Progress Report:
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Ansys Fluent Simulation Group

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Overview

Mixing identical fluids in varying geometries

Pressure variations within flow domains

Discrete particle tracking

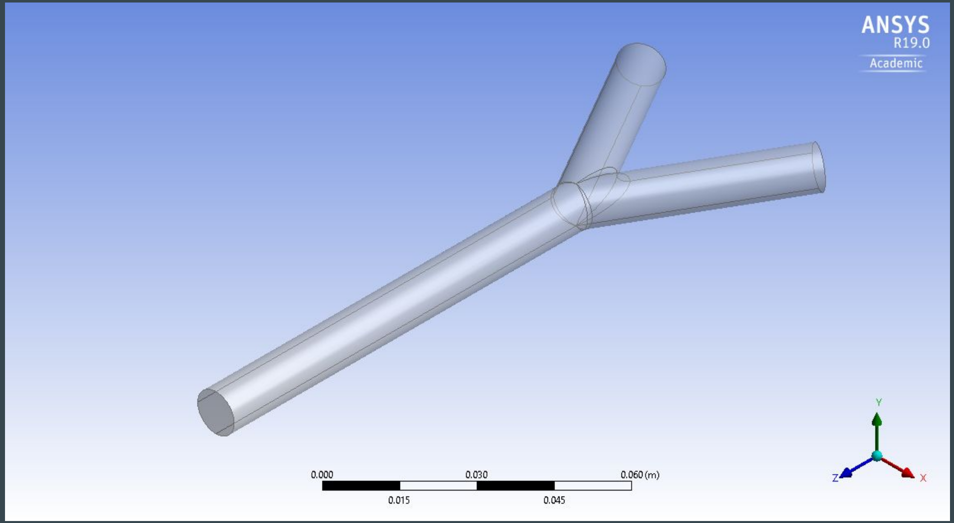
Time transient solutions

Geometry Variation of the pipes

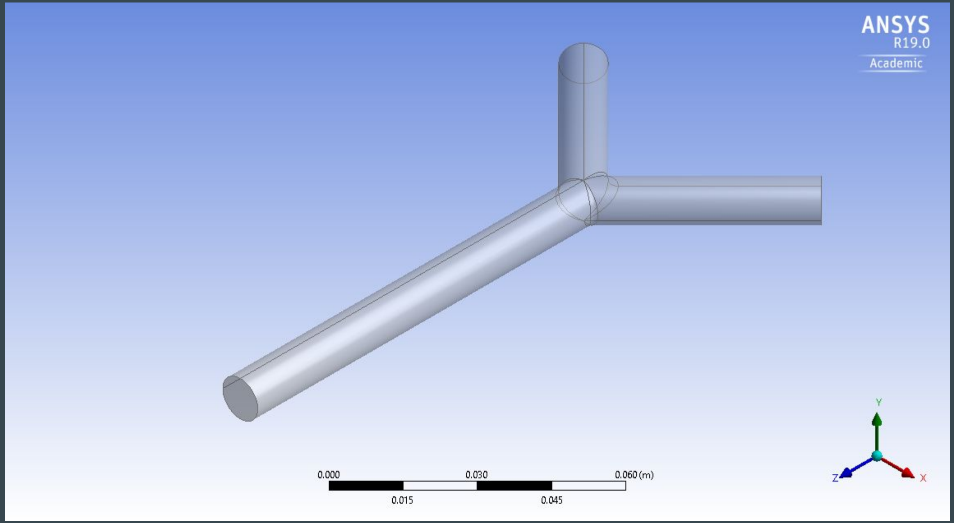
- See the effect on mixing of two identical fluids whilst varying inlet angles
- Two inlets and one outlet i.e. a faucet or a shower head and results could be applied for ex. two conjoining flows in a river for mixing of dyes
- 1 cm diameter pipe with outlet pipe 10 cm in length

The different geometries

- 60 degree angle entry

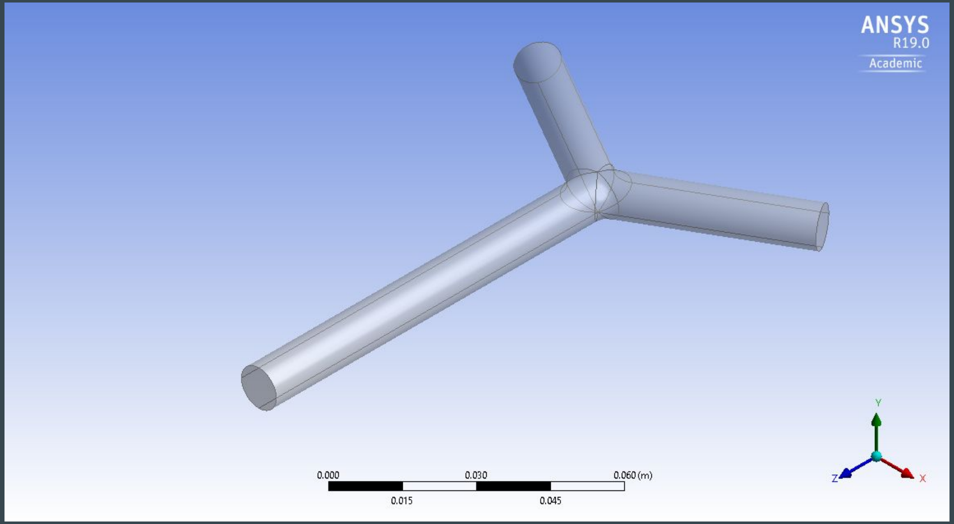


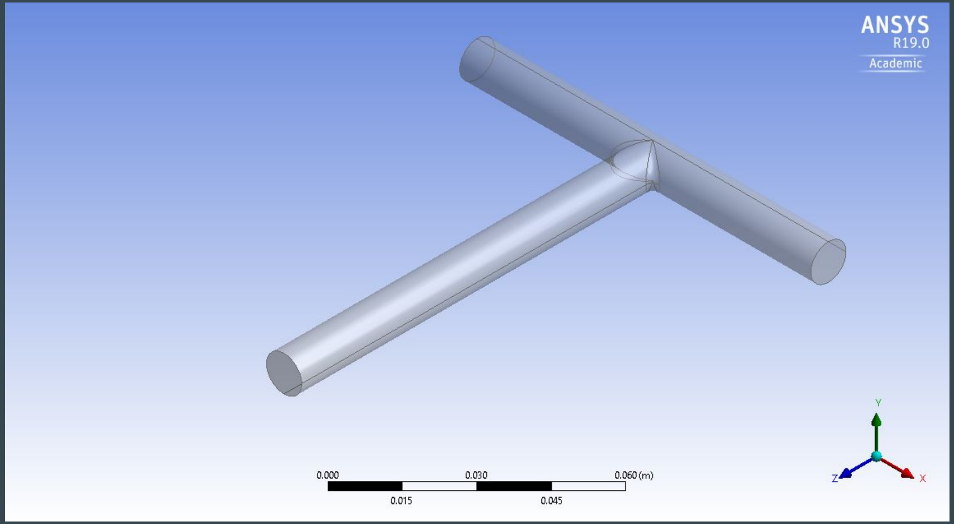
- 90 degree angle entry



The different geometries contd.

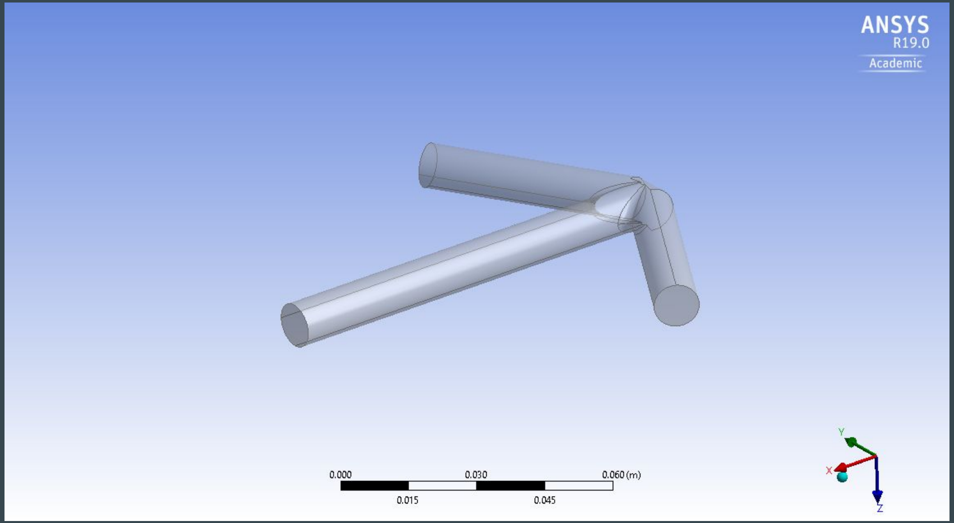
- 120 degree angle entry
- 180 degree angle entry(T-Pipe)



