Project #3

MAE 598 Applied CFD

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Task 1

(a)

Task 1a was to perform a transient analysis of a 2-D chamber that is initially filled with air, and has water flowing through the inlet. A fine mesh, with local mesh refinement near the walls of the domain was used with a time step of 0.0005 seconds. Below is the requested deliverable of the volume fraction of water at $t = 0.4s$.

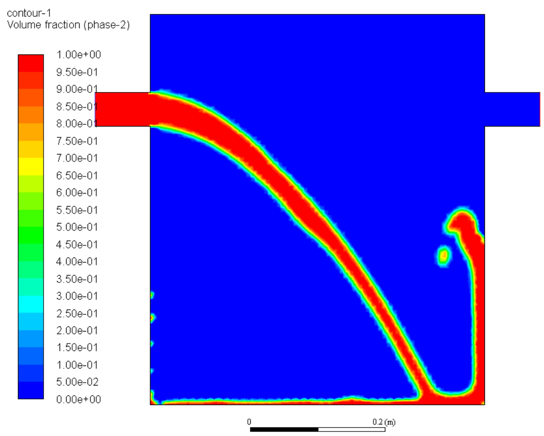

Figure 1: Volume Fraction of Water at $t = 0.4s$

(b)

Task 1b was to perform the same analysis but with the chamber initially filled with liquid kerosene to a depth of 15 cm, and the remainder of the chamber initially filled with air – again, water flows through the inlet. The same mesh and time step were utilized.

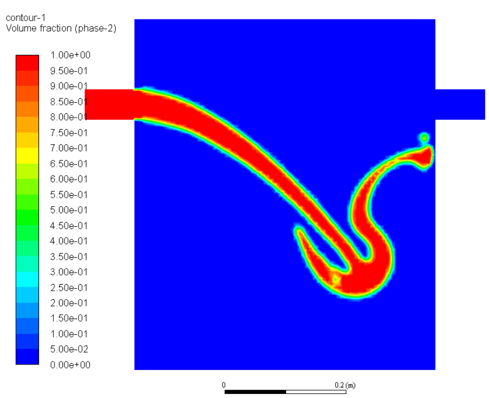

Figure 2: Volume Fraction of Water at $t = 0.4s$

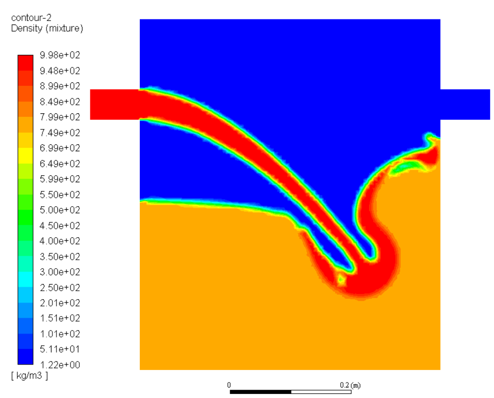

Figure 3: Density of Mixture at $t = 0.4s$

Task 2

(a)

Task 2a was to perform a transient analysis of a 2-D warehouse where methane is leaking out of an underground reservoir, and air is pumped into the warehouse through an opening at the left at 2 m/s. A fine mesh, with local mesh refinement near the walls of the domain was used with a time step of 0.005 seconds. Below are the requested deliverables of the volume fraction of methane at $t = 2s$ and $t = 5s$.

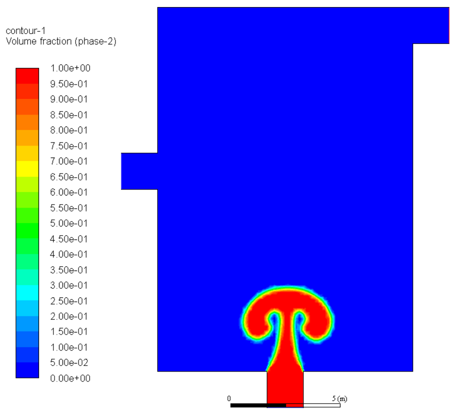

Figure 4: Volume Fraction of Methane at $t = 2s$

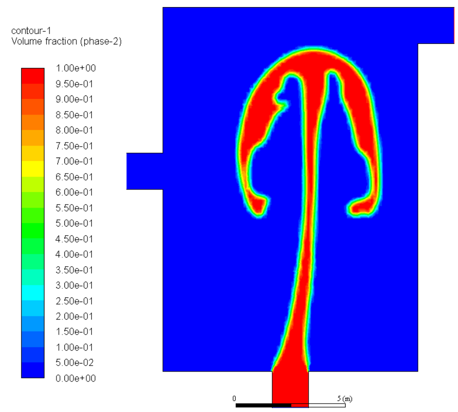

Figure 5: Volume Fraction of Methane at $t = 5s$

(b)

