MAE 598
Applied CFD
Project # 2

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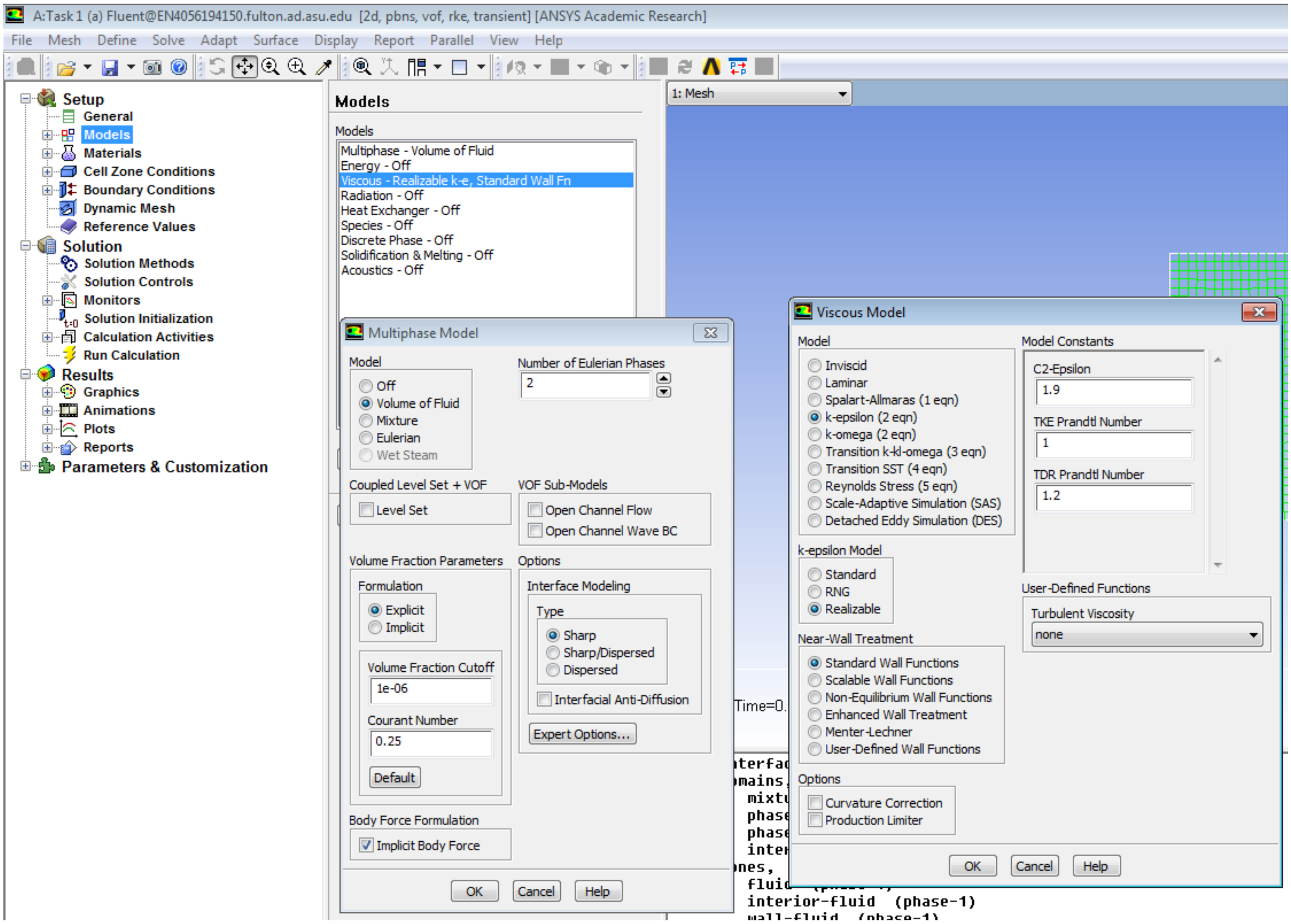
Task 1
(a)

Setup

For this problem Gravity is enabled in the Y-direction and its value is -9.8 m/s^2. The time is used as transient. The mesh used is Fine.

Since two phases are used Water and Engine oil, we switch on multiphase and insert the Number of Phases as 2. The task uses turbulent flow k-epsilon.



A:Task 1 (a) Fluent@EN4056194150.fulton.ad.asu.edu [2d, pbns, vof, rke, transient] [ANSYS Academic Research]

Models

Models

- Multiphase - Volume of Fluid
- Energy - Off
- Viscous - Realizable k-e, Standard Wall Fn
- Radiation - Off
- Heat Exchanger - Off
- Species - Off
- Discrete Phase - Off
- Solidification & Melting - Off
- Acoustics - Off

Multiphase Model

Model: ○ Off ● Volume of Fluid ○ Mixture ○ Eulerian ○ Wet Steam

Number of Eulerian Phases: 2

Coupled Level Set + VOF: ☐ Level Set

VOF Sub-Models: ☐ Open Channel Flow ☐ Open Channel Wave BC

Volume Fraction Parameters

Formulation: ● Explicit ○ Implicit

Volume Fraction Cutoff: 1e-06

Courant Number: 0.25

Options

Interface Modeling

Type: ● Sharp ○ Sharp/Dispersed ○ Dispersed

☐ Interfacial Anti-Diffusion

Body Force Formulation: ☑ Implicit Body Force

Viscous Model

Model: ○ Inviscid ○ Laminar ○ Spalart-Allmaras (1 eqn) ● k-epsilon (2 eqn) ○ k-omega (2 eqn) ○ Transition k-kl-omega (3 eqn) ○ Transition SST (4 eqn) ○ Reynolds Stress (5 eqn) ○ Scale-Adaptive Simulation (SAS) ○ Detached Eddy Simulation (DES)

k-epsilon Model: ○ Standard ○ RNG ● Realizable

Near-Wall Treatment: ● Standard Wall Functions ○ Scalable Wall Functions ○ Non-Equilibrium Wall Functions ○ Enhanced Wall Treatment ○ Menter-Lechner ○ User-Defined Wall Functions

Options: ☐ Curvature Correction ☐ Production Limiter

Model Constants

C2-Epsilon: 1.9

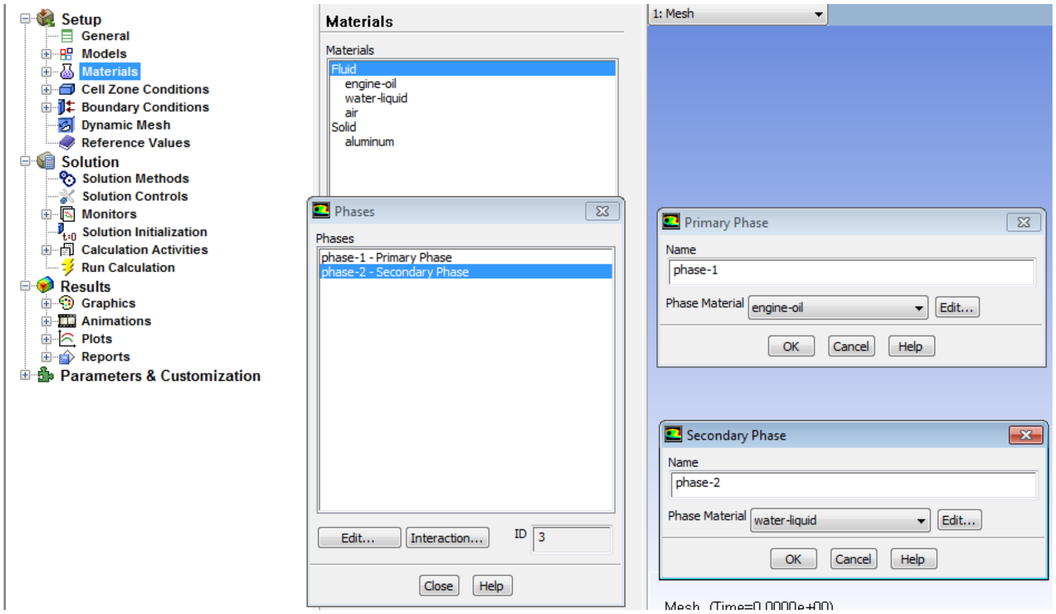
TKE Prandtl Number: 1

TDR Prandtl Number: 1.2

User-Defined Functions

Turbulent Viscosity: none

Engine oil is used as phase-1 and water-liquid is used as phase-2.



Phases

phase-1 - Primary Phase
phase-2 - Secondary Phase

ID: 3

Primary Phase

Name: phase-1

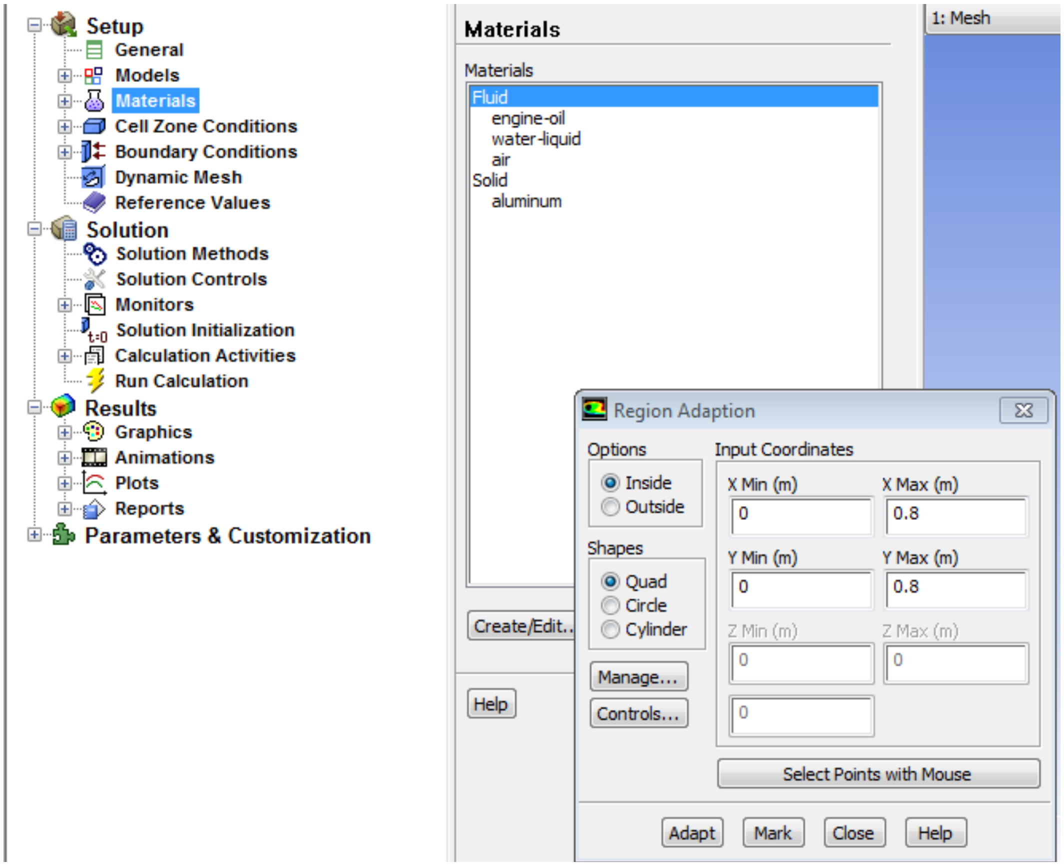
Phase Material: engine-oil

Secondary Phase

Name: phase-2

Phase Material: water-liquid

We have to use two phases on the same geometry. To use two phases we have to define the region in which water (phase-2) is filled and the region that is filled with engine oil (phase-1). From the question we have been given the co-ordinates for the region of Water. We input the co-ordinates and mark the region.