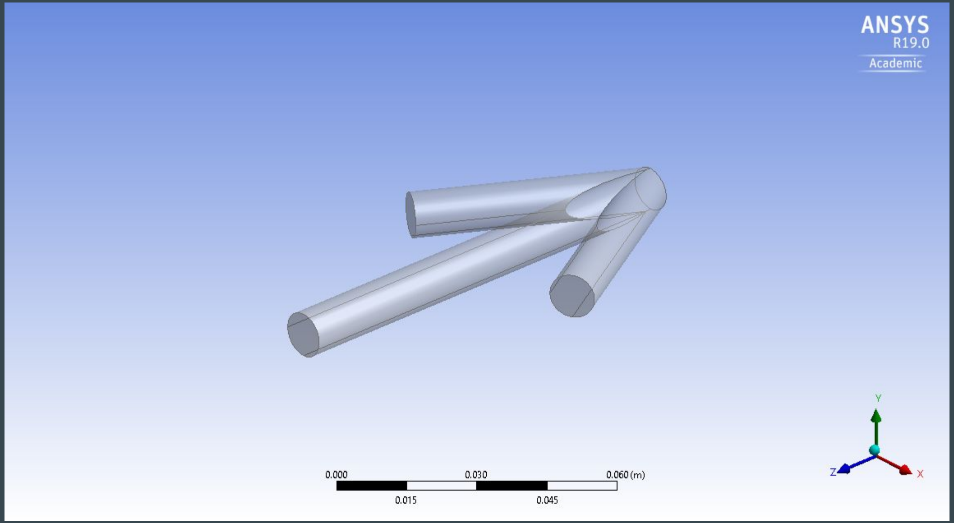


The different geometries cont. 2

- 240 degree angle entry



- 300 degree angle entry

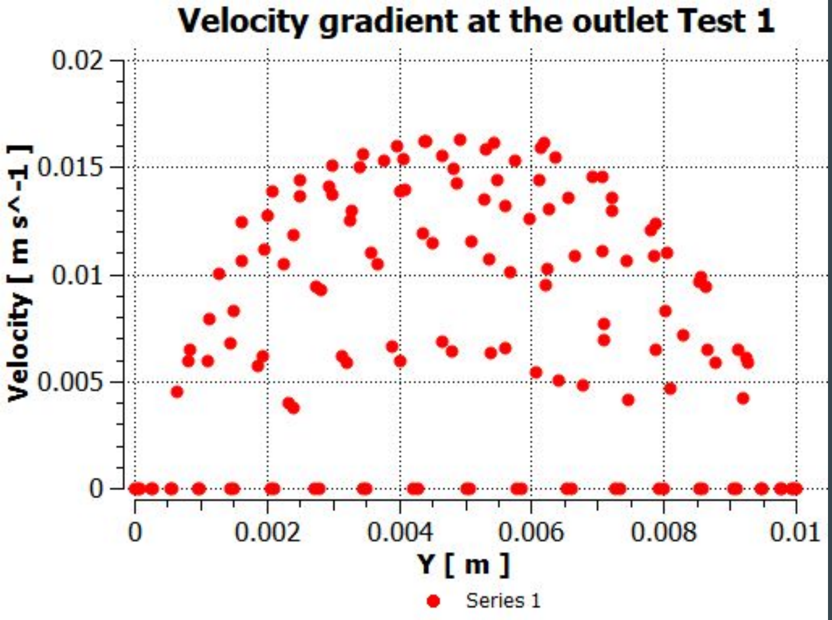


Data: Level of mixing

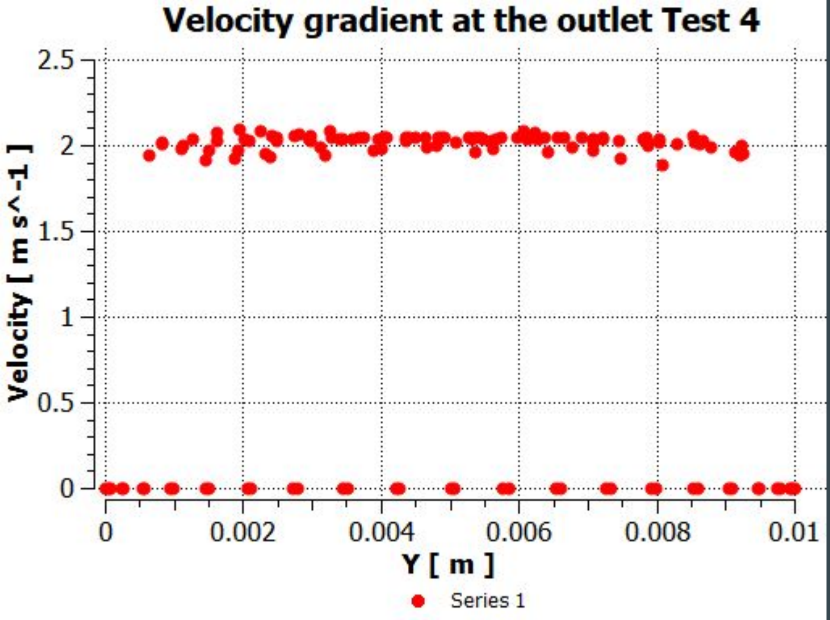
Dimensions Outlet Length: ~10 cm Pipe Outlet surface area: 1 cm diameter Pipe inlet surface area(s): 1 cm diameter Simulation type: Steady state	Test #	Inlet 1 velocity (m/s)	Inlet 2 Velocity (m/s)	Type of flow	Mass Flow rate for Inlet 1 [kg s^-1]	Mass Flow rate for Inlet 2 [kg s^-1]	Mass Flow rate for Outlet [kg s^-1]	Mixing Level 60-degree bend	Mixing Level 90-degree bend	Mixing level 120-degree bend	Mixing Level 180-degree bend (T-pipe)	Mixing Level 240-degree bend	Mixing Level 300-degree bend
	1	.005	.005	Laminar	0.000390381	0.000390381	-0.000780921	No mixing	No mixing	No mixing	No mixing	No mixing	no mixing
	2	.01	.01	Laminar	0.00078076	0.000780763	-0.00156123	No mixing	No mixing	No mixing	No mixing	No mixing	No mixing
	3	.5	.5	Turbulent	0.0390381	0.0390381	-0.0779936	No mixing	No mixing	No mixing	No mixing	No mixing	No mixing
	4	1	1	Turbulent	0.0779936	0.0779936	-0.156308	No mixing	No mixing	No mixing	No mixing	No mixing	No mixing
	5	.001	.003	Laminar	7.80763e-005	0.000234229	-0.000312303	Very Little mixing	Enveloping flow	Little mixing	Little mixing	Little mixing	Little mixing
	6	.005	.1	Laminar	0.000390381	0.00780763	-0.00820448	Very Little mixing	Enveloping flow	Little mixing	Little mixing	Little mixing	Little mixing
	6	.5	1.5	Turbulent	0.0390381	0.117114	-0.156079	Very Little mixing	Little mixing	Little mixing	Little mixing	Little mixing	Little mixing
	8	.5	5	turbulent	0.0390381	0.390381	-0.429524	No mixing	No mixing	No mixing	No mixing	No mixing	No mixing
	9	.5	20	Turbulent	0.0390381	1.56153	-1.60008	Enveloping flow	Enveloping flow	Enveloping flow	Enveloping flow	Enveloping flow	Enveloping flow
	10	.5	.6	Turbulent	0.0391342	0.0469611	-0.0861732	Little mixing	Little mixing	Little mixing	Better mixing	better mixing	Better mixing