Task 2b was to perform the same analysis but with the air being pumped into the warehouse at 5 m/s. Below are the requested deliverables of the volume fraction of methane at $t = 2s$ and $t = 5s$, and contour plots of velocity in the x and y-directions at $t = 5s$.

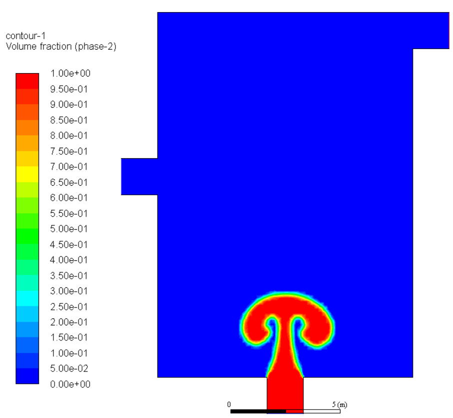

Figure 6: Volume Fraction of Methane at $t = 2s$

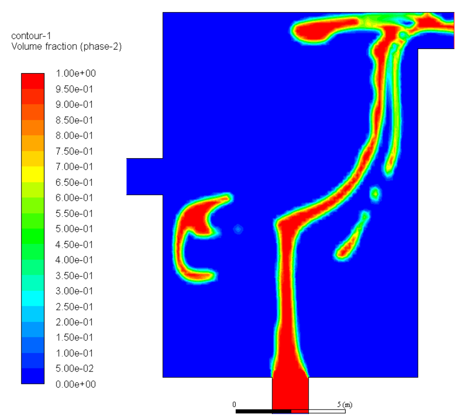

Figure 7: Volume Fraction of Methane at $t = 5s$

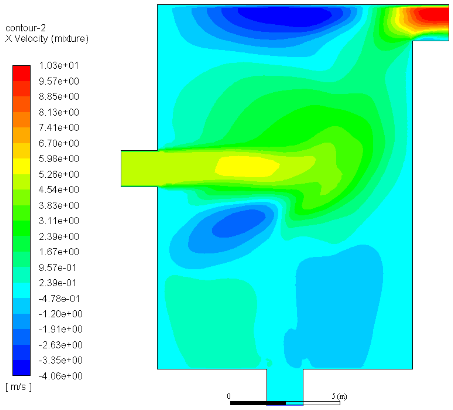

Figure 8: X-Velocity at $t = 2s$

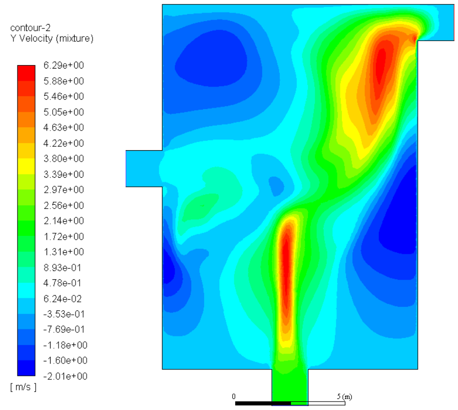

Figure 9: Y-Velocity at $t = 5s$

Task 3

(a)

Task 3a was to perform a transient analysis on a 2-D system consisting of two identical open containers connected at the bottom by a short pipe, where the initial water level in the left container is 35cm and the initial water level in the right container is 15cm, using the viscous-laminar model. A time step of 0.001 seconds was chosen with a maximum of 10 iterations per time step being performed.

For the boundary conditions of the top openings of the two containers, pressure outlets were chosen for both the left and right openings. This is because pressure outlets allow flow in either direction across the interface. Air is expected to enter and exit both opening throughout the analysis, therefore, the result should be similar to using pressure inlets for both.

