Introduction

1 Fluid

A gas is a fluid.

2 Continuum

No individual molecules.

“Points” are small regions of fluid:

- small compared to the typical length scales of the flow
- still big enough to hold many interacting molecules

3 Lagrangian Description

- A Lagrangian or material region is a fixed chunk of fluid.
- This is the sort of regions the usual laws of physics and thermodynamics hold for.

Lagrangian coordinates are not used that much in fluid mechanics. One exception: Dr. Van Dommelen’s Ph.D. thesis.

4 Eulerian Description

- A control volume is a general region.
- Examples: a jet engine, balloon, the vicinity of a car or a plane, ...
- At different times, a control volume will usually not contain the same fluid.
- While a Lagrangian description follows the fluid, a typical Eulerian description keeps the spatial location constant.

Warning:

The laws of physics and thermodynamics do not apply directly to control volumes. Corrections are needed:
- for regions: integrals over the surface
- for pointwise quantities: conversion of Lagrangian time derivatives
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Exercise:

Give some simple examples of control volumes where the basic laws of physics or thermodynamics are not satisfied.

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5 Density

Density $\rho$ is the mass per unit volume. Specific volume $v$ is the volume per unit mass.

$$\rho = \frac{\sum dV m_i}{dV} \quad \rho = 1 \frac{1}{v}$$

For the density $\rho(x, y, z, t)$ to make sense, $dV$ must still be big enough to hold many molecules. This requires that the typical spacing of the molecules must be small compared to the typical length scale of the flow.

6 Velocity

For velocity, take a mass-weighted average:

$$\vec{v} = \frac{\sum dV m_i \vec{v}_i}{\sum dV m_i}$$

For the molecules to behave as a group with a single relevant velocity, the free path length must be small compared to the typical length scale of the flow.