Velocity profiles

Laminar Flow

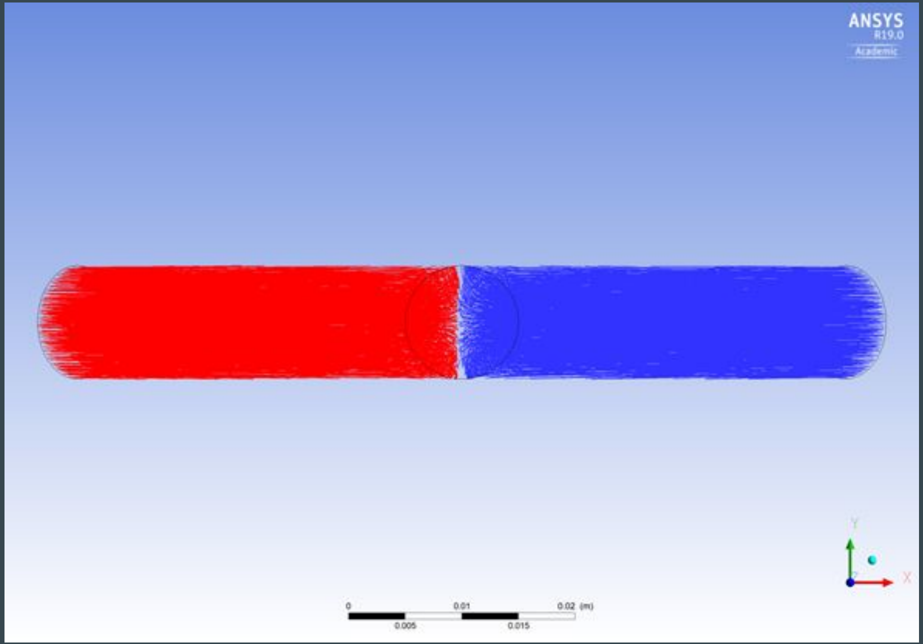


Turbulent

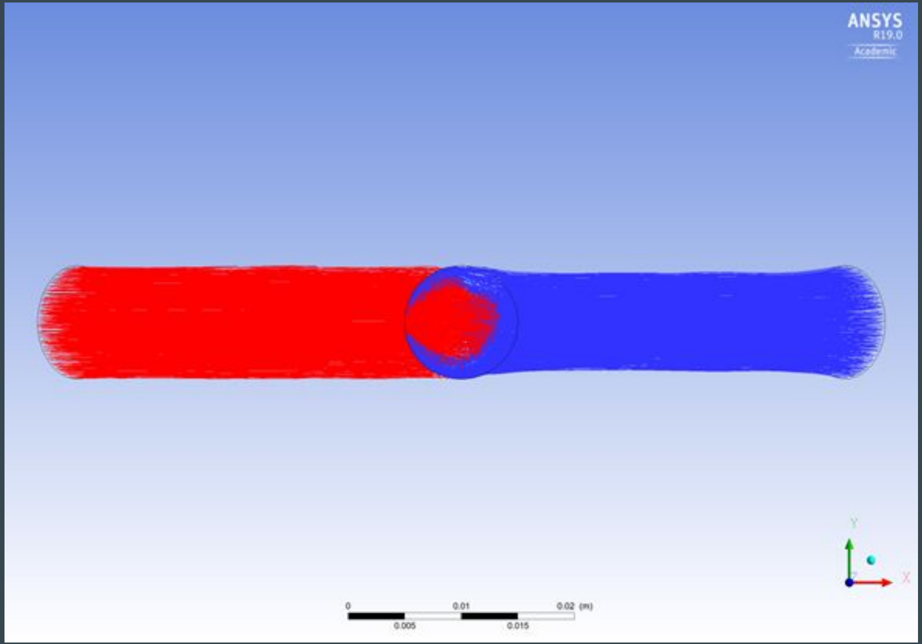


Mixing levels

No mixing



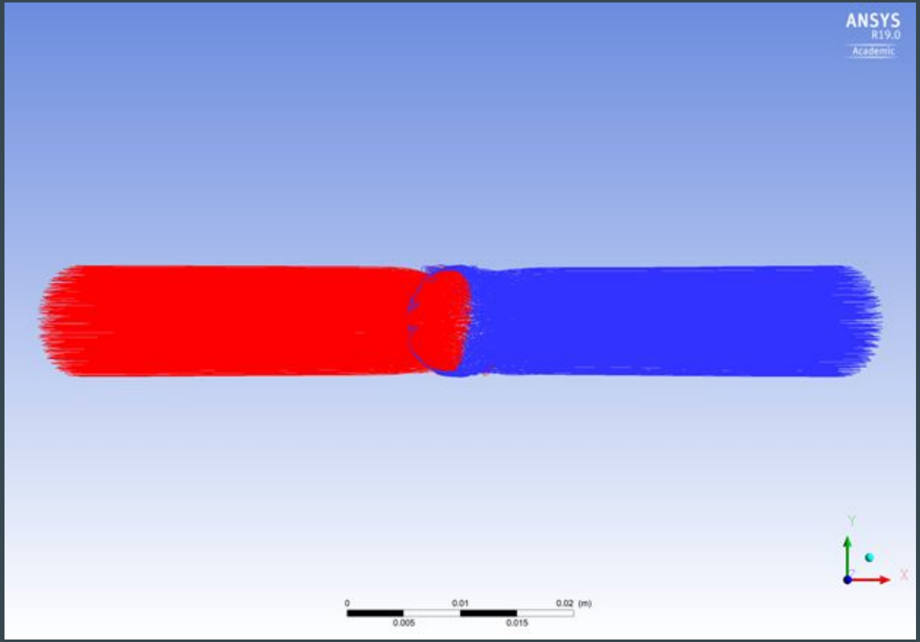
Enveloping flow



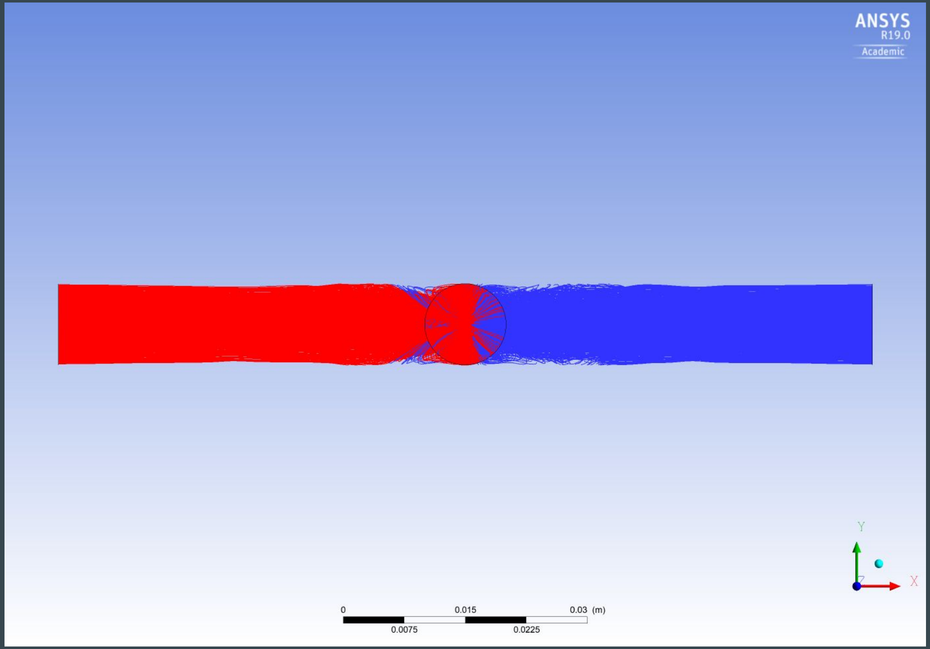
1000 Streamlines for each inlet

Mixing levels Cont.

Little mixing



Better mixing



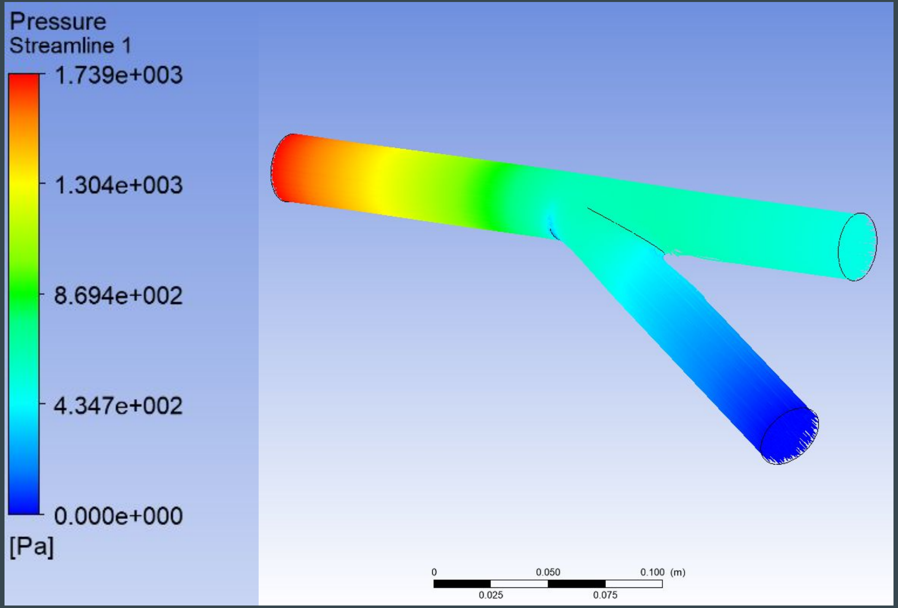
Conclusions

- Flow through two inlets of a tighter angle seem to go down their own paths
- As the angle of entry for two inlets gets bigger and bigger, a mixing chamber-esque volume seems to form
- Faucets and shower pipes seem to have two inlets that also go into mixing chamber volume
- Mixing seems to be greater in turbulent flow situations when compared to laminar

Pressure Variation

- Introduce pressure differences throughout pipe to simulate pressurized flow
- 1 inlet, 2 outlets
- 2 kPa gauge pressure at inlet, 500 Pa at outlet 1, atmospheric pressure at outlet 2
- Air cell zone material
- 40 cm long, 3 cm diameter
- Re number ≅ 406

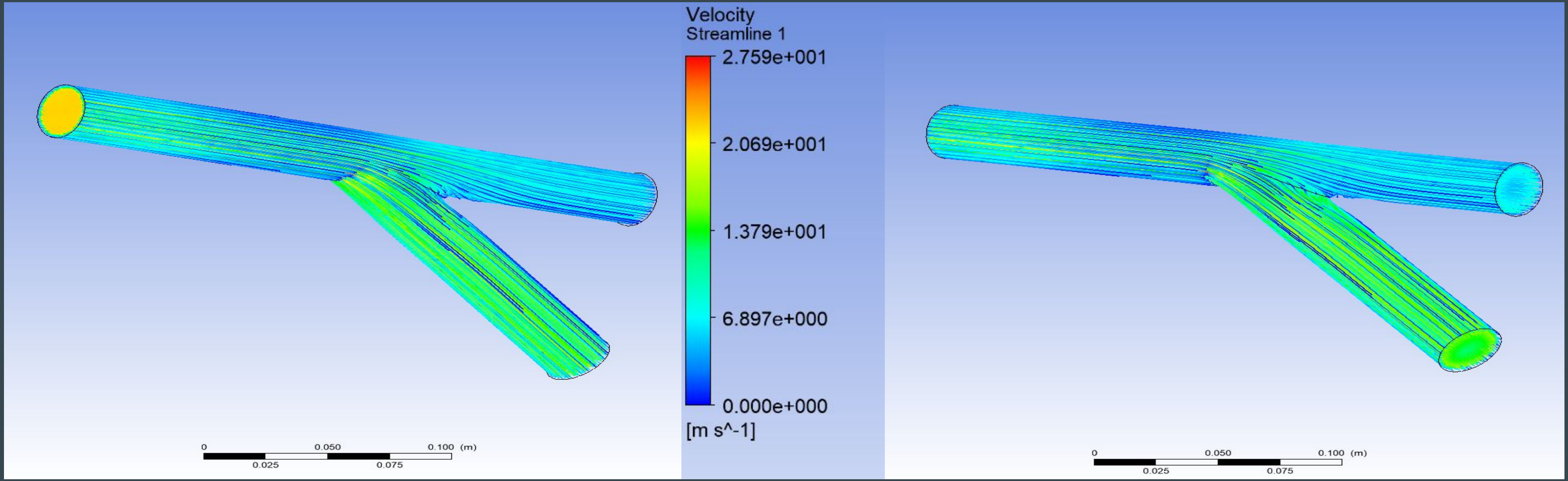
Pressure max: 1,739 Pa
Pressure min: 0 Pa