Region Adaption

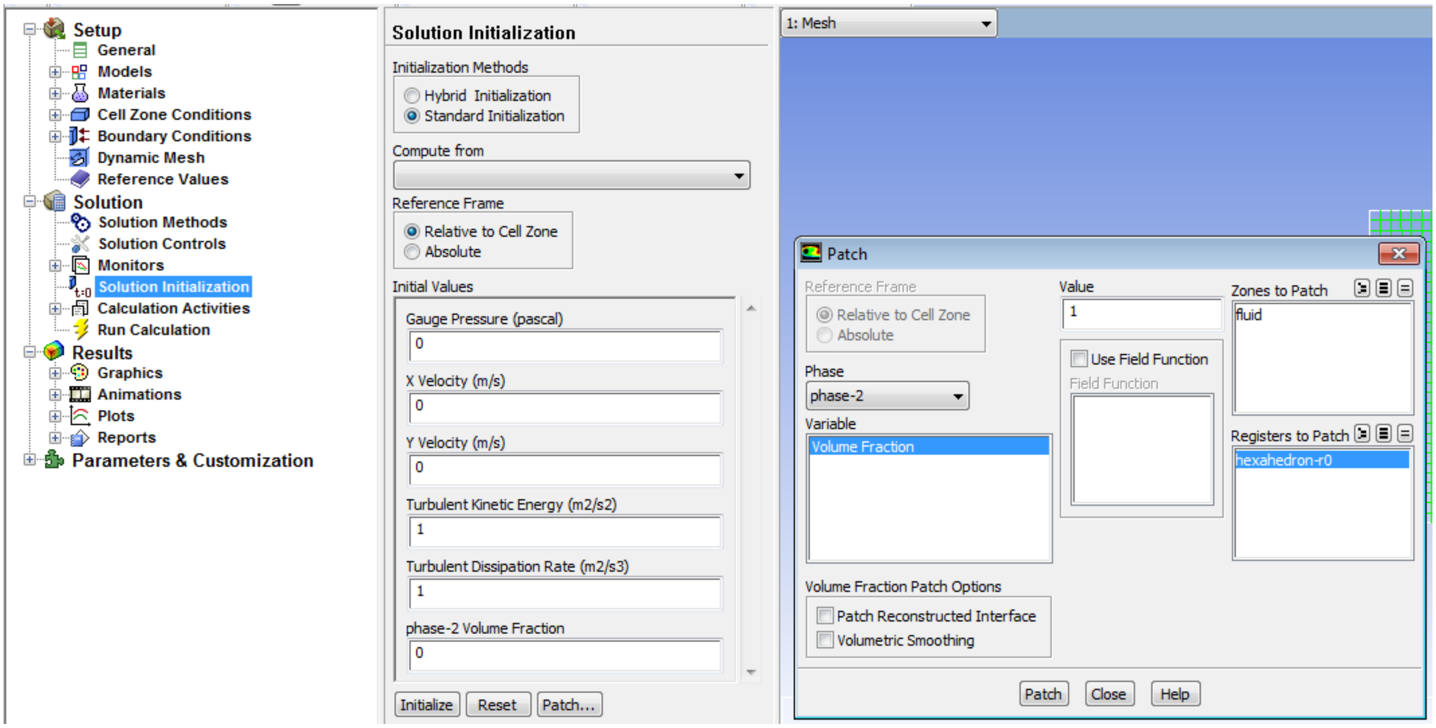
Options: ● Inside ○ Outside

Shapes: ● Quad ○ Circle ○ Cylinder

Input Coordinates

X Min (m): 0	X Max (m): 0.8
Y Min (m): 0	Y Max (m): 0.8
Z Min (m): 0	Z Max (m): 0
0	

We initialize the solution and patch the phase-2 with Volume Fraction 1 for the region that we created.



Solution Initialization

Initialization Methods
○ Hybrid Initialization
● Standard Initialization

Compute from

Reference Frame
● Relative to Cell Zone
○ Absolute

Initial Values

Gauge Pressure (pascal): 0
X Velocity (m/s): 0
Y Velocity (m/s): 0
Turbulent Kinetic Energy (m2/s2): 1
Turbulent Dissipation Rate (m2/s3): 1
phase-2 Volume Fraction: 0

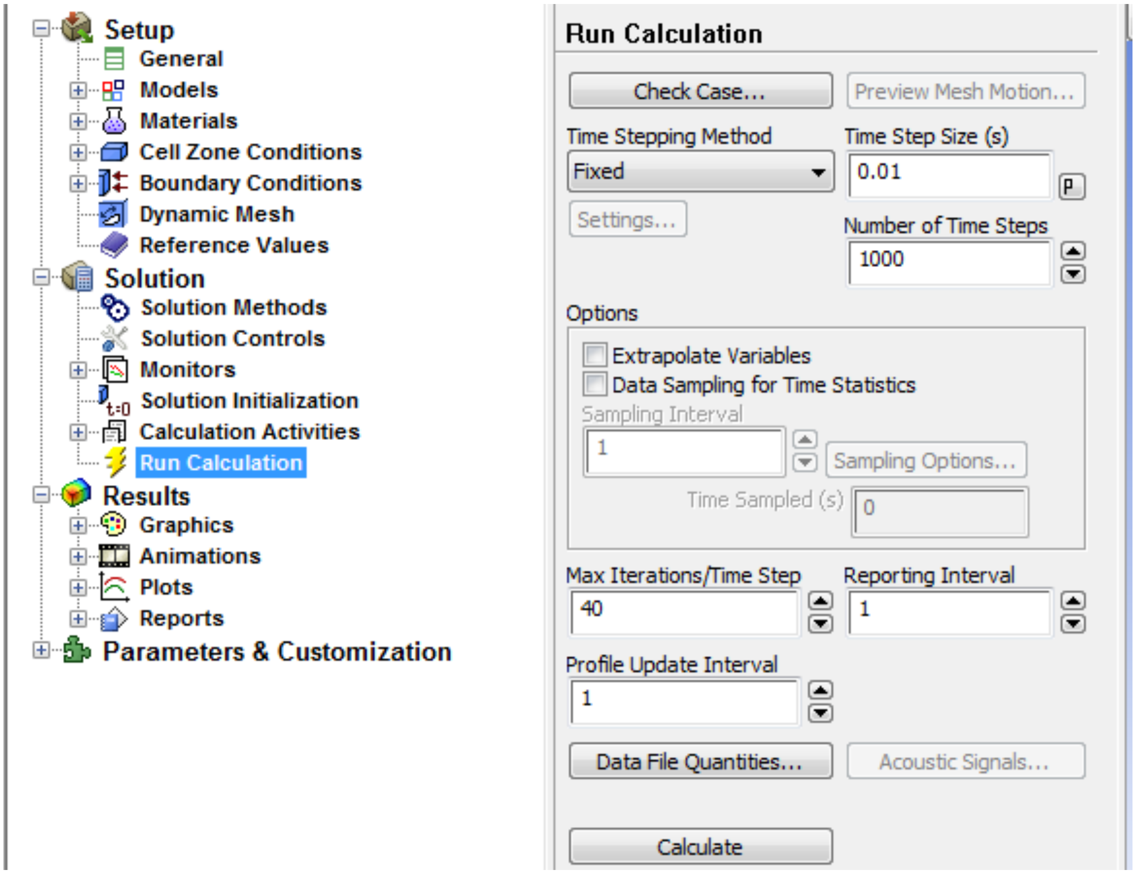
Patch

Reference Frame
● Relative to Cell Zone
○ Absolute

Phase: phase-2
Variable: Volume Fraction
Value: 1
☐ Use Field Function
Field Function
Zones to Patch: fluid
Registers to Patch: hexahedron-r0

Volume Fraction Patch Options
☐ Patch Reconstructed Interface
☐ Volumetric Smoothing

The calculation is run with time step **0.01** and for **1000** number of time steps where the data is saved after every 200 time steps to get the solution for 2, 6 and 10 seconds.



Run Calculation

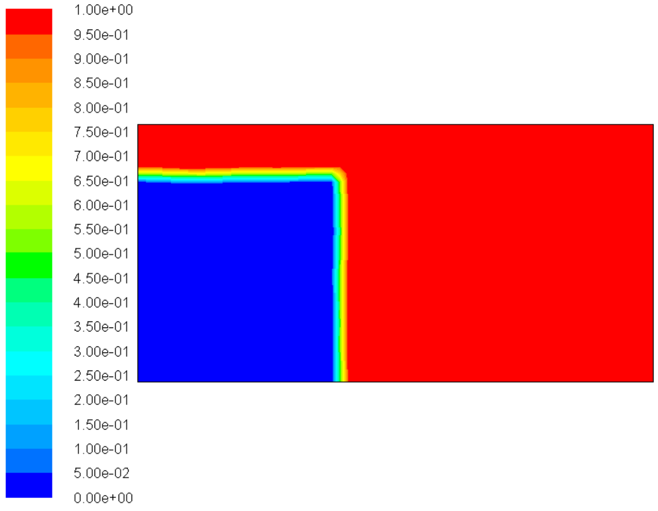
Time Stepping Method: Fixed
Time Step Size (s): 0.01
Number of Time Steps: 1000

Options
☐ Extrapolate Variables
☐ Data Sampling for Time Statistics
Sampling Interval: 1
Time Sampled (s): 0

Max Iterations/Time Step: 40
Reporting Interval: 1
Profile Update Interval: 1

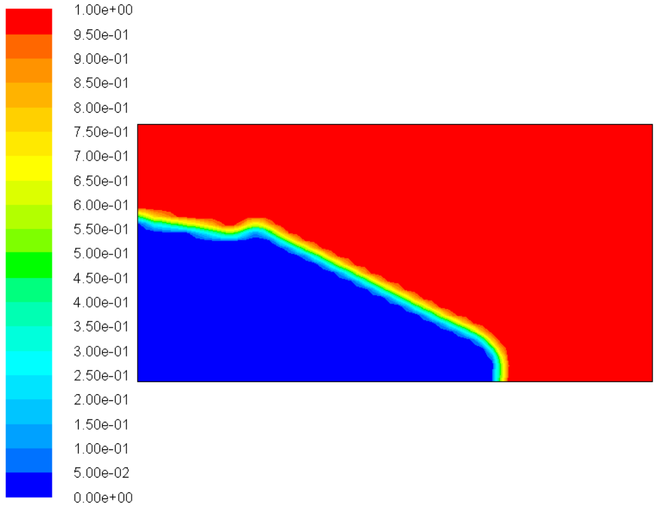
Results

Time = 0 second



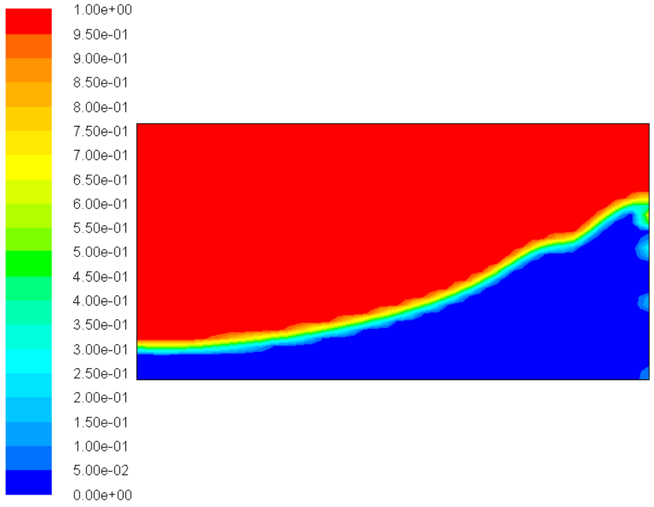
Contours of Volume fraction (phase-1) (Time=0.0000e+00)

