ME 517: Micro- and Nanoscale Processes

Lecture 18: Microfluidics - Continuum or Molecular?

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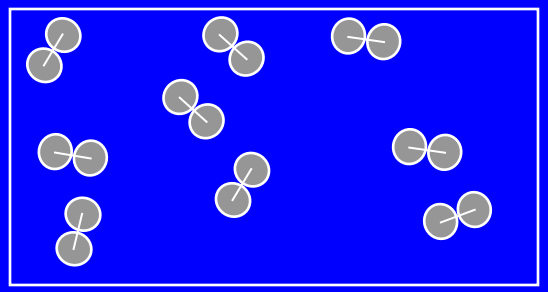
The Smallest Length Scale of a Continuum

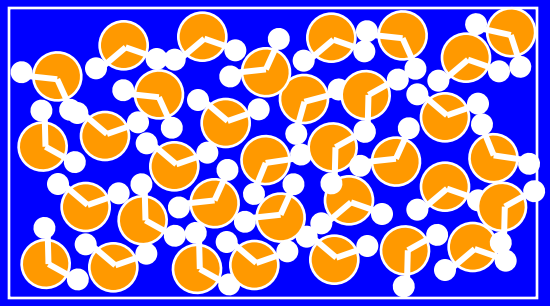
(Deen, Analysis of Transport Phenomena, 1998)

Gases (STP)



Molecular diameter	0.3 nm
Number density (m^{-3})	3 E25
Intermolecular spacing	3 nm
Displacement distance	100 nm
Molecular Velocity	500 m/s

Liquids



Molecular diameter	0.3 nm
Number density (m^{-3})	2 E28
Intermolecular spacing	0.4 nm
Displacement distance	1 pm
Molecular Velocity	10^3 m/s

The Smallest Length Scale of a Continuum
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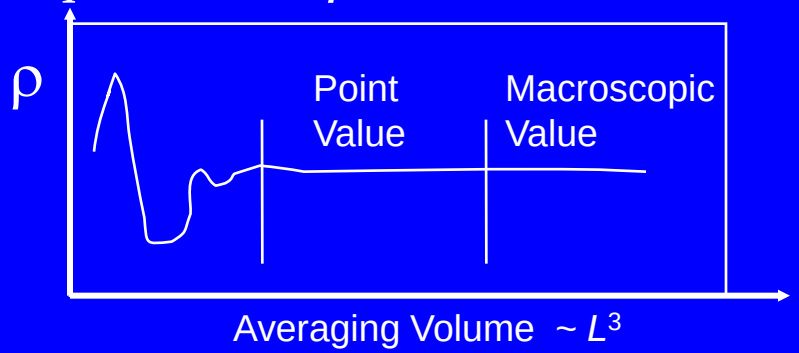
Average over sufficient number of molecules

- Point quantities, ρ, ***u***, *T*



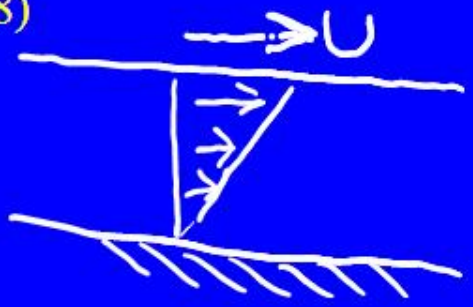
- Random process theory
  - $N \sim 10^4$ molecules

$$\sigma_\mu = \frac{\sigma_x}{N^{1/2}}$$

- ***L* ~ 70 nm** (gases at STP)
- ***L* ~ 8 nm** (liquids)

The Smallest Length Scale of a Continuum

(Deen, Analysis of Transport Phenomena, 1998)



Length scale of molecular interactions

(transport properties, μ, κ, D)

- Gases: mean free path ~ 100 nm
- Liquids: molecular diameter ~ 0.3 nm

Average over ~ 10^3 interaction length scales

- $L \sim$ **1 μm** (gases)
- $L \sim$ **3 nm** (liquids)

Taking the max of these two types of quantities

- $L \sim$ **1 μm** (gases)
- $L \sim$ **10 nm** (liquids)