Velocity Streamline of Pressurized Pipe

Velocity max: 2.759 m/s
Velocity min: 0 m/s

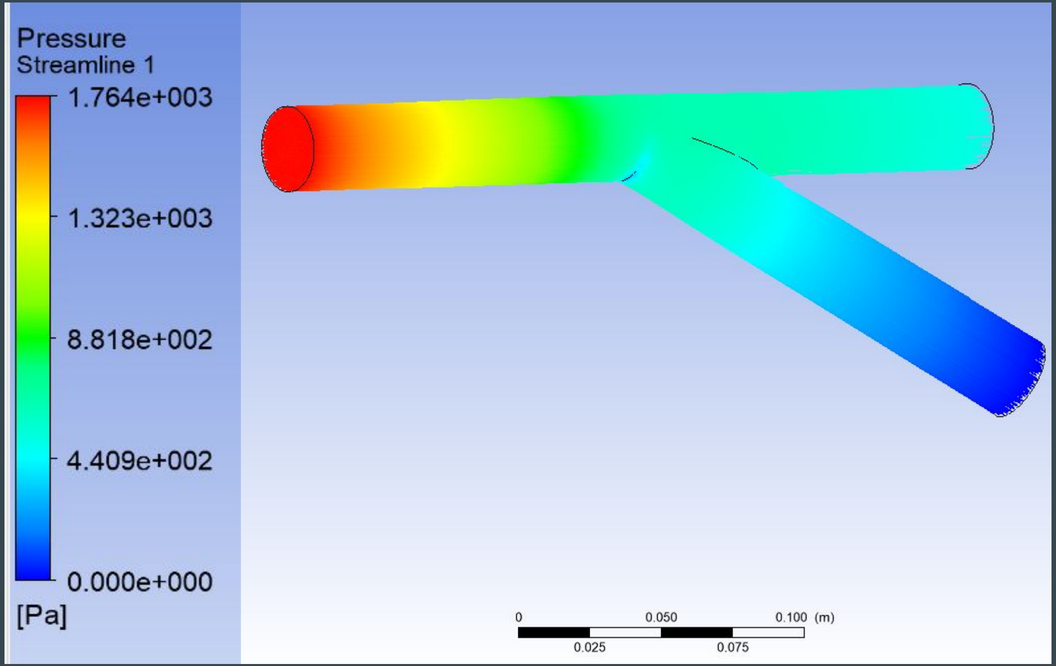
View from Inlet | View from Outlets



Pressure Variation Using Carbon Dioxide

- Same pipe dimensions as previous case
- Re number ≅ 6470

Pressure max: 1,764 Pa
Pressure min: 0 Pa

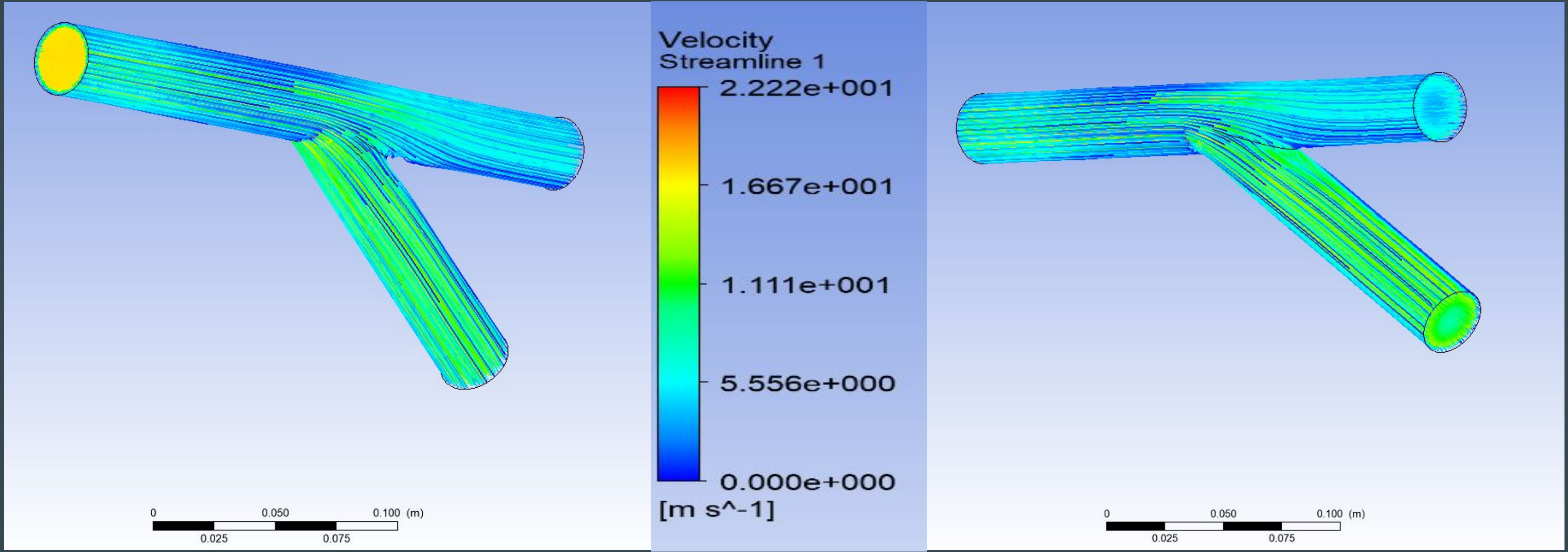


Velocity Streamlines with Carbon Dioxide Material

View With CO_2 Inlet

Velocity max: 2.22 m/s
Velocity min: 0 m/s

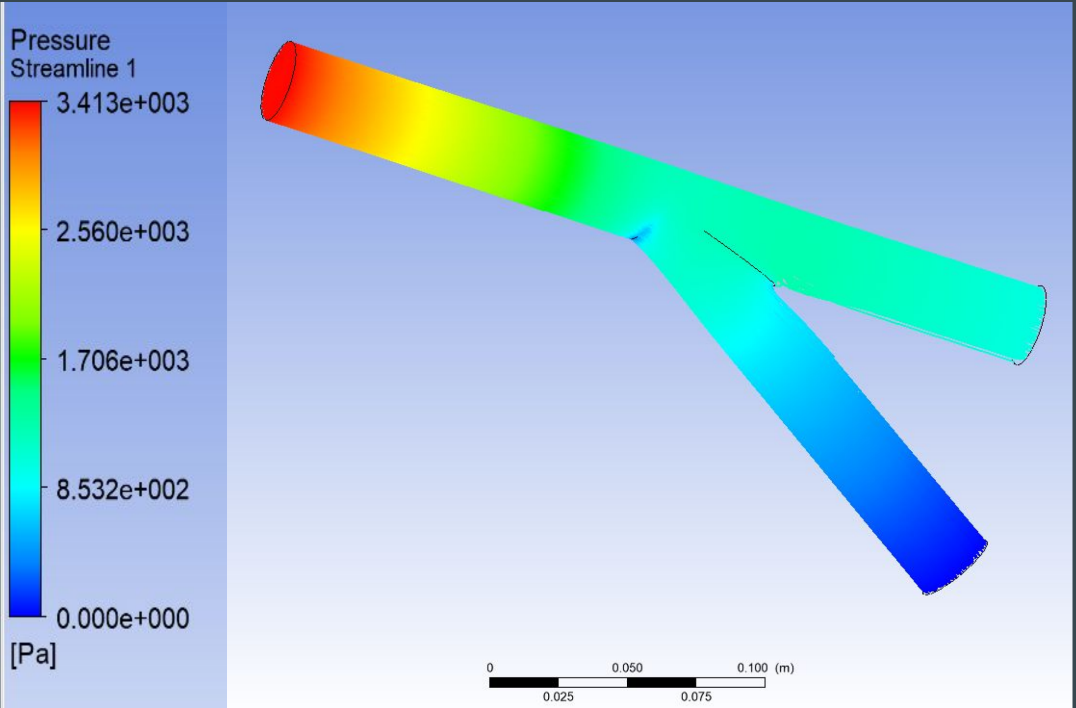
View With CO_2 Outlet



Velocity Streamlines with CO_2- Double Pressure

- Test Case 2: double pressures at inlet and outlets
- Re number ≅ 11,300

Pressure max: 3,413 Pa
Pressure min: 0 Pa

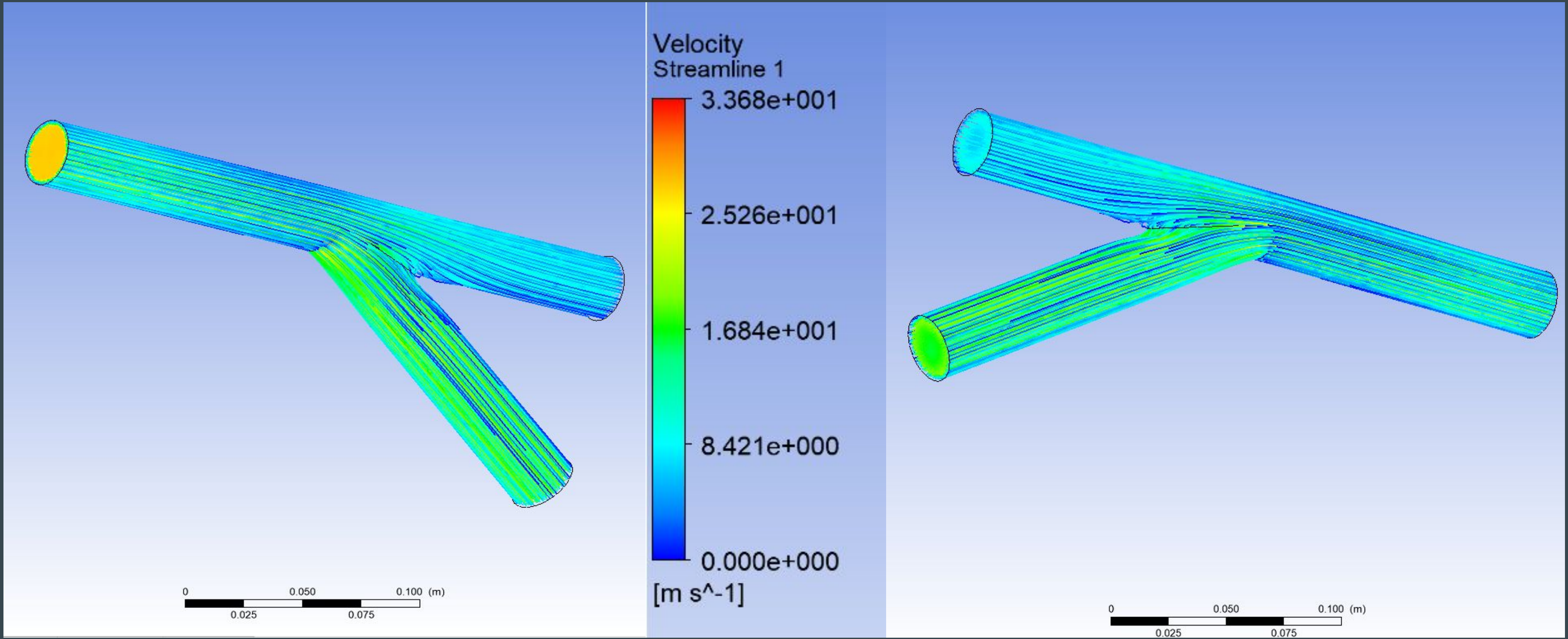


Resultant Velocity Streamlines- Double Pressure CO_2

Inlet View

Velocity max: 3.368 m/s
Velocity min: 0 m/s

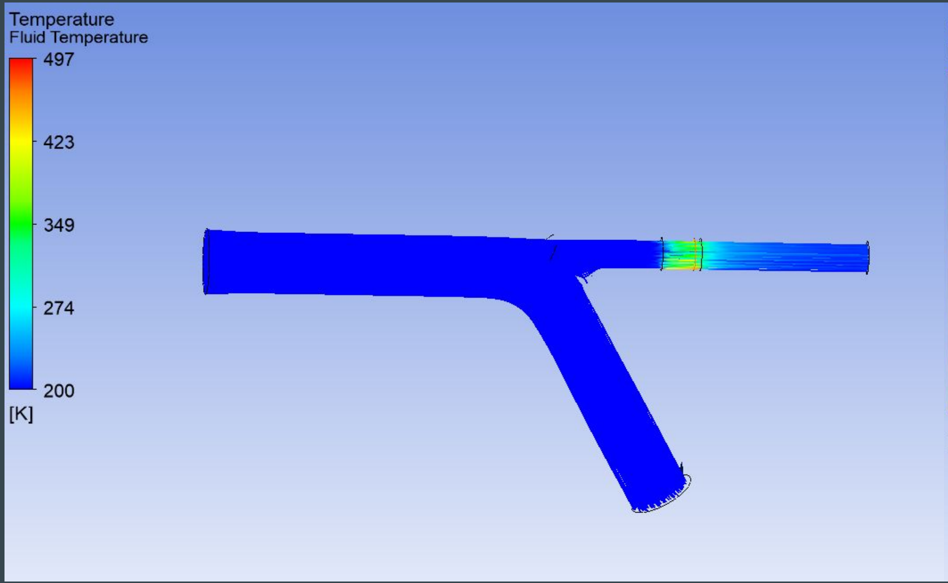
