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* decription 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

-

Exercise:

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

-

5 Density

Density ρ is the mass per unit volume. Specific volume v is the volume per unit mass.

$$\boxed{\rho = \frac{\sum_{\mathrm{dV}} m_i}{\mathrm{dV}} \qquad \rho = \frac{1}{\mathrm{v}}}$$

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:

$$\vec{v} = \frac{\sum_{\mathrm{dV}} m_i \vec{v}_i}{\sum_{\mathrm{dV}} m_i}$$

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.