Time =2 seconds



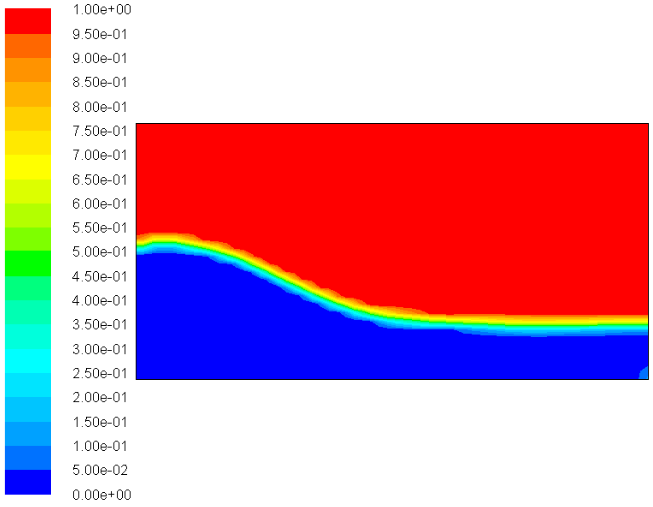
Contours of Volume fraction (phase-1) (Time=2.0000e+00)

Time = 6 seconds



Contours of Volume fraction (phase-1) (Time=6.0000e+00)

Time =10 seconds



Contours of Volume fraction (phase-1) (Time=1.0000e+01)

Task 1

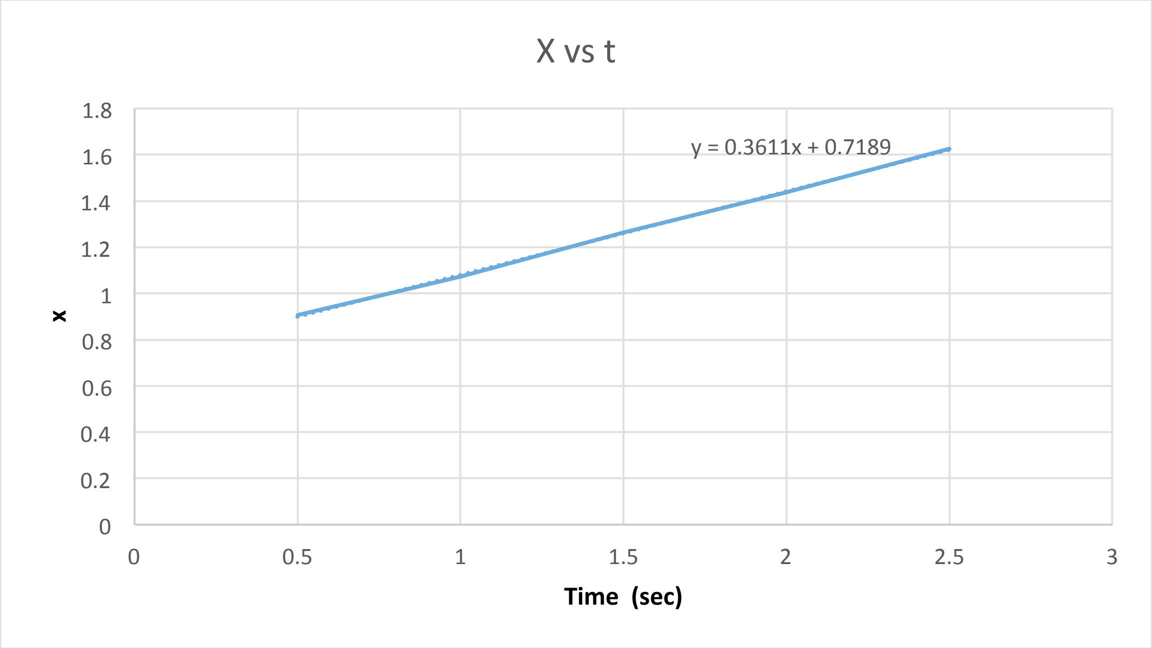
(b)

The value of x was found using the tool probe in result. The probe was used to find the x coordinate where the leading edge of water mixes with engine oil. The values of all 5 data points were inserted in excel and a scattered plot was generated using the values of x and t. Using the tools in excel linear least-square and the slope of the line was found.

The value of Δx is the length **2m** divided by the number of cells in the horizontal direction created during the meshing process (61 cells).

The value of **Δ**x = **0.03**

The value of Δt is the number of time step size
The value of **Δ**t = **0.01**



The equation of line is y=0.3611x+0.7189 which represents y = mx + c and m is the value of the slope which is the value of the velocity U.

The value of U is **0.3611 m/s**

The Courant number, C ~ UΔt/Δx ~ (0 .3611*0.01) /0.03

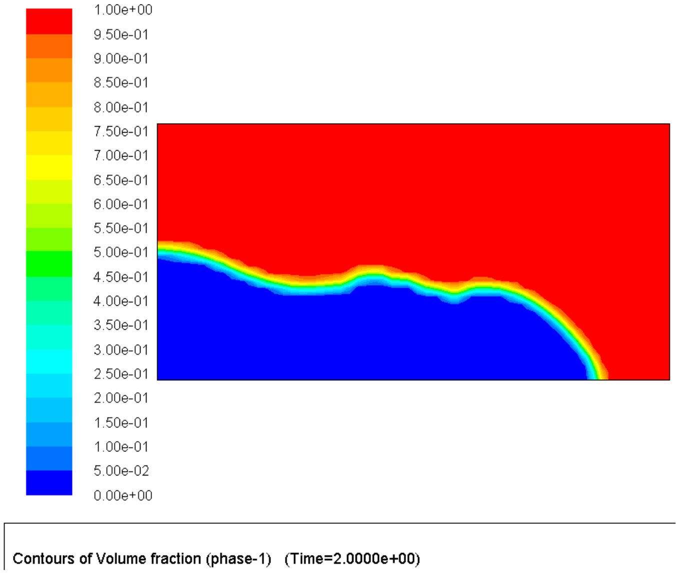
The Courant number, **C ~ 0.120366667**

The Courant Number is less than 1.

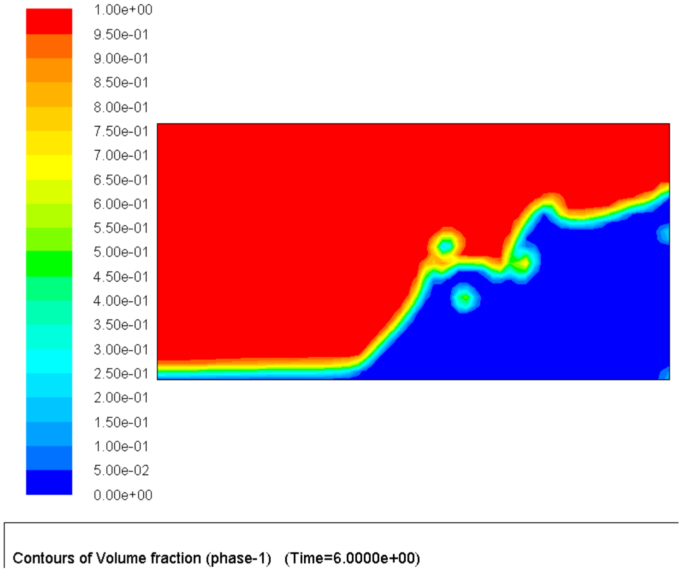
Task 1
(c)

Result

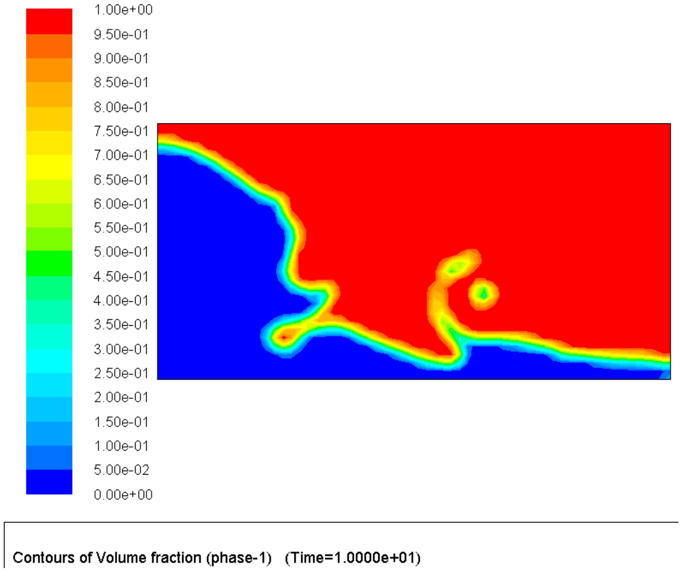
Time = 2 seconds



Time = 6 seconds



Time = 10 seconds

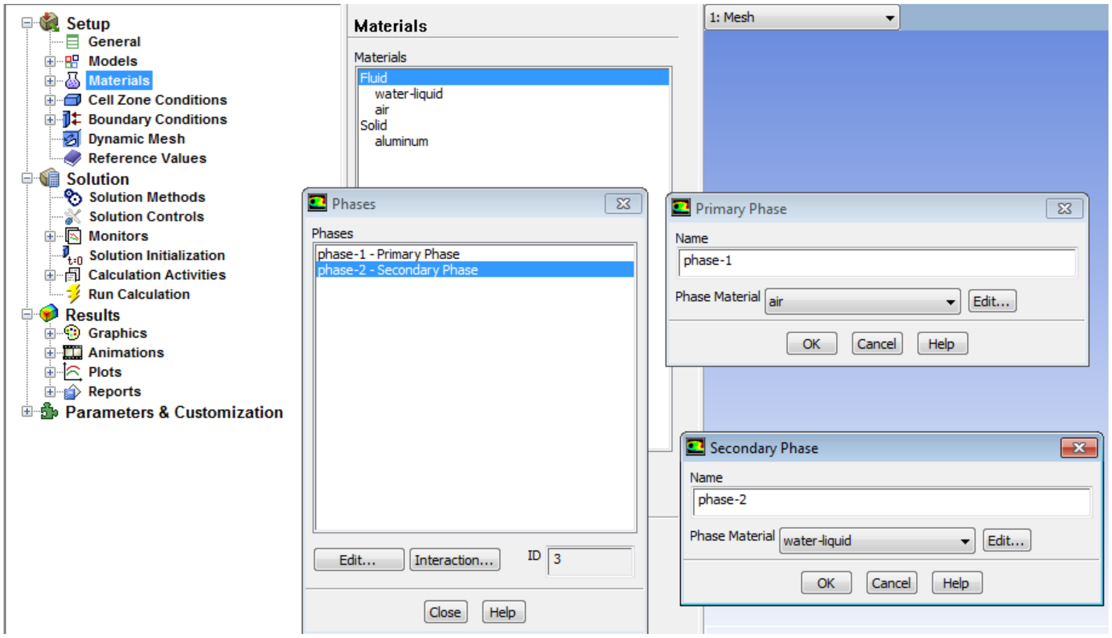


From (a) we know that the flow is turbulent. In turbulent flow, unsteady vortices appear on many scales and interact with each other. Drag due to boundary layer skin friction increases. At 0 seconds the height of the water is at 0.8m and its center of mass is around 0.3m on the x-axis and 0.4 on the y-axis. When the water hits the other wall after 10 seconds and rebounds it can be seen from the plots that the height of the water level has dropped below 0.8 m since its center of mass has dropped. This is because the energy has been dissipated due to friction.

From (c) we know that the flow is inviscid. Inviscid flow has no friction and therefore no energy is dissipated. From the Plots we can see that after 10 seconds when the water rebounds from the other wall, the height of the water almost remains the same.

Task 2

Air is used as phase-1 and water-liquid is used as phase-2.