A line plot of the water levels of the left and right containers as a function of time is shown below. This data was extracted by measuring the mass flow rate of the left container's opening over the analysis, and using the mass flow rate to calculate the change in height over time. The MATLAB script used can be found in the Appendix.

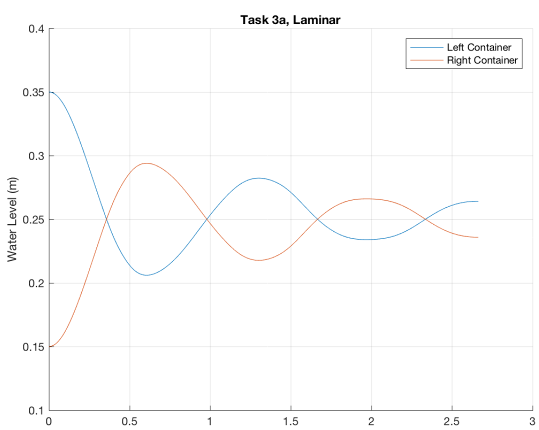

Figure 10: Water Levels of Left and Right Containers, Laminar

The specific times when the water levels of the two containers are equal (where t_1 is the first instance and t_2 is the second), and the period of oscillation are found in the table below.

t_1 (s)	t_2 (s)	T (s)
0.358	0.980	1.332

Plots of the velocity vector fields at t_1 and t_2 are shown below.

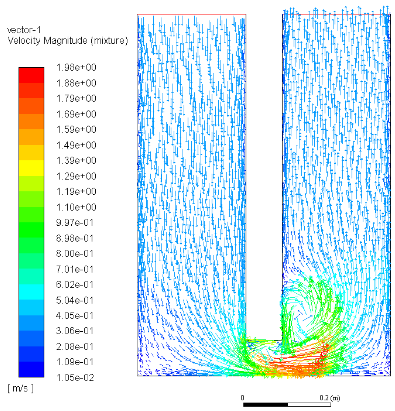

Figure 11: Velocity Vector Field at t_1

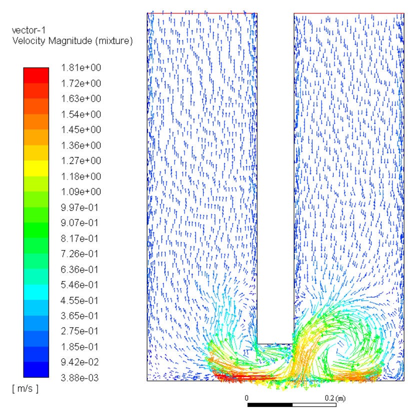

Figure 12: Velocity Vector Field at t_2

A contour plot of the volume fraction of water at the time when the water level of the right container peaks for the first time is shown below.

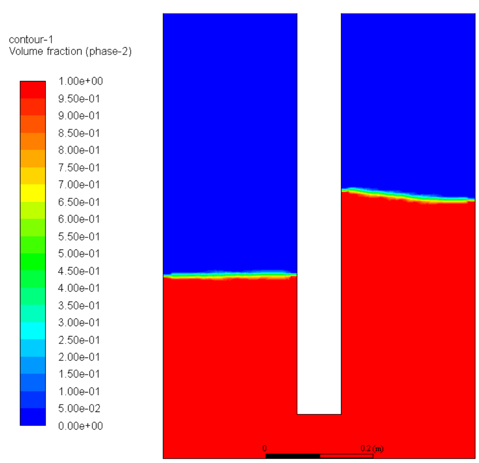

Figure 13: Volume Fraction of Water at First Half-Cycle

(b)

Task3b was to complete the same analysis, but using the inviscid model. The same boundary conditions (pressure outlets) were used for both openings because it is expected that air will flow into and out of the system through both openings throughout the analysis.

Below is the line plot of the water levels of the left and right containers as a function of time.