Outlet View

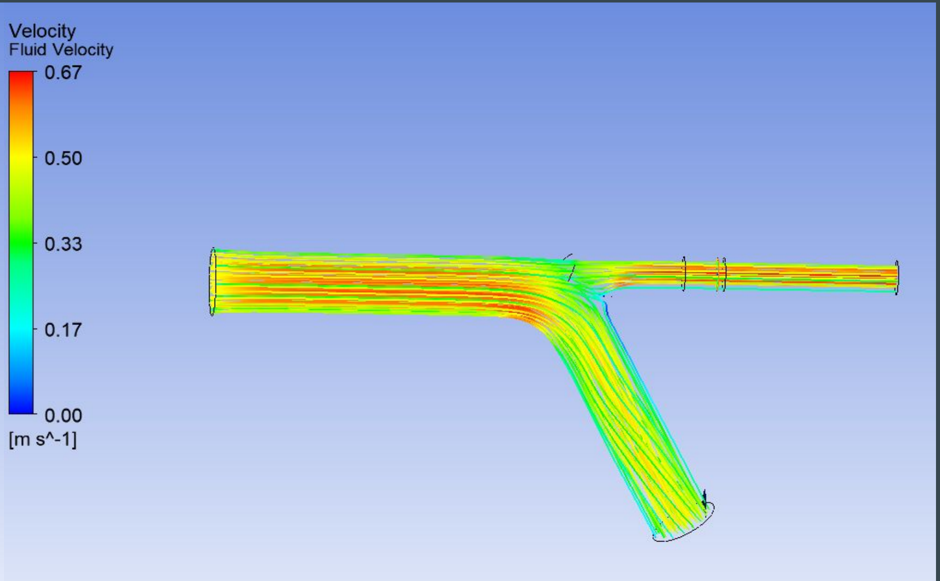


Deductions

- Changing the working fluid from Air to Carbon Dioxide changed the velocity of the streamlines
- ~24% velocity increase with change from Carbon Dioxide to Air.
  - Increase in molar mass leads to decrease in average velocity w/ pressure constant
- Pressure held constant.
- Interesting relationship
  - Molar mass of air is 29 g/mol, Carbon Dioxide is 44.01 g/mol.
  - $\sqrt{44.01/29} = 1.231$
- An increase in overall pressure (pressure difference) in the pipe increases velocity

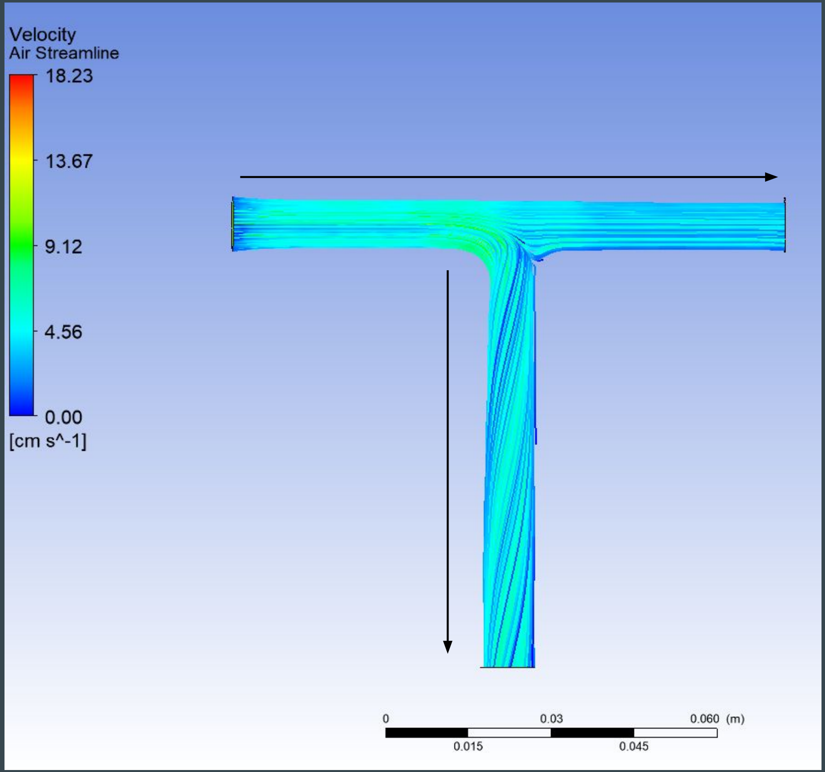
Temperature Manipulation





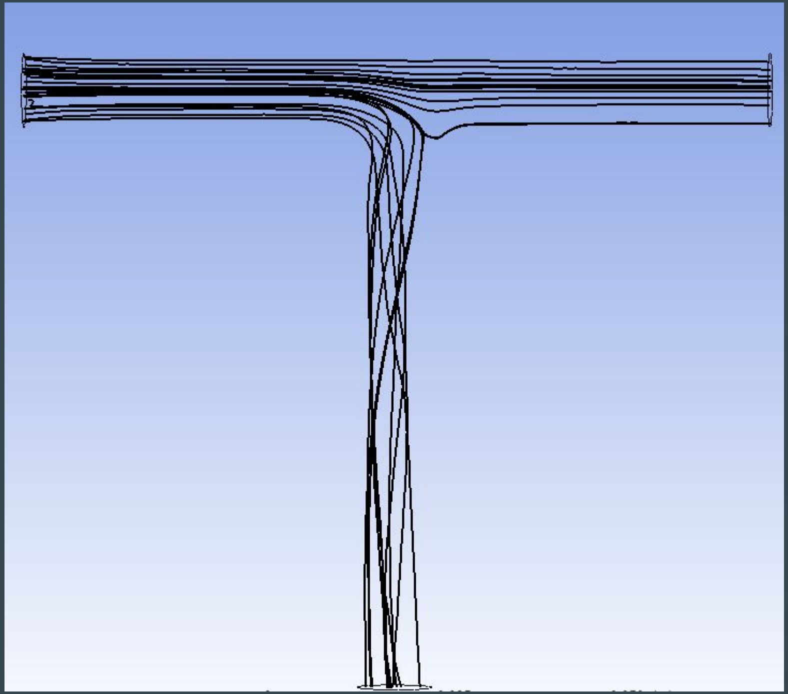
300 K pipe with 500 K hot zone

Particle Injection and Particle Size

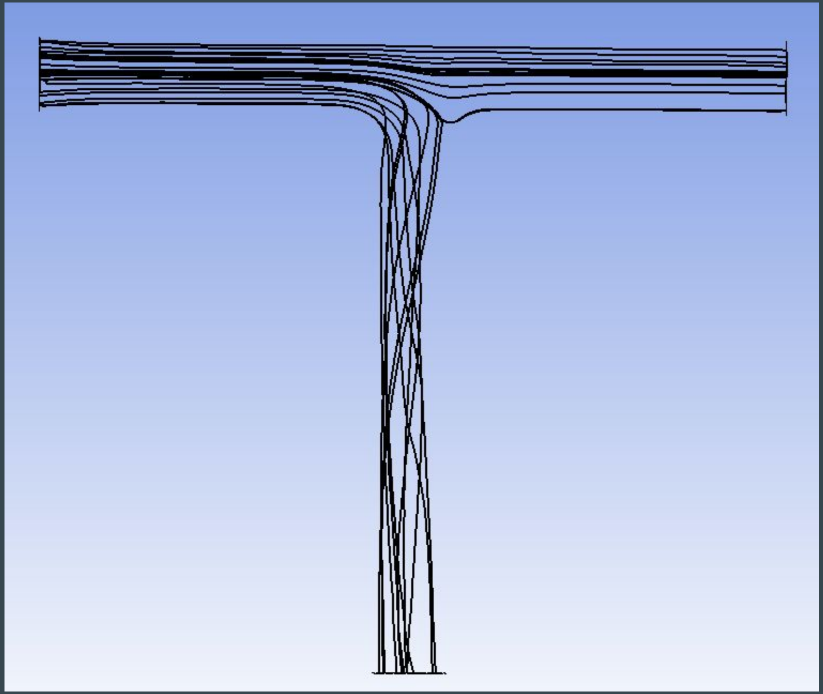


- 10 cm pipe, 1 cm diameter
- Airflow at 10 cm/s
- Inject particles at varying sizes
- Particle density - 1550 kg/m³