Materials

Materials
Fluid
water-liquid
air
Solid
aluminum

Phases

Phases
phase-1 - Primary Phase
phase-2 - Secondary Phase

ID 3

Primary Phase

Name: phase-1

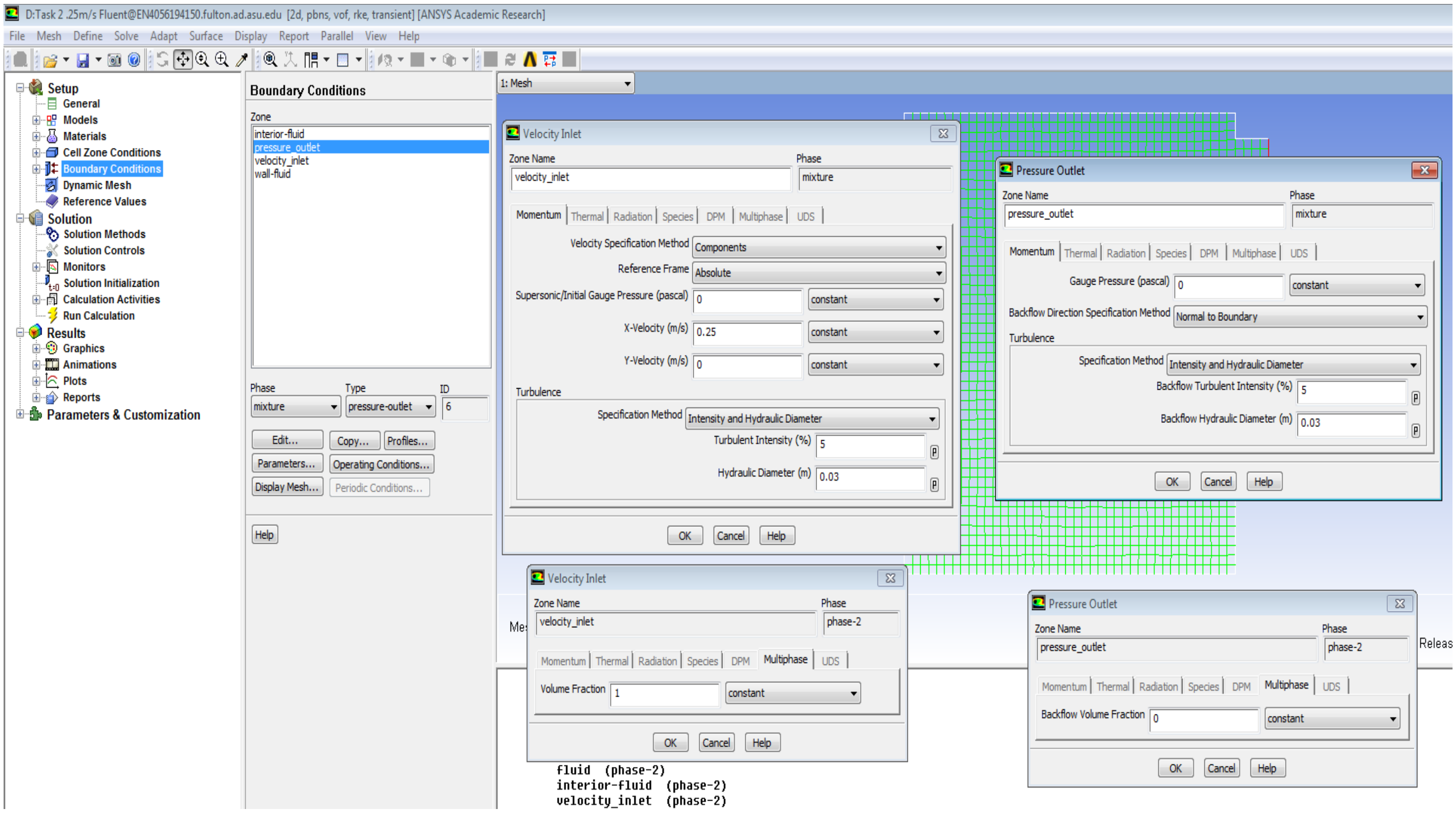
Phase Material: air

Secondary Phase

Name: phase-2

Phase Material: water-liquid

We define the Boundary conditions for the inlet and outlet. Velocity .25m/s and .5 m/s is used for the first and second case respectively in the X-direction. The Phase-2 volume fraction is used as 1 for the Velocity-Inlet.



D:Task 2 .25m/s Fluent@EN4056194150.fulton.ad.asu.edu [2d, pbns, vof, rke, transient] [ANSYS Academic Research]

Boundary Conditions

Zone
interior-fluid
pressure_outlet
velocity_inlet
wall-fluid

Phase: mixture
Type: pressure-outlet
ID: 6

Velocity Inlet

Zone Name: velocity_inlet
Phase: mixture

Velocity Specification Method: Components
Reference Frame: Absolute
Supersonic/Initial Gauge Pressure (pascal): 0 constant
X-Velocity (m/s): 0.25 constant
Y-Velocity (m/s): 0 constant

Turbulence
Specification Method: Intensity and Hydraulic Diameter
Turbulent Intensity (%): 5
Hydraulic Diameter (m): 0.03

Pressure Outlet

Zone Name: pressure_outlet
Phase: mixture

Gauge Pressure (pascal): 0 constant
Backflow Direction Specification Method: Normal to Boundary

Turbulence
Specification Method: Intensity and Hydraulic Diameter
Backflow Turbulent Intensity (%): 5
Backflow Hydraulic Diameter (m): 0.03

Velocity Inlet

Zone Name: velocity_inlet
Phase: phase-2

Volume Fraction: 1 constant

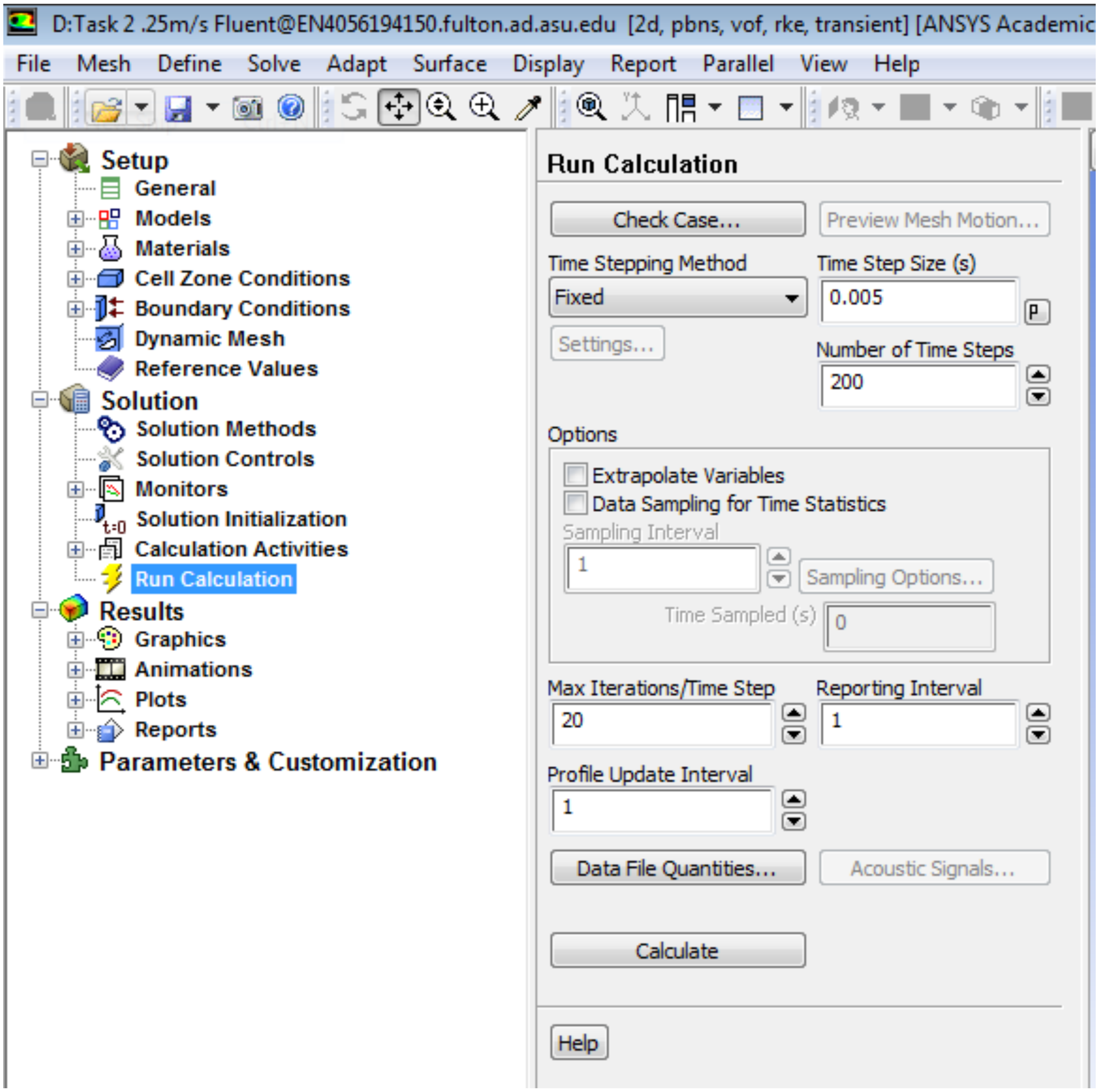
Pressure Outlet

Zone Name: pressure_outlet
Phase: phase-2

Backflow Volume Fraction: 0 constant

```
fluid  (phase-2)
interior-fluid  (phase-2)
velocity_inlet  (phase-2)
```

The calculation is run with time step **0.005** and for **200** number of time steps for 1 second.



D:Task 2 .25m/s Fluent@EN4056194150.fulton.ad.asu.edu [2d, pbns, vof, rke, transient] [ANSYS Academic

Run Calculation

Time Stepping Method: Fixed

Time Step Size (s): 0.005

Number of Time Steps: 200

Options

☐ Extrapolate Variables

☐ Data Sampling for Time Statistics

Sampling Interval: 1

Time Sampled (s): 0

Max Iterations/Time Step: 20

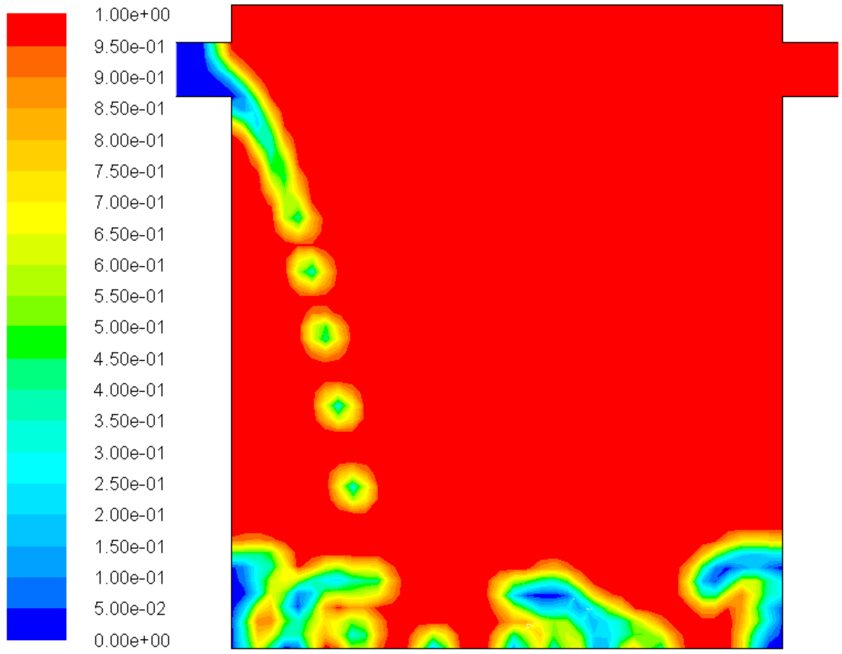
Reporting Interval: 1

Profile Update Interval: 1

Results

a)