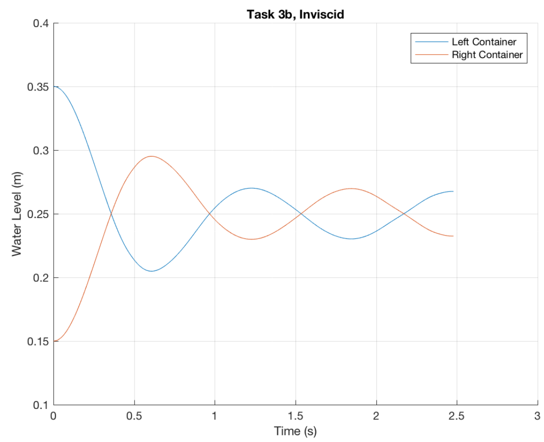

Figure 14: Water Levels of Left and Right Containers, Inviscid

The specific times when the water levels of the two containers are equal (where t_1 is the first instance and t_2 is the second), and the period of oscillation are found in the table below.

t_1 (s)	t_2 (s)	T (s)
0.358	0.968	1.239

The values of t_1 are the same for both the laminar and inviscid models. The value of t_2 for the laminar model is greater than the value for the inviscid model. And similarly, the period of oscillation for the laminar model is greater than the period of oscillation for the inviscid model. The reason why the t_1 times are the same is most likely due to the fact that the inertial forces are much larger than the viscous forces (not modeled when using inviscid) at the start of the analysis when the difference between the water levels is largest, and therefore neglecting viscosity does not have a large impact. However, as time progresses, the viscous forces become larger players and slow down the period of oscillation over time. This results in the laminar model having a larger t_2 and period of oscillation compared to the inviscid model.

Task 4

(a)

Task 4a was to run a 2-D transient analysis on a drop of engine oil placed on an inclined plane. The viscous-laminar model was used, along with a time step of 0.005 seconds with a maximum of 10 iterations per time step. A pressure inlet was used for the left boundary and pressure outlets were used for the top and right boundaries. Additionally, to simplify the system, the plate was modeled horizontally with the gravity vector at an angle of 30°. Below are plots of the time evolution of the droplet.

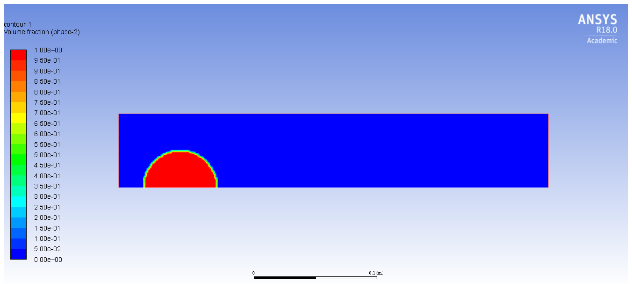

Figure 15: Drop at $t = 0$

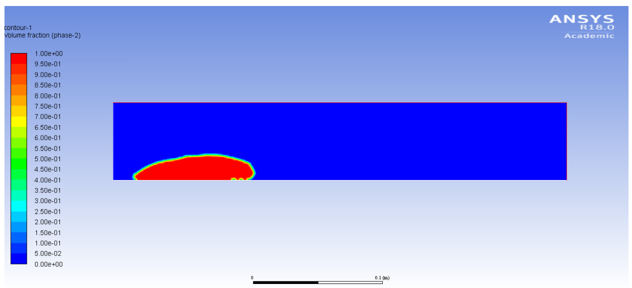

Figure 16: Drop at $t = 0.1$

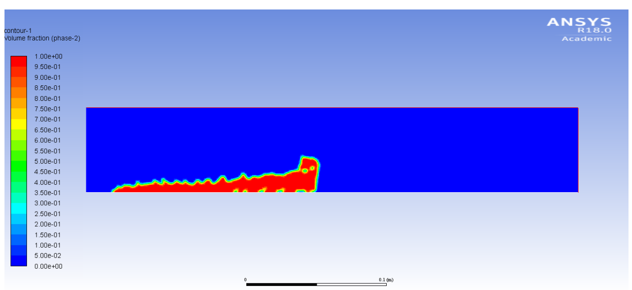

Figure 17: Drop at $t = 0.3$

The folding back motion that occurs at the front end of the droplets path was unexpected, but continued to appear with increasing the mesh refinement and decreasing the time step. Adequate spaced boundary conditions were utilized in this analysis, so interference from the boundaries is not expected to be the cause.

(b)

Task 4b was to repeat the analysis but for a 3-D system. Similar boundary conditions were used, with the side boundaries also being pressure outlets. To show the 3-D time evolution of the droplet, the iso-surface of the volume fraction of engine oil equal to 0.9 was shown.

