	~12 inches
Lens size	49mm
Aperture	f2.8
Shutter speed	1/50 sec

The image was modified for better observation of phenomenon. It was just brightened. Figure 3 is the image that shows the result of the model. Figure 4 is the modified numerical model for the phenomenon.

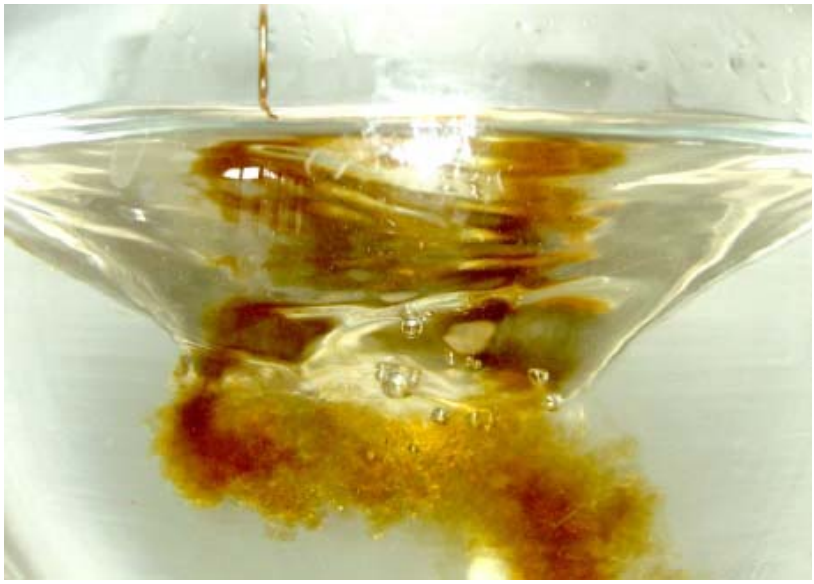