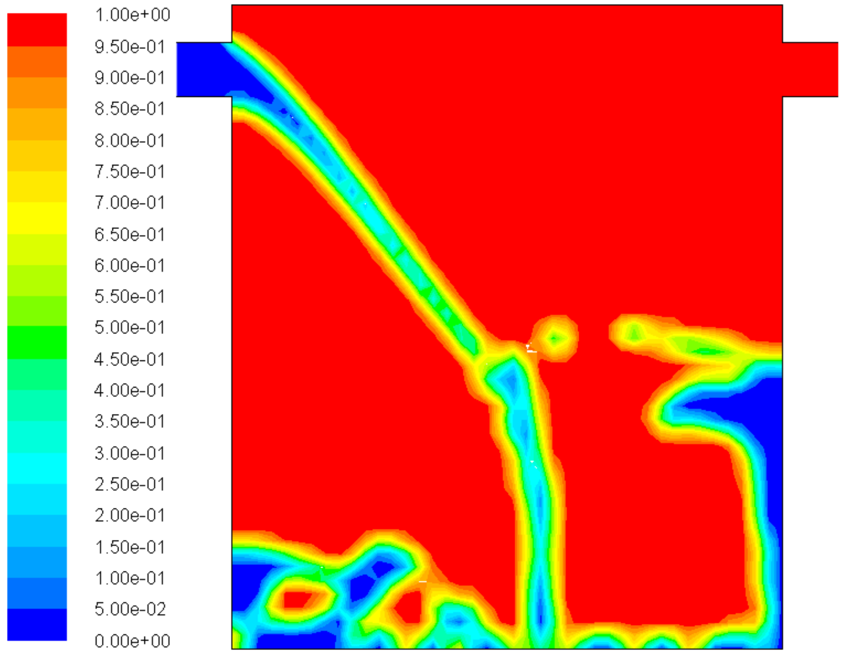
V_{inlet} =0.25 m/s



Contours of Volume fraction (phase-1) (Time=1.0000e+00)

b)

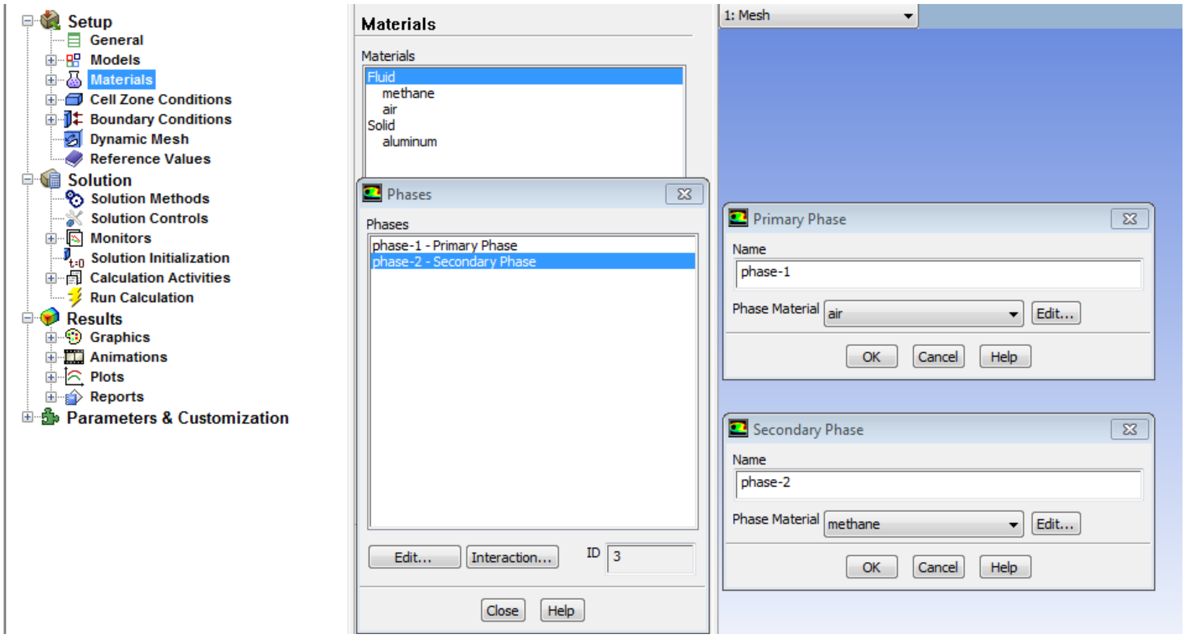
V_{inlet} =0.5 m/s



Contours of Volume fraction (phase-1) (Time=1.0000e+00)

Task 3

Air is used as phase-1 and Methane is used as phase-2.



Materials

Materials
Fluid
methane
air
Solid
aluminum

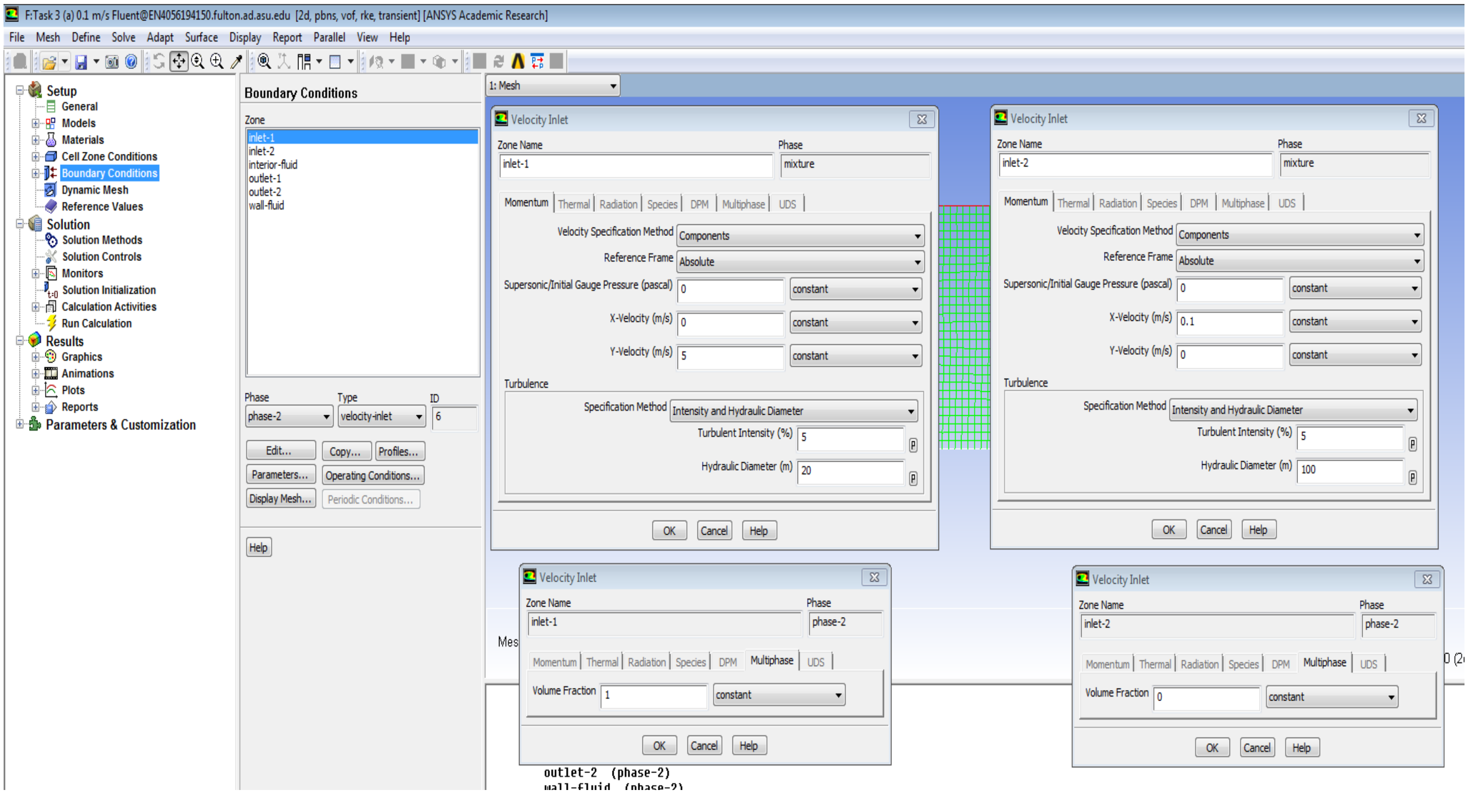
Phases

Phases
phase-1 - Primary Phase
phase-2 - Secondary Phase
ID 3

Primary Phase
Name phase-1
Phase Material air

Secondary Phase
Name phase-2
Phase Material methane

We define the Boundary conditions for the inlet and outlet. V_{inlet}=0.25m/s and V_{inlet}=.5 m/s is used for the first and second case for velocity-inlet-2 respectively in the X-direction. The V_{inlet}= 5 m/s is used for velocity-inlet-1 in the Y-direction The Phase-2 volume fraction is used as 1 for the Velocity-Inlet-1. Volume fraction is 0 for phase-2 at velocity-inlet-2.



F:Task 3 (a) 0.1 m/s Fluent@EN4056194150.fulton.ad.asu.edu [2d, pbns, vof, rke, transient] [ANSYS Academic Research]

Boundary Conditions

Zone
inlet-1
inlet-2
interior-fluid
outlet-1
outlet-2
wall-fluid

Phase phase-2
Type velocity-inlet
ID 6

Velocity Inlet
Zone Name inlet-1
Phase mixture
Velocity Specification Method Components
Reference Frame Absolute
Supersonic/Initial Gauge Pressure (pascal) 0 constant
X-Velocity (m/s) 0 constant
Y-Velocity (m/s) 5 constant
Turbulence
Specification Method Intensity and Hydraulic Diameter
Turbulent Intensity (%) 5
Hydraulic Diameter (m) 20

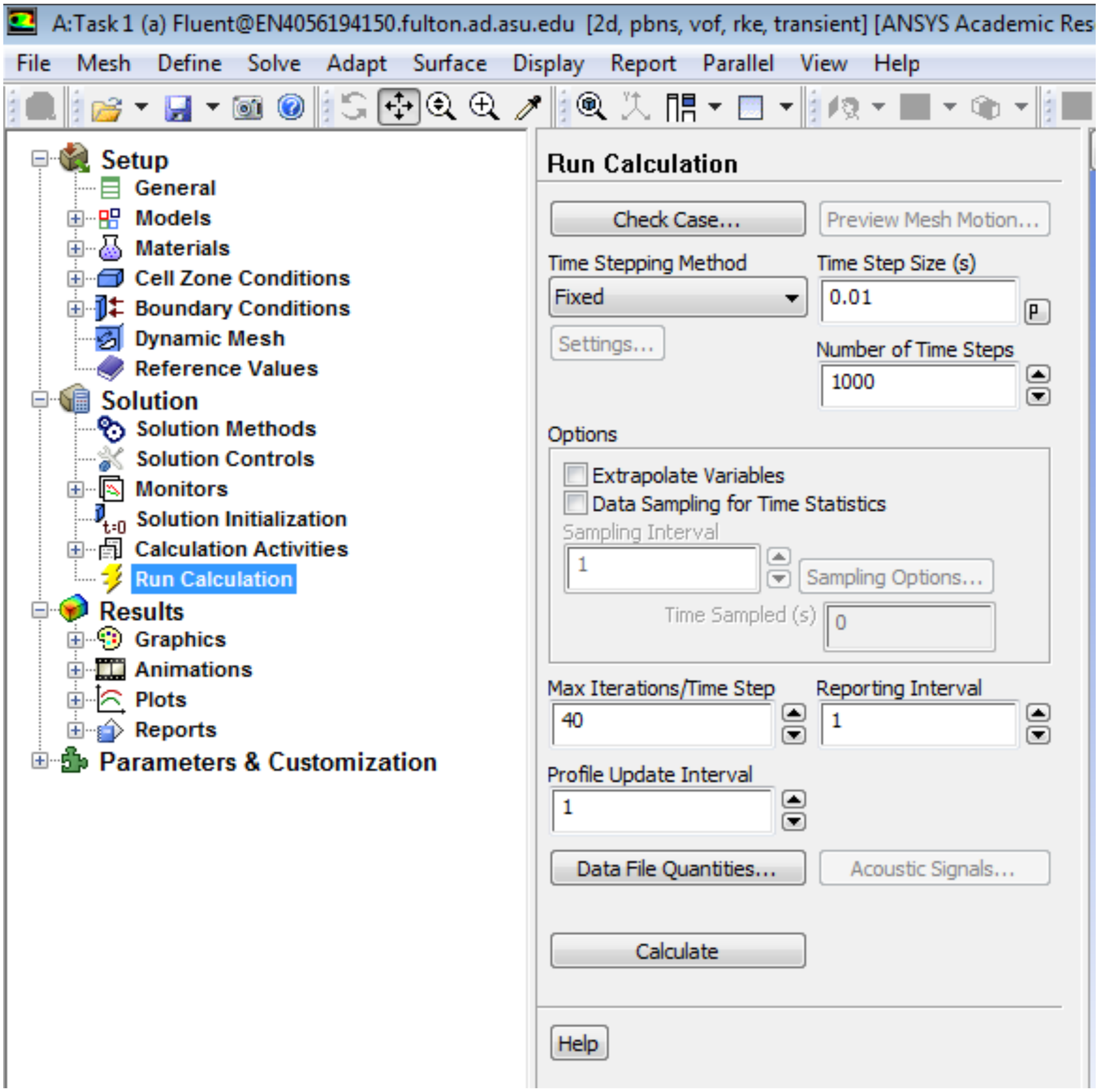
Velocity Inlet
Zone Name inlet-2
Phase mixture
Velocity Specification Method Components
Reference Frame Absolute
Supersonic/Initial Gauge Pressure (pascal) 0 constant
X-Velocity (m/s) 0.1 constant
Y-Velocity (m/s) 0 constant
Turbulence
Specification Method Intensity and Hydraulic Diameter
Turbulent Intensity (%) 5
Hydraulic Diameter (m) 100