Particle Tracks 10 cm/s

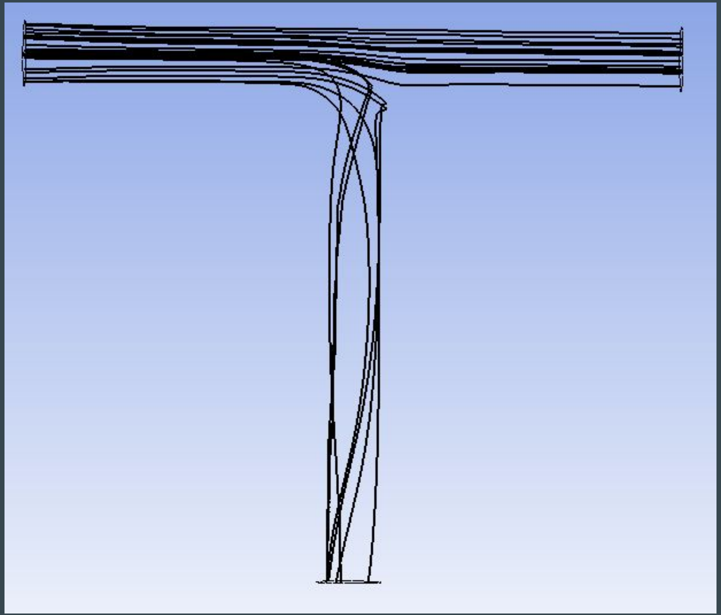


1 µm diameter particle
40% down, 60% right

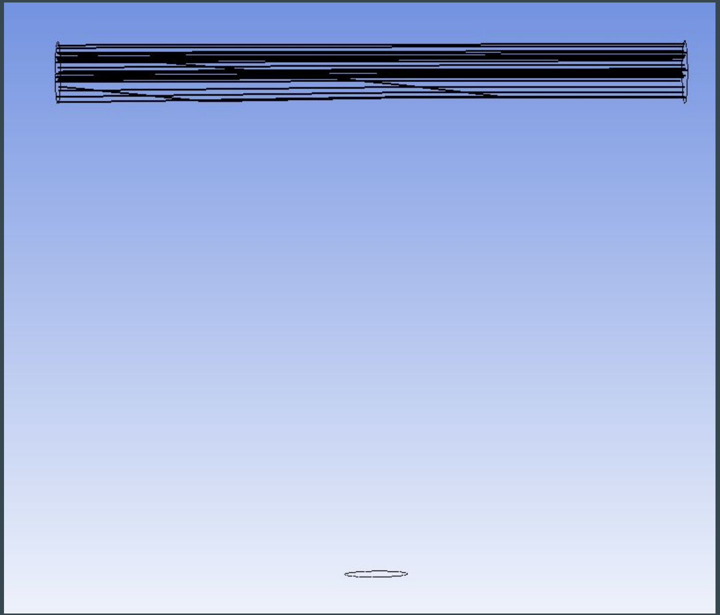


10 µm diameter particle
44 % down, 56% right

Particle Tracks 10 cm/s

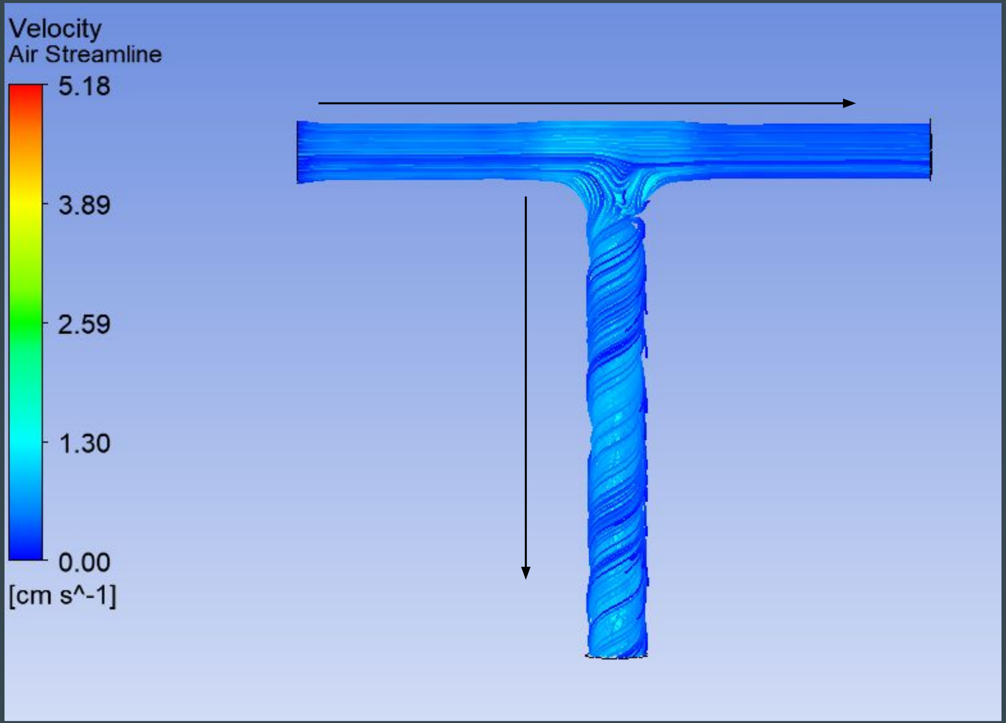


100 µm diameter particle
28% down, 72% right



1 mm diameter particle
100% right

Particle Injection and Particle Size



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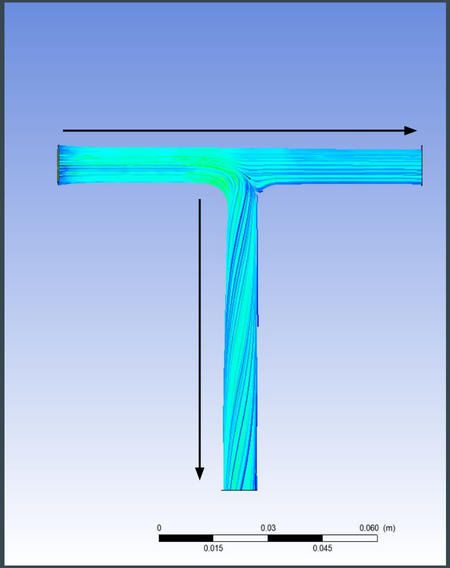
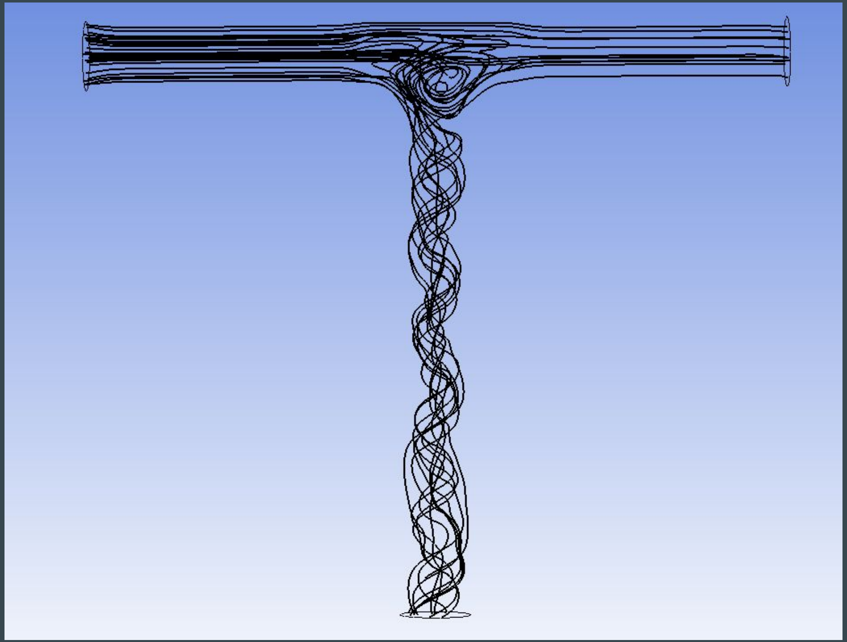
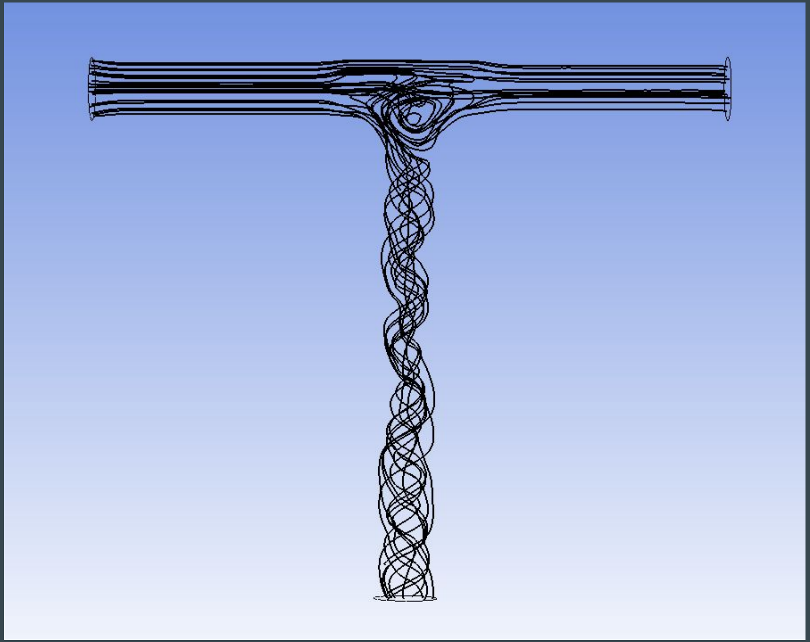
- Airflow at 1 cm/s
- Inject particles at varying sizes
- Particle density - 1550 kg/m³