Figure 3: Spiral

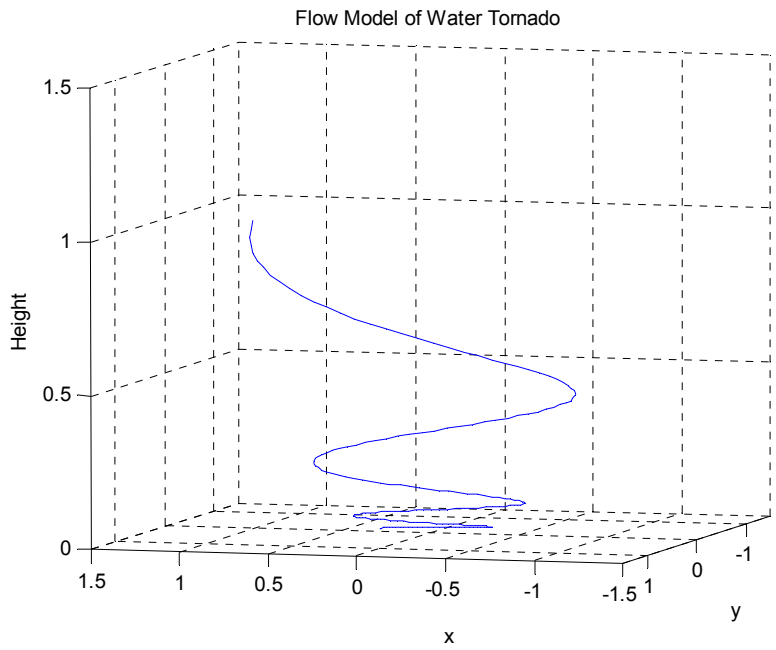


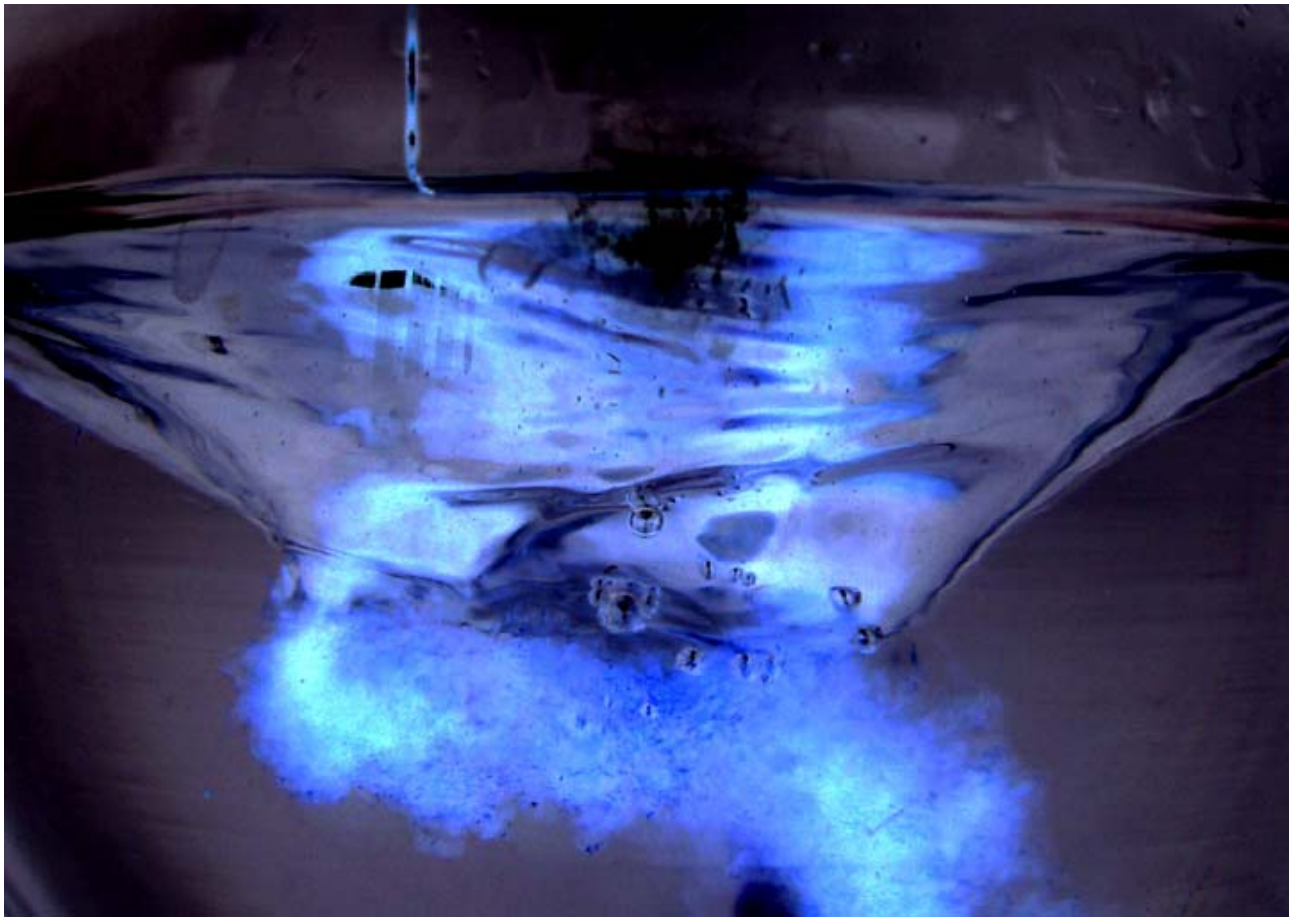
Figure 4: Modified to Actual Result

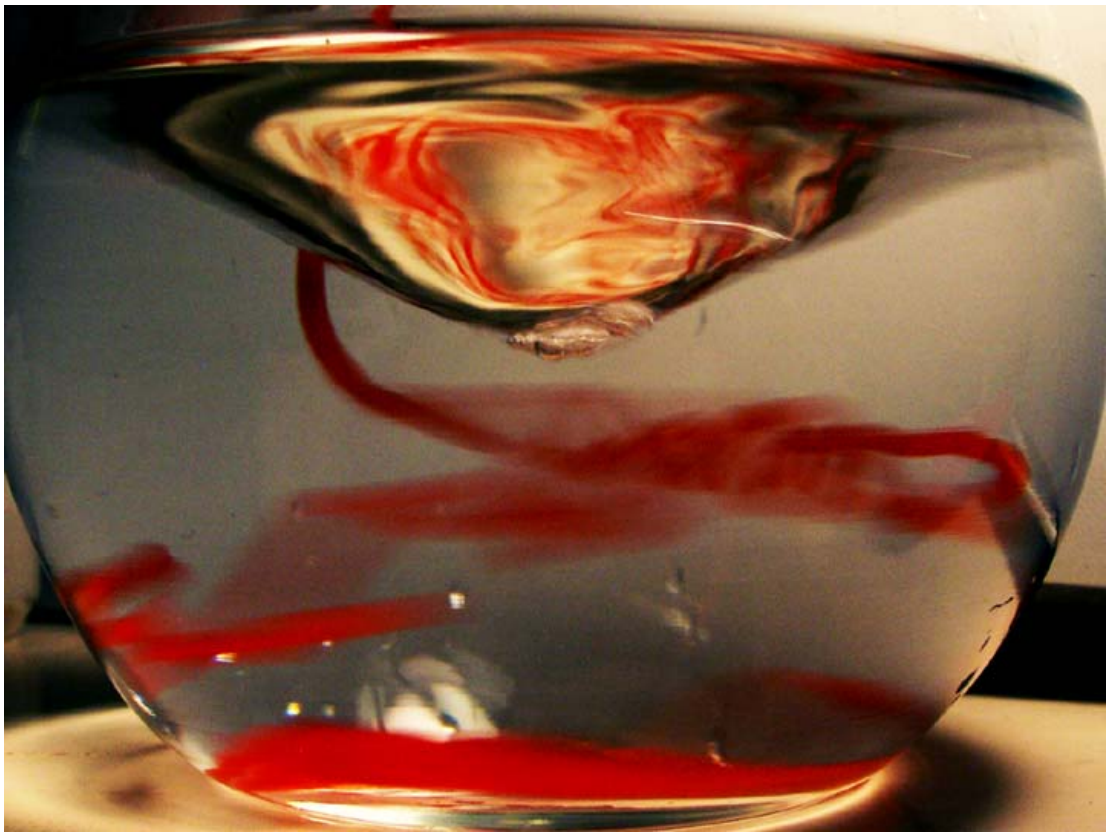
The image reveals very top portion of the spiral. It was taken when the camera was in zoom to see the jar