Velocity Inlet
Zone Name inlet-1
Phase phase-2
Volume Fraction 1 constant

Velocity Inlet
Zone Name inlet-2
Phase phase-2
Volume Fraction 0 constant

```
outlet-2  (phase-2)
wall-fluid  (phase-2)
```

The calculation is run with time step **0.01** and for **1000** number of time steps for 10 seconds and calculation is run with time step **0.01** and for **2000** number of time steps for 20 seconds.



A:Task 1 (a) Fluent@EN4056194150.fulton.ad.asu.edu [2d, pbns, vof, rke, transient] [ANSYS Academic Res

Run Calculation

Time Stepping Method: Fixed

Time Step Size (s): 0.01

Number of Time Steps: 1000

Options

☐ Extrapolate Variables

☐ Data Sampling for Time Statistics

Sampling Interval: 1

Time Sampled (s): 0

Max Iterations/Time Step: 40

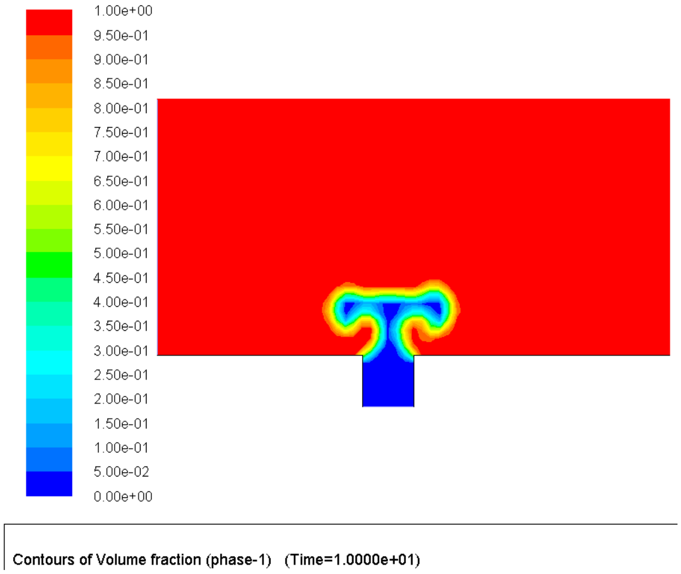
Reporting Interval: 1

Profile Update Interval: 1

Results

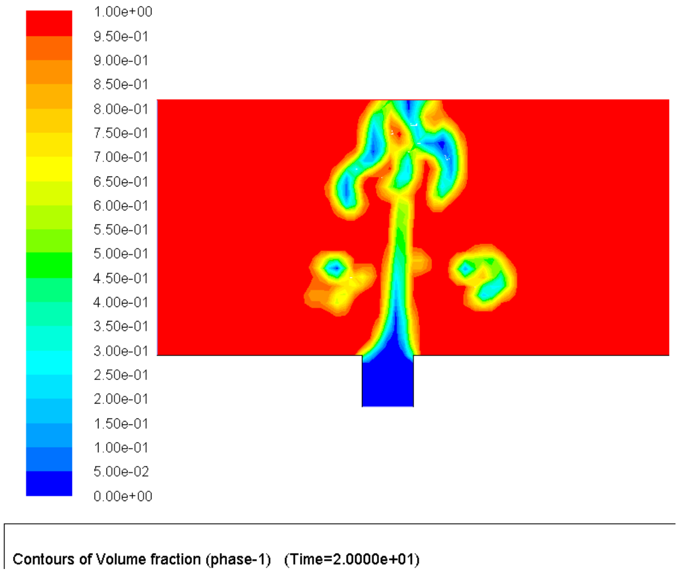
a)

Velocity= 0.25m/s t=10 seconds



Contours of Volume fraction (phase-1) (Time=1.0000e+01)

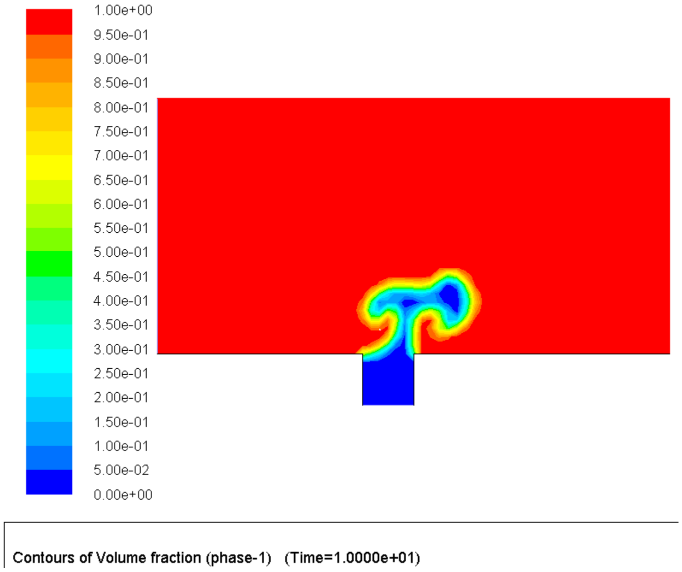
Velocity= 0.25m/s t=20 seconds



Contours of Volume fraction (phase-1) (Time=2.0000e+01)

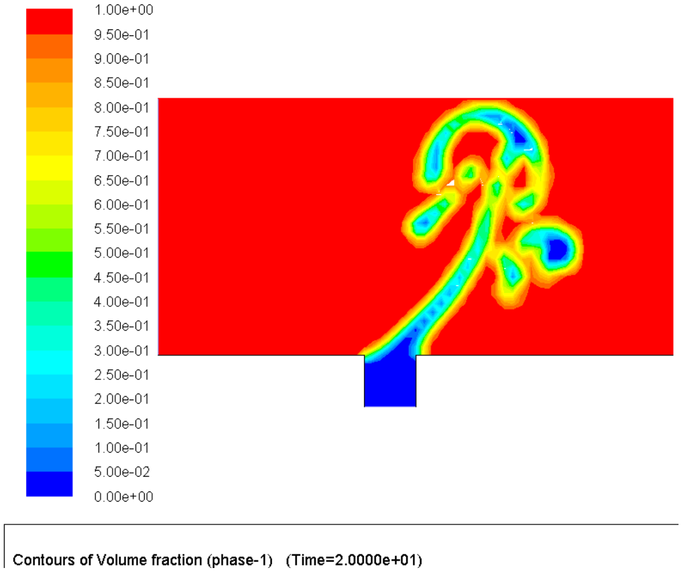
b)

Velocity= 0.5m/s t=10 seconds



Contours of Volume fraction (phase-1) (Time=1.0000e+01)

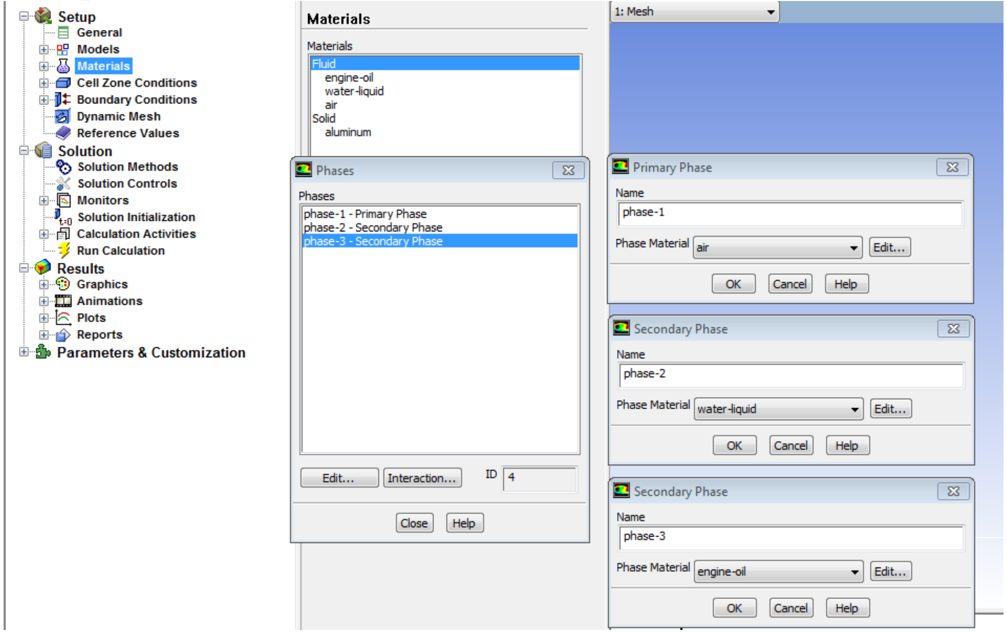
Velocity= 0.5 m/s t=20 seconds



Contours of Volume fraction (phase-1) (Time=2.0000e+01)

Task 4

In this case three phases are used. Air is used as phase-1, water-liquid is used as phase-2 and engine oil is used as phase-3



Materials
Fluid: engine-oil, water-liquid, air
Solid: aluminum

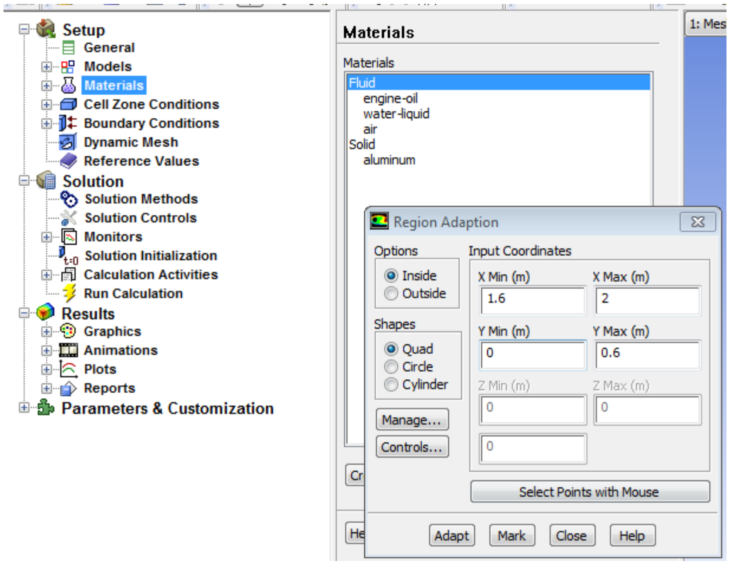
Phases
phase-1 - Primary Phase
phase-2 - Secondary Phase
phase-3 - Secondary Phase
ID 4