Particle Tracks 1 cm/s

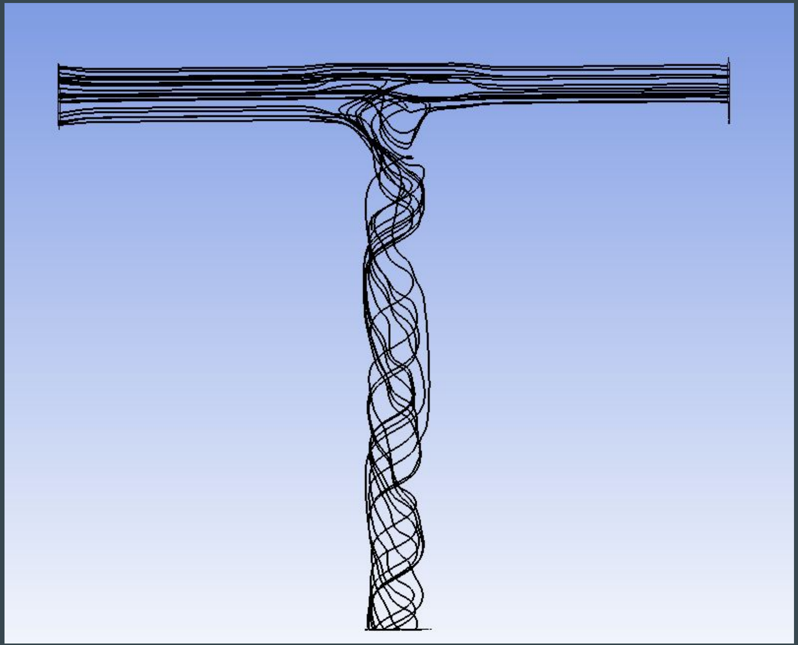


1 µm diameter particle
48% down, 52% right

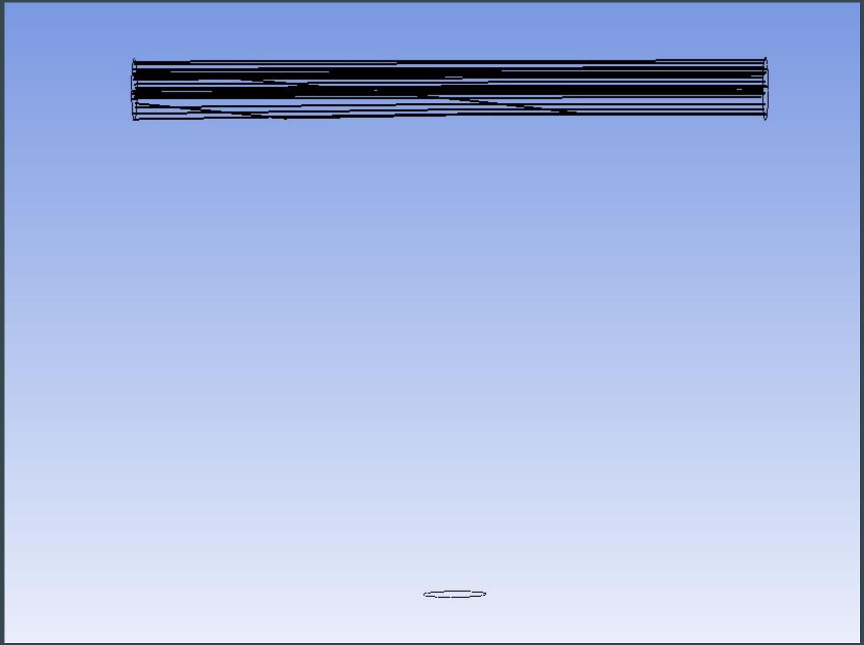


10 µm diameter particle
48% down, 52% right

Particle Tracks 1 cm/s



100 µm diameter particle
48% down, 52% right



1 mm diameter particle
100% right

Transient time solutions

Explore conditions that vary per time step

Use of a discrete phase model

Show vectors/streamlines/particle tracks that evolve over time

Can view still frames per time step and create animations

Constraints of transient time

Serve increase of computation time

Courant number: $C=c*(\Delta t/\Delta x)$

Shows imperative relationship between mesh size and time-step size