very closely about bottom 20% of the jar was not in the field of view. I didn't like what I did. However, observing many trials and the stability of the flow seemed to be better with cutting the bottom. There is an additional image that was taken with the ketchup. The flow tends to back up when the flow hits the bottom of the jar. If the jar is deep enough and I have better tools for the creating a water tornado, this flow visualization would be improved. This idea can be applied in several area such as atmospheric tornado (back word of this model – divergent spiral to the upward), the black hole observation (gravity forces and the gas around the black hole), vortices in the river or injection method.

Additional Images

Color Inverted





MatLab Code

```
% Name : Hwapyong Ko
% MCEN 4228
% Flow Visualization
% Water Tornado model
% This program generates simple black hole type model with water tornado.
% It is to show how the denser object is going to act on the fluid surface
% to the point where has centripal force is concentrated.

clc
clear all
close all

t = [0:pi/100:2*pi];
for i = 1:length(t)
    x(i) = exp(-0.2*t(i))*cos(3*t(i));
    y(i) = exp(-.71*t(i))*sin(3*t(i));
    z(i) = exp(-.72*t(i));
end

figure
plot3(x,y,z)
grid on
title('Flow Model of Water Tornado')
xlabel('x')
ylabel('y')
zlabel('Height')
axis([-1.5 1.5 -1.5 1.5 0 1.5])
```

Image Assessment Form

Flow Visualization

Spring 2006

Name(s)

Ko, Hwapyong

Assignment: Get Wet **Date:** 2/8/06

Scale: +, ! = excellent √ = meets expectations; good. ~ = Ok, could be better. X = needs work. NA = not applicable

Art	Your assessment	Instructor assessment
Intent was realized	~	
Effective	√	
Impact	√	
Interesting	√	
Beautiful	NA	
Dramatic	NA	
Feel/texture	NA	
No distracting elements	√	
Framing/cropping enhances image	√	
Flow	Your assessment	Instructor assessment
Clearly illustrates phenomena	~	
Flow is understandable	√	
Physics revealed	√	
Details visible	!	
Flow is reproducible	√	
Flow is controlled	√	
Creative flow or technique	!	
Publishable quality	√	
Photographic technique	Your assessment	Instructor assessment
Exposure: highlights detailed	!	
Exposure: shadows detailed	!	
Full contrast range	!	
Focus	!	
Depth of field	!	
Time resolved	!	
Spatially resolved	!	
Clean, no spots	!	
OK, simple print	!	
Mat	!	
Mounting	!	

Report		Your assessment	Instructor asssessment
Describes intent	Artistic	NA	
	Scientific	!	
Describes fluid phenomena		!	
Estimates appropriate scales	Reynolds number etc.	!	
Calculation of time resolution etc.	How far did flow move during exposure?	!	
References:	Web level	!	
	Refereed journal level	!	
Clearly written		!	
Information is organized		!	
Good spelling and grammar		√	
Professional language (publishible)		!	
Provides information needed for reproducing flow	Fluid data, flow rates	√	
	geometry	~	
	timing	!	
Provides information needed for reproducing vis technique	Method	!	
	dilution	!	
	injection speed	√	
	settings	!	
lighting type	(strobe/tungsten, watts, number)	NA	
	light position, distance	!	
Provides information for reproducing image	Camera type	!	
	Camera model	!	
	Field of view	!	
	Focal length	!	
	aperture	!	
	shutter speed	!	
	film type and speed	!	
	# pixels (width X ht)	!	
	Photoshop techniques	√	
	Print details	√	
	"before" Photoshop image	√	