Primary Phase
Name: phase-1
Phase Material: air

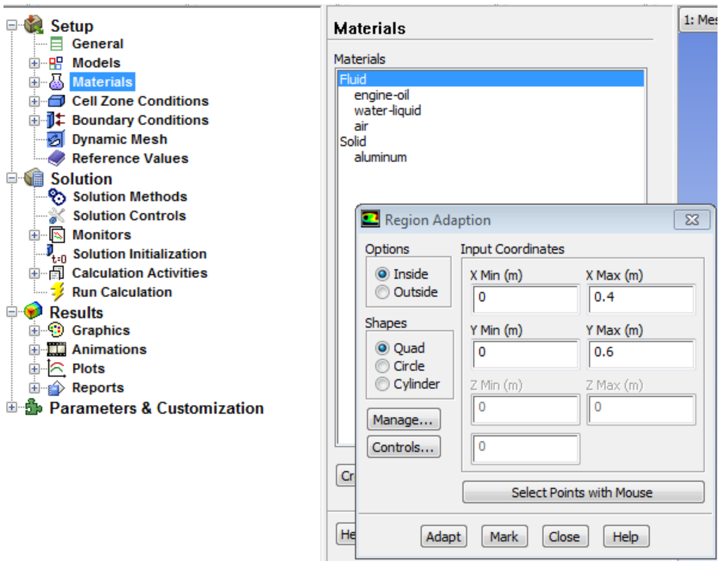
Secondary Phase
Name: phase-2
Phase Material: water-liquid

Secondary Phase
Name: phase-3
Phase Material: engine-oil

We have to use three phases on the same geometry. To use three phases we have to define the region in which water (phase-2) is filled and the region that is filled with engine oil (phase-1) rest of the region is filled with air (phase-1). From the question we have been given the co-ordinates for the region of Water and Engine-oil. We input the co-ordinates and mark the region.
Region-1 is for water and the Region-2 is for engine oil.



Options: ● Inside ○ Outside
Shapes: ● Quad ○ Circle ○ Cylinder
Input Coordinates
X Min (m): 1.6
X Max (m): 2
Y Min (m): 0
Y Max (m): 0.6
Z Min (m): 0
Z Max (m): 0

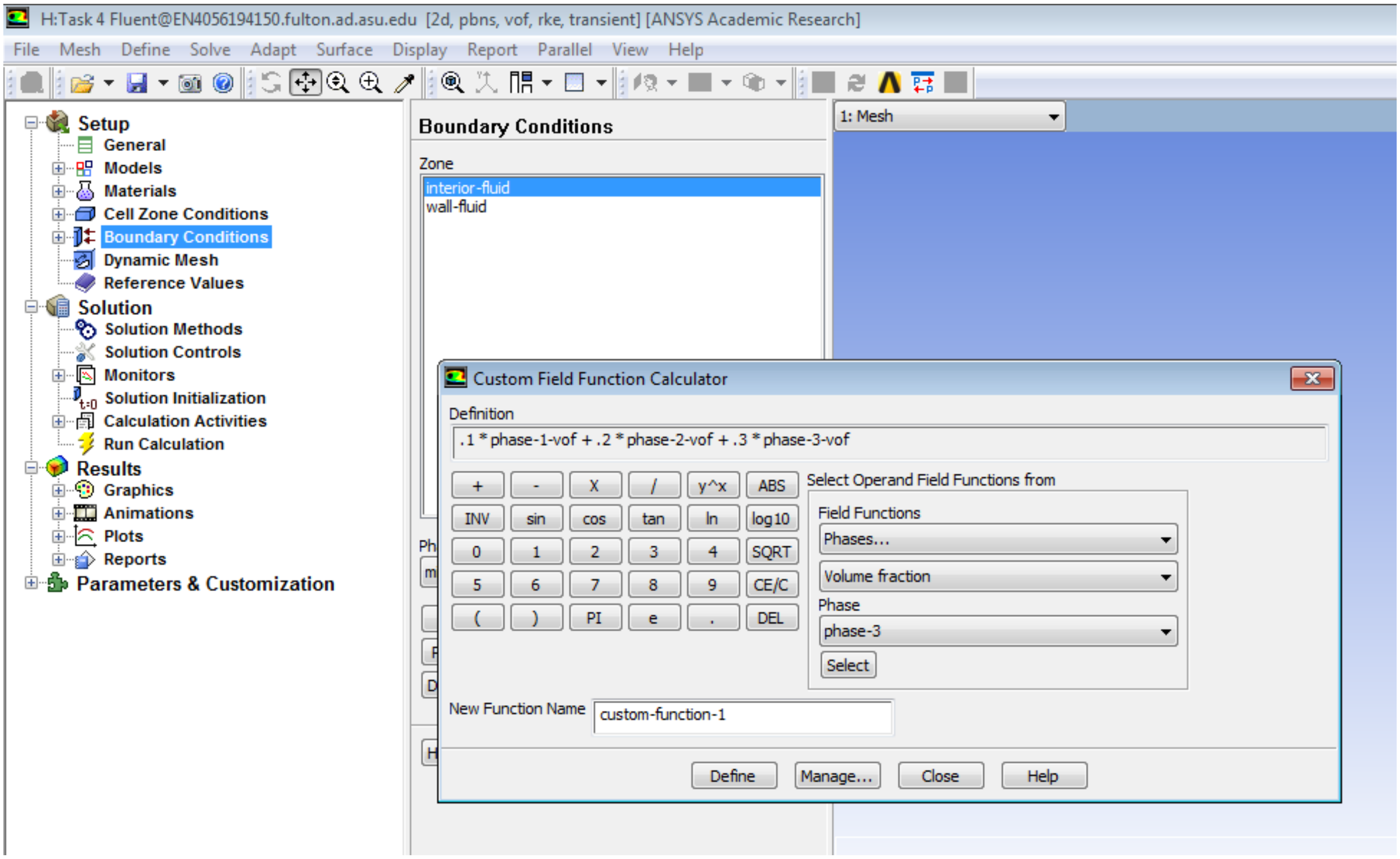


Options: ● Inside ○ Outside
Shapes: ● Quad ○ Circle ○ Cylinder
Input Coordinates
X Min (m): 0
X Max (m): 0.4
Y Min (m): 0
Y Max (m): 0.6
Z Min (m): 0
Z Max (m): 0

A plot of the volume fraction of phase-1 would not properly show the distribution of the three phases, since the areas covered by both phase-2 and phase-3 will have zero values. For example, Custom Field Function is used

$$\boldsymbol{CF} = 0.1*\mathrm{VF1} + 0.2*\mathrm{VF2} + 0.3*\mathrm{VF3}\ ,$$

VFn is the volume fraction of the n-th phase, the contour plot of **CF** will have the values of 0.1, 0.2, and 0.3 for the areas covered by phase-1, phase-2, and phase-3.



H:Task 4 Fluent@EN4056194150.fulton.ad.asu.edu [2d, pbns, vof, rke, transient] [ANSYS Academic Research]

Custom Field Function Calculator

Definition: .1 * phase-1-vof + .2 * phase-2-vof + .3 * phase-3-vof

Select Operand Field Functions from

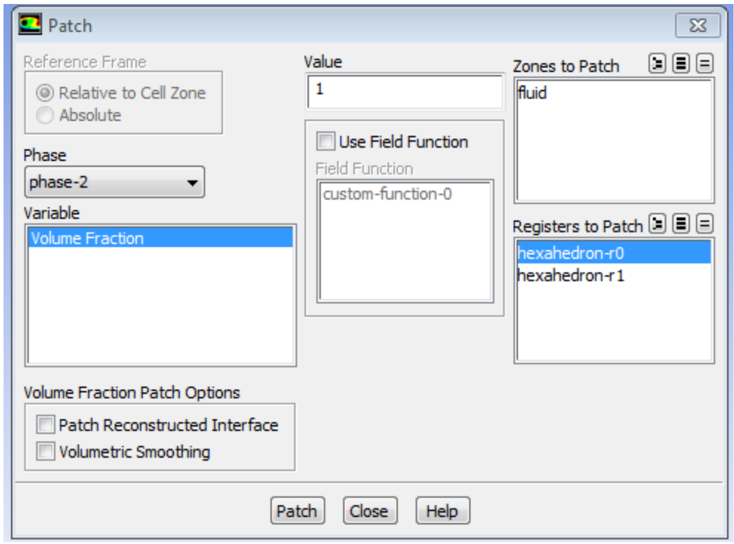
Field Functions: Phases...

Volume fraction

Phase: phase-3

New Function Name: custom-function-1

We initialize the solution and patch the phase-2 with Volume Fraction 1 for the Region 1 and phase-2 with Volume Fraction 0 for the Region 2. We also patch the phase-3 with Volume Fraction 1 for the Region 2 and phase-3 with Volume Fraction 0 for the Region 1.



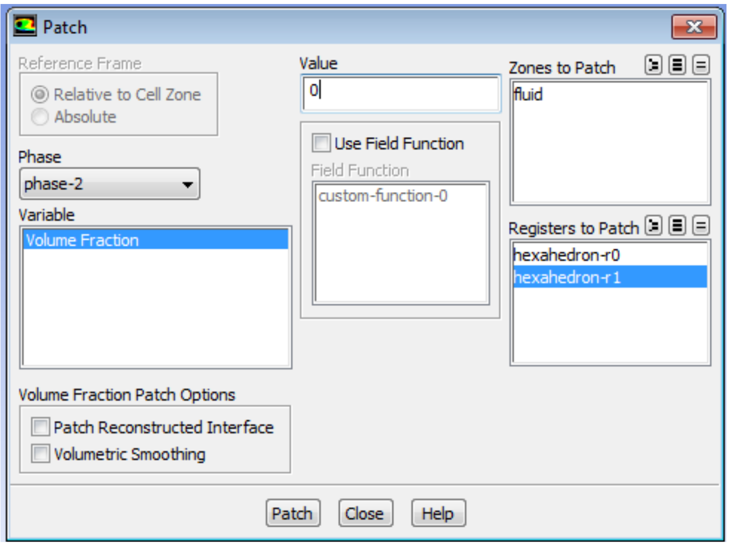
Phase: phase-2

Variable: Volume Fraction

Value: 1

Zones to Patch: fluid

Registers to Patch: hexahedron-r0 (selected), hexahedron-r1



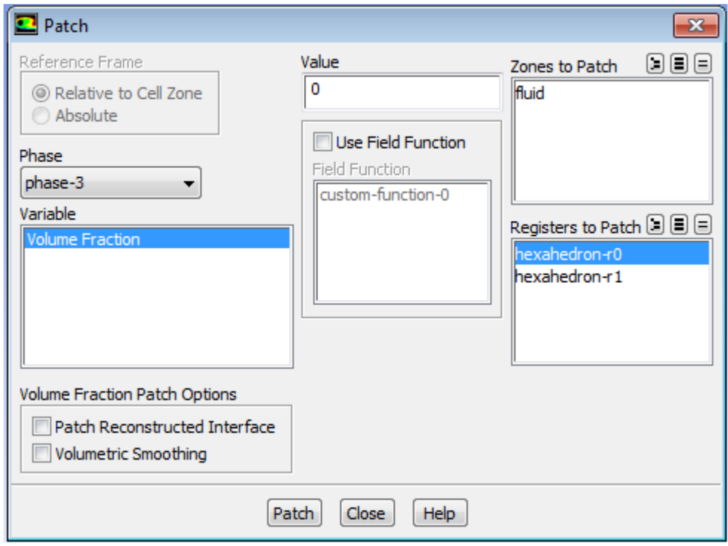
Phase: phase-2

Variable: Volume Fraction

Value: 0

Zones to Patch: fluid

Registers to Patch: hexahedron-r0, hexahedron-r1 (selected)