Solutions become divergent if C > 250, and program will crash

Implies that useful solutions always require high computation time

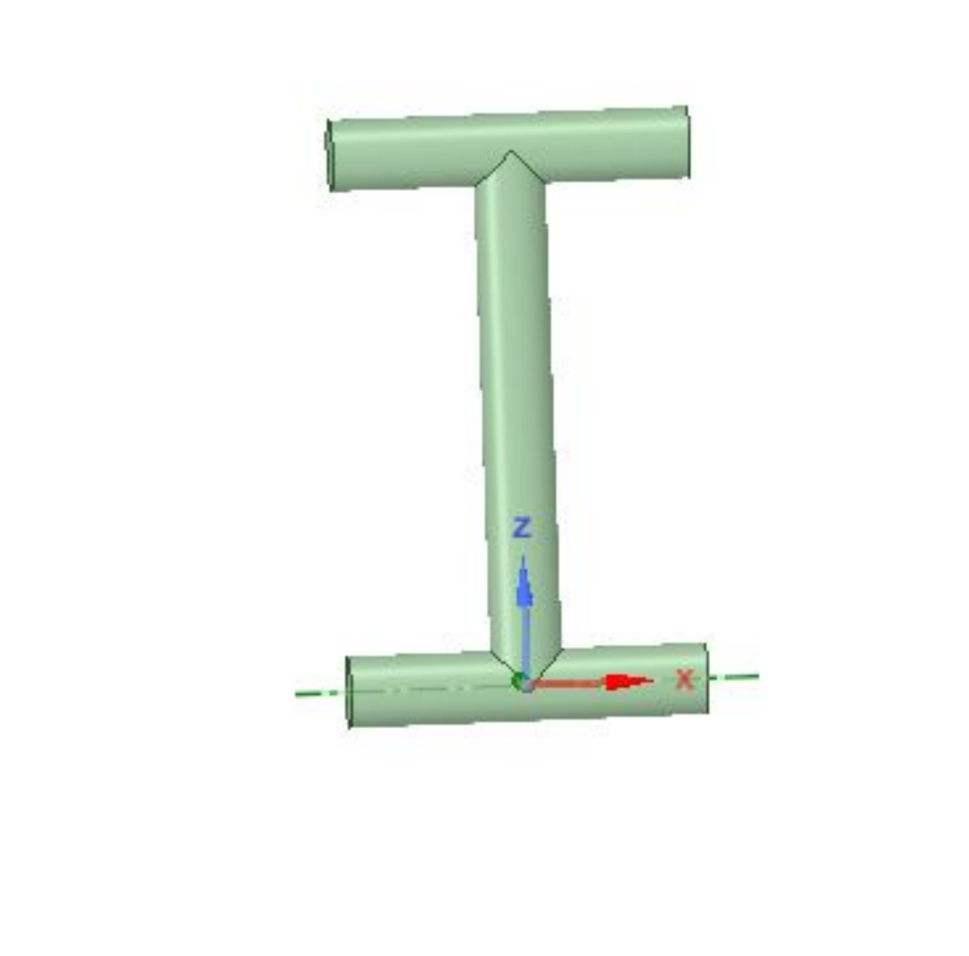
Brief synopsis

I-pipe geometry

0.5 m/s per outlet

K-epsilon turbulence model

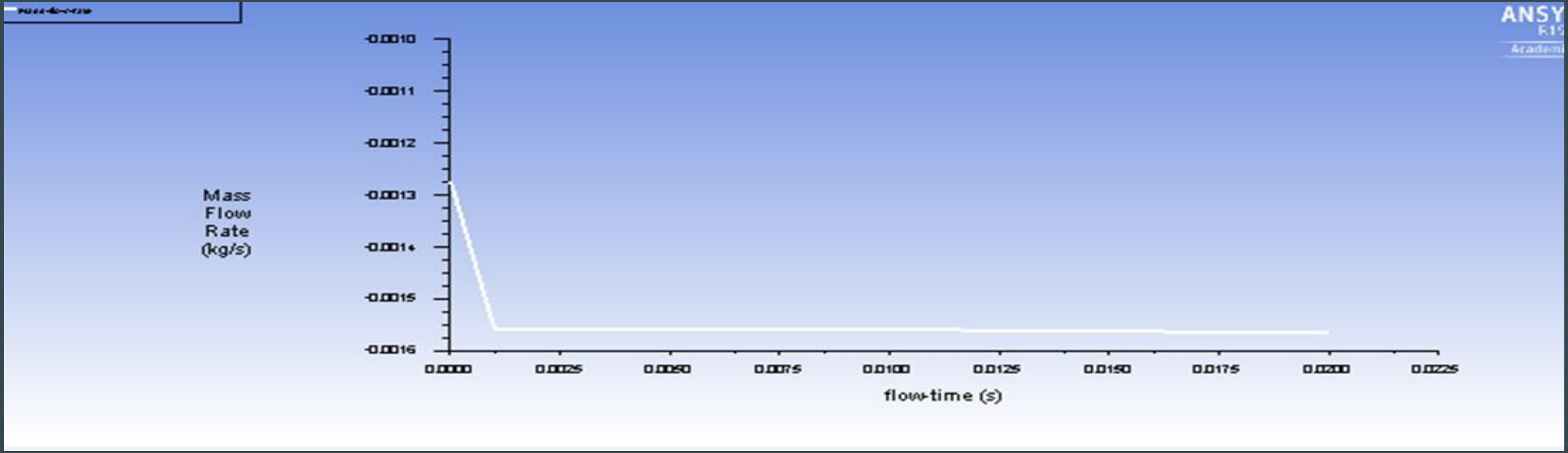
200 time steps, dt = 0.001s



Mass flow rate vs. time check

Mass flow rate from outlet

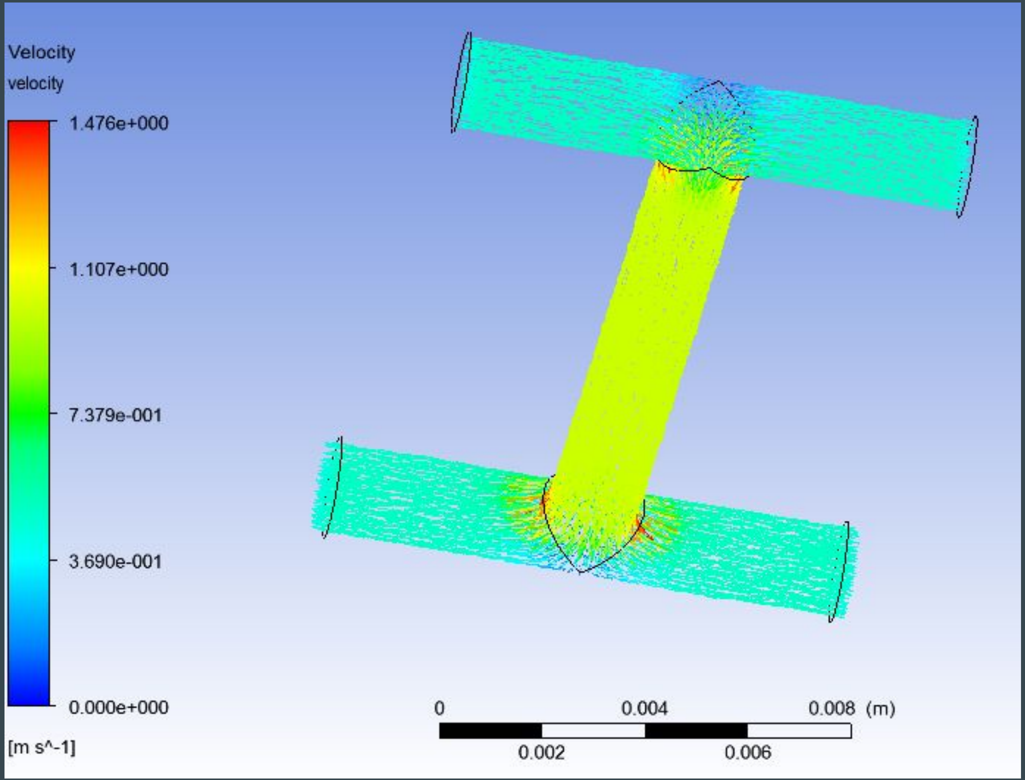
Starts at zero, becomes abruptly negative



Step 1 dt = 0.001s

Red: 1.47 m/s

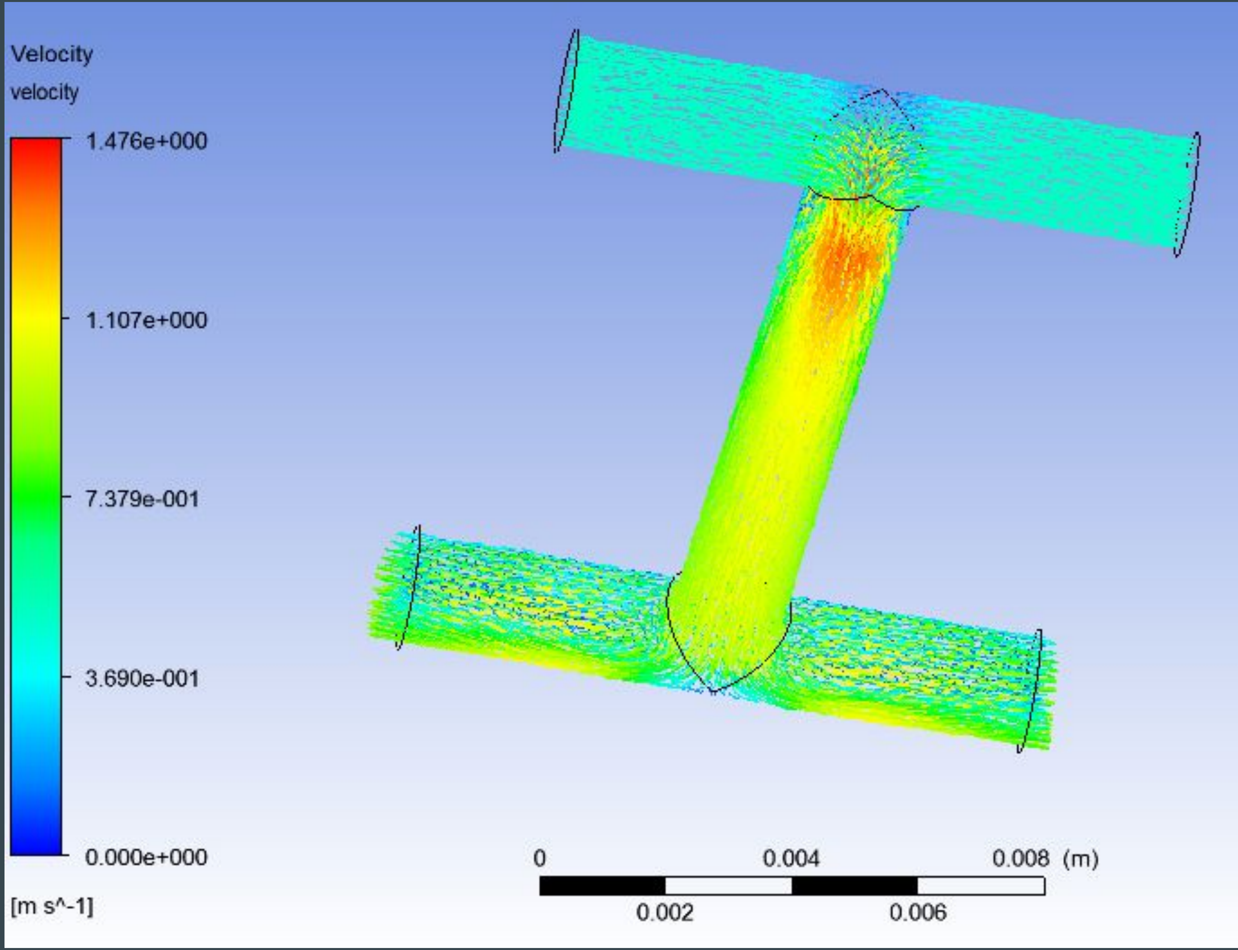
Dark blue: 0 m/s



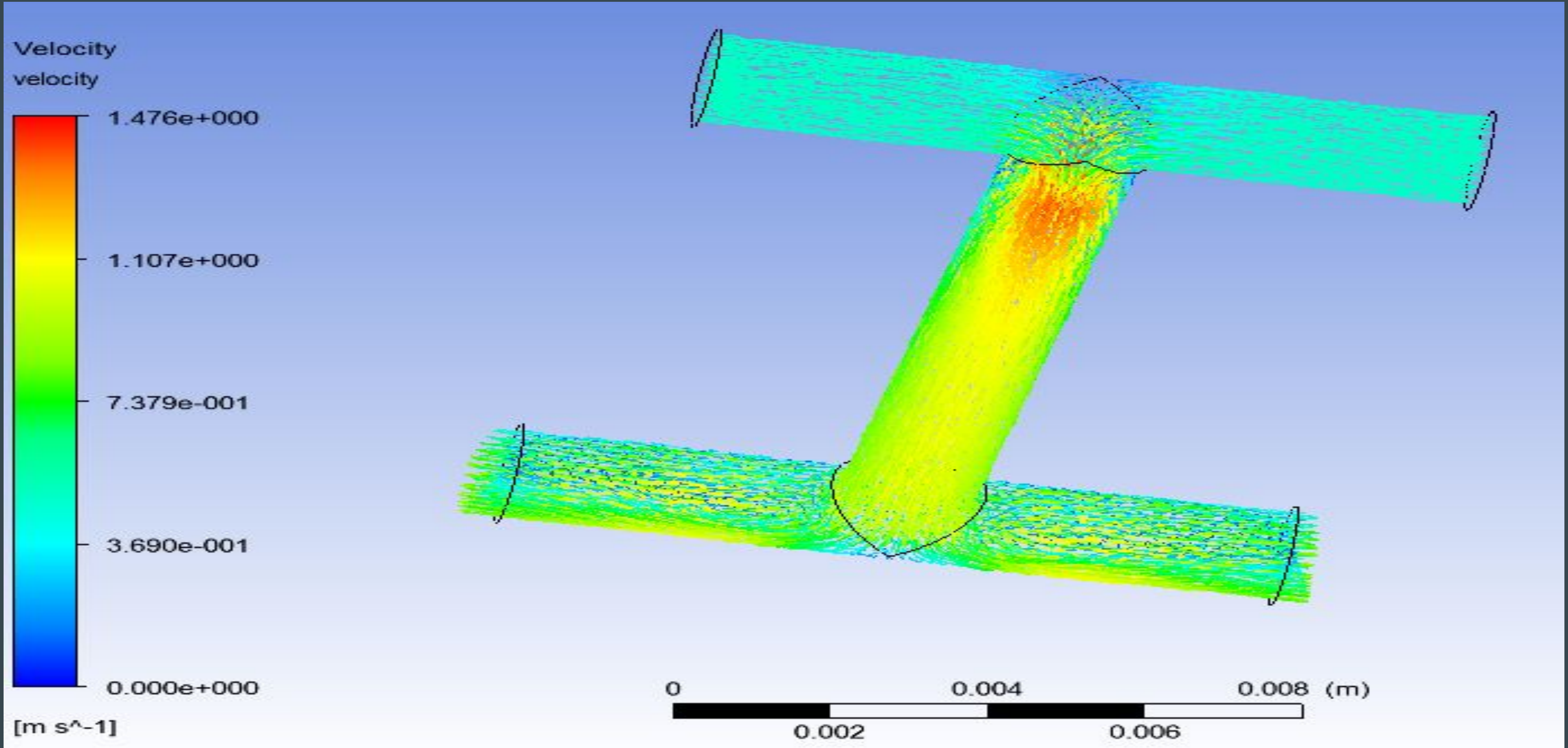
Step 20

Red: 147 m/s

Dark blue: 0 m/s



Step 100; t = 0.1s



Step 200; t = 0.2s