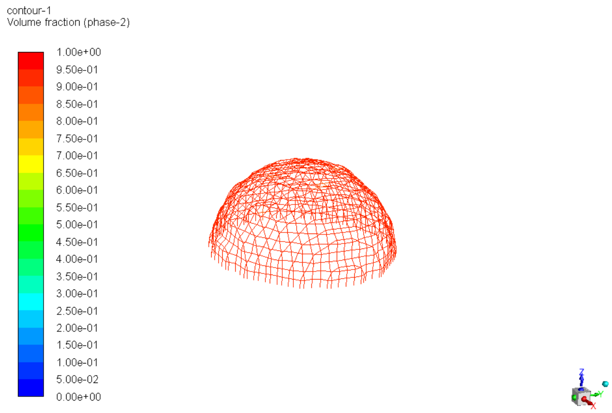

Figure 18: Drop at $t = 0$

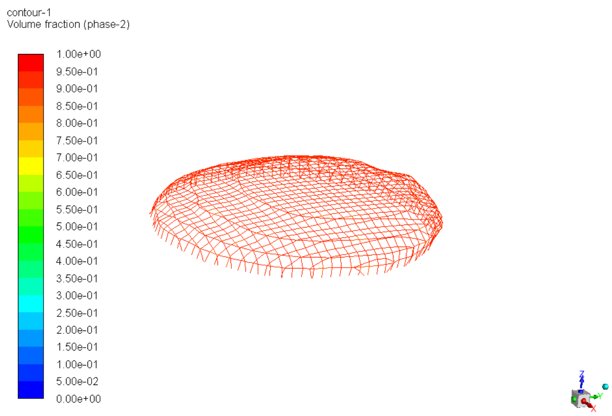

Figure 19: Drop at $t = 0.1$

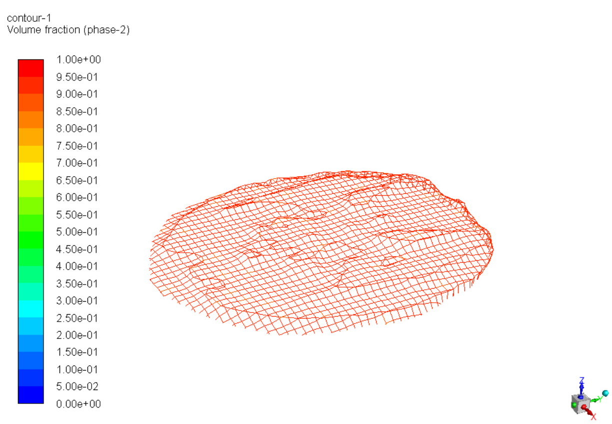

Figure 20: Drop at $t = 0.3$

Appendix

Task 3 Code

```
clear; close all; clc;

data = dlmread('left_massflow.out',' ',3,0);
time = data(:,2); %s
mdot = data(:,3); %kg/s

dm(1) = 0;
for i = 2:length(mdot)
    dm(i) = trapz(time(1:i),mdot(1:i)); %kg
end

dh = -dm./(1.225*0.15*1); %m
h_left = 0.35+dh; %m
h_right = 0.15-dh; %m

figure; hold on; grid on;
plot(time(1:2663),h_left(1:2663),time(1:2663),h_right(1:2663));
title('Task 3a, Laminar'); xlabel('Time (s)'); ylabel('Water Level (m)');
legend('Left Container','Right Container'); xlim([0 3]); ylim([0.1 0.4]);
saveas(gcf,'task3a.png');

clear;

data = dlmread('left_massflow_3b.out',' ',3,0);
time = data(:,2); %s
mdot = data(:,3); %kg/s

dm(1) = 0;
for i = 2:length(mdot)
    dm(i) = trapz(time(1:i),mdot(1:i)); %kg
end

dh = -dm./(1.225*0.15*1); %m
h_left = 0.35+dh; %m
h_right = 0.15-dh; %m

figure; hold on; grid on;
plot(time(1:2479),h_left(1:2479),time(1:2479),h_right(1:2479));
title('Task 3b, Inviscid'); xlabel('Time (s)'); ylabel('Water Level (m)');
legend('Left Container','Right Container'); xlim([0 3]); ylim([0.1 0.4]);
saveas(gcf,'task3b.png');
```