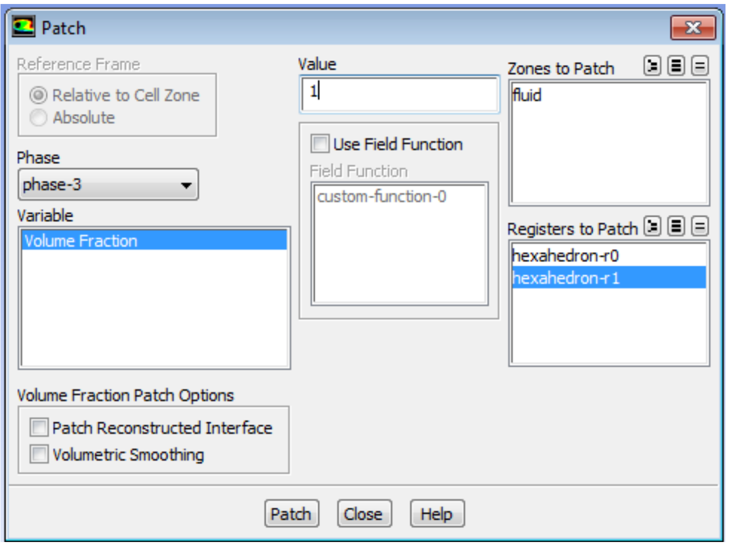
Phase: phase-3

Variable: Volume Fraction

Value: 0

Zones to Patch: fluid

Registers to Patch: hexahedron-r0 (selected), hexahedron-r1



Phase: phase-3

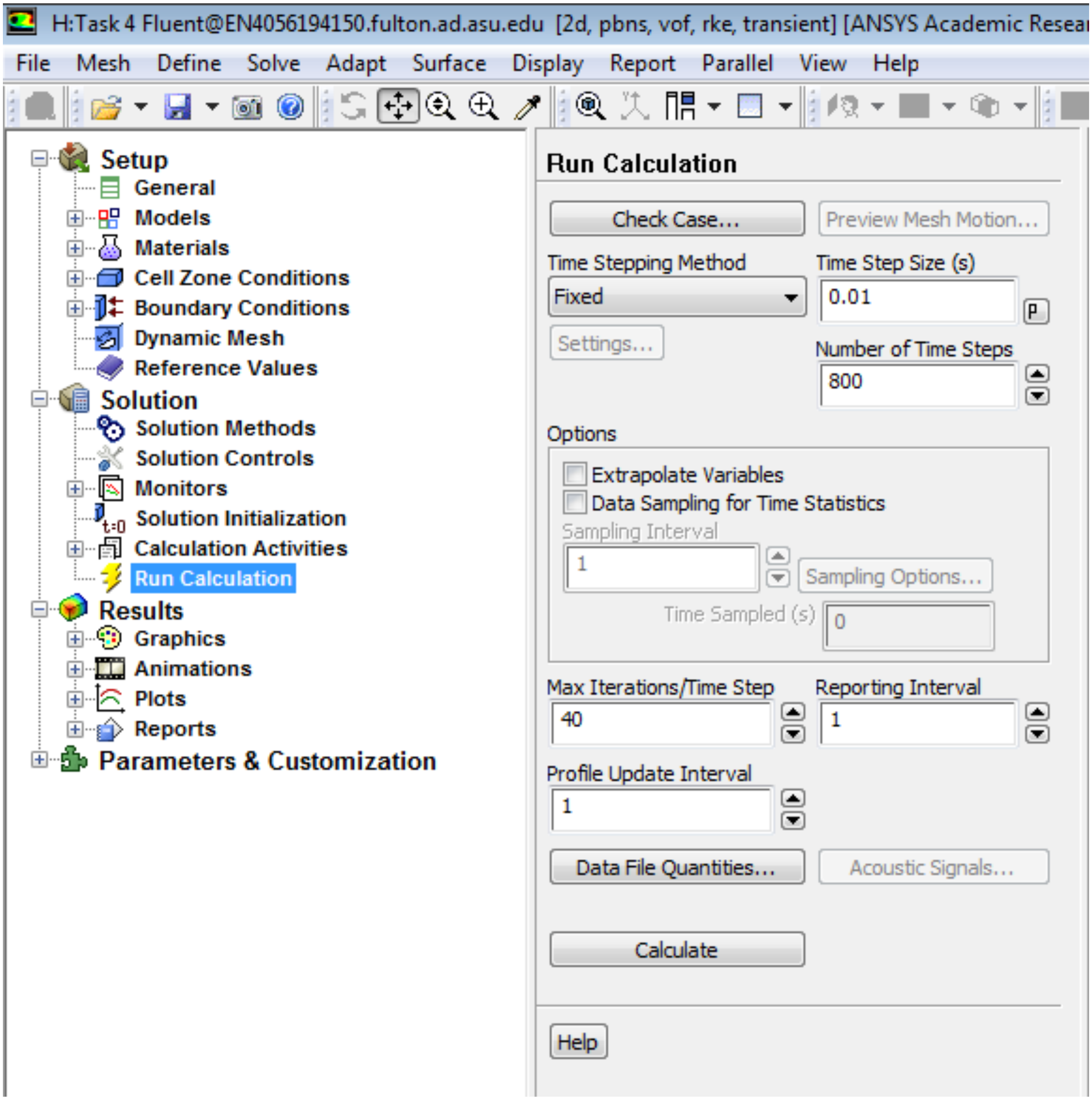
Variable: Volume Fraction

Value: 1

Zones to Patch: fluid

Registers to Patch: hexahedron-r0, hexahedron-r1 (selected)

The calculation is run with time step **0.01** and for **800** number of time steps where the data is saved after every 100 time steps to get the solution for 1, 4 and 8 seconds.



Time Stepping Method: Fixed

Time Step Size (s): 0.01

Number of Time Steps: 800

☐ Extrapolate Variables

☐ Data Sampling for Time Statistics

Sampling Interval: 1

Time Sampled (s): 0

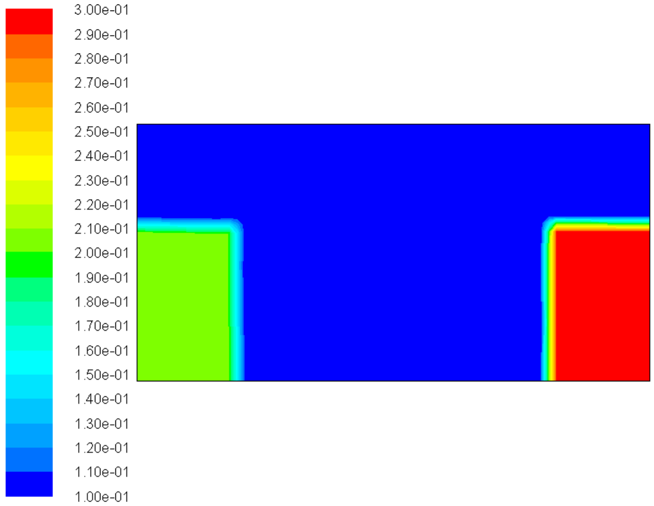
Max Iterations/Time Step: 40

Reporting Interval: 1

Profile Update Interval: 1

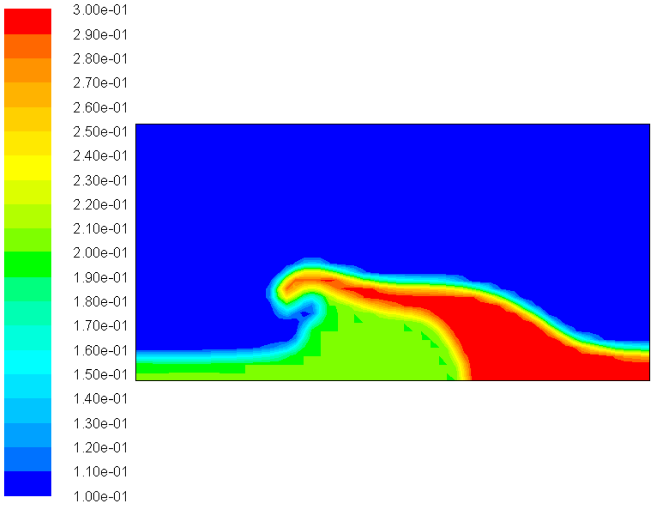
Results

Time= 0 second



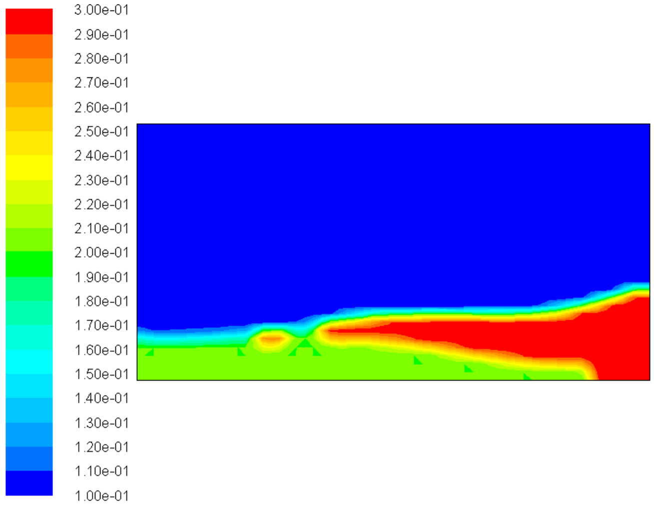
Contours of custom-function-0 (mixture) (Time=0.0000e+00)

Time= 1 second



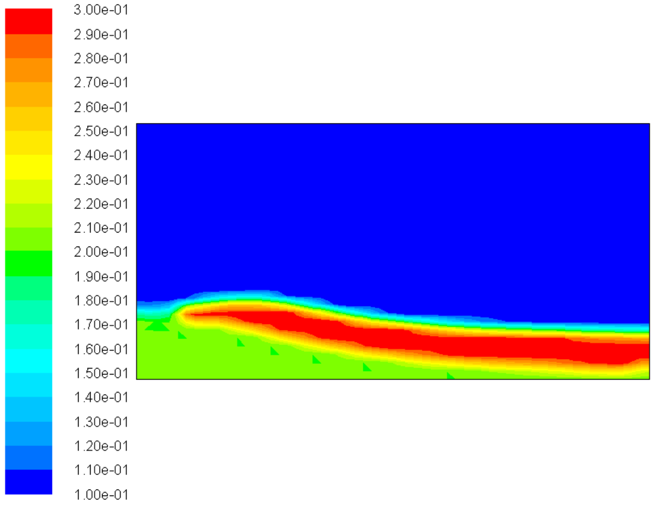
Contours of custom-function-0 (mixture) (Time=1.0000e+00)

Time= 4 seconds



Contours of custom-function-0 (mixture) (Time=4.0000e+00)

Time= 8 seconds



Contours of custom-function-0 (mixture) (Time=8.0000e+00)

From the plots we can see that at 0 seconds both the water and the engine oil are in their respective regions. When they start mixing, since the density of engine oil is les than the density of water it floats on top of the water. Therefore we can see that the red color, which is the engine oil, is on top of the green color, which is water. Moreover from the plots we can see that the green color goes up to the end while the red color just goes up to 3/4th of the region in 8 seconds, this is because the viscosity of water is less than engine oil therefore water mixes to a great extent than that of engine oil.