Review: Basic Laws of Mechanics for a System

- All the laws of solid mechanics are written for a *system*, defined as an arbitrary quantity of mass of fixed identity.
- Conservation of mass, $m_{sys} = \text{const}$ or $\frac{dm}{dt} = 0$
- The Newton's second law (linear momentum equation), $\mathbf{F} = m\mathbf{a} = m\frac{d\mathbf{V}}{dt} = \frac{d(m\mathbf{V})}{dt}$
- Moment and angular momentum relation, $\mathbf{M} = \frac{d\mathbf{H}}{dt}$ where the angular momentum $\mathbf{H} = \sum(\mathbf{r}\times\mathbf{V})\delta m$
- Conservation of energy, $\delta Q - \delta W = dE$ or $\dot{Q} - \dot{W} = \frac{dE}{dt}$
- The second law of thermal dynamics, $dS \geq \frac{\delta Q}{T}$
- State relations $p = p(\rho, T)$.

Example:

- Ideal gas: $p = \rho PT$

Introduction(Chapter 1)

AIM: Basic definitions of a fluid and its properties (the continuum model), density (ρ), ideal gas law ($P = \rho RT$)

- 3 phases of matter:
- Fluid mechanics is the study of fluids either at rest (Fluid Statics) or in motion (Fluid Dynamics).
- Interested in interaction of a fluid at its boundary with –

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- Almost everything on earth is either a fluid or is in contact with a fluid
- Fluid behaviour is a branch of Mechanics $\rightarrow$

  satisfies a set of well-defined "laws"

Introduction(continued)

- Some theoretical solutions are possible, usually for simple/idealized situations.

- In many practical cases, the effects of complex geometry + fluid viscosity $\rightarrow$ Turbulence so that the equations cannot be solved directly.
- So, we need a range of tools:
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Introduction(continued)

- Now, what is the difference between a solid and a fluid?

Definition of a fluid:

- A fluid is any substance that deforms continuously (flows) when acted upon by a shearing stress.
- By definition a body of fluid at rest must be in a state of zero shear stress.
- In contrast, a solid can resist a shear stress by static deformation.
- There are 2 classes of fluids:

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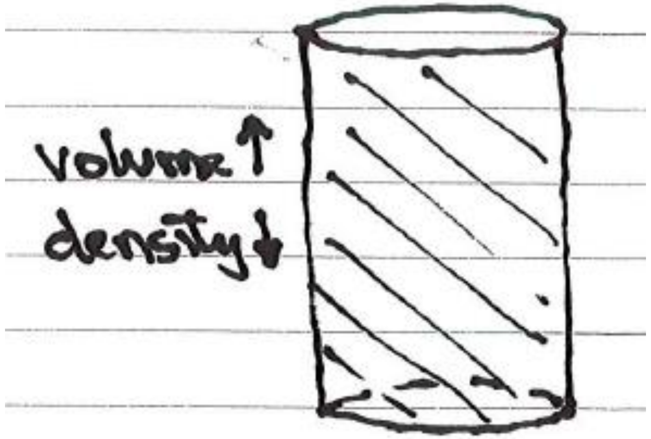
2 classes of Fluid

Liquid

- Relatively closely packed molecules with strong cohesive forces
- Tends to retain its volume
- Forms a free surface in a gravitational field unless confined from above
- Flows but is not easily compressed

Gas



- Widely spaced molecules, negligible cohesive forces
- Free to expand until confined, forming an atmosphere
- Cannot form a free surface, ∴ only gravitational effect is buoyancy
- Flows and is compressible

Fluids: Less-clear-cut cases

Rheological Fluids:

- Can resist small shear stresses but then “yield” and flow like fluids (eg. slurries)

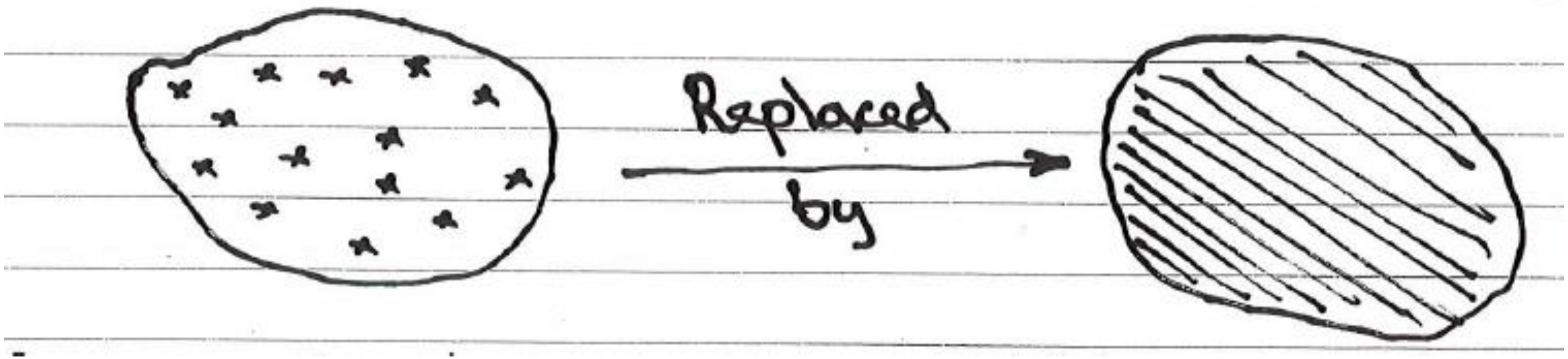
Two-phase flows:

- Liquid and gases co-exist (eg. steam and water, water with air bubbles, fizzy pop!)

Fluid Properties

The Continuum Model:

- As engineers we don’t need to characterize the behaviour of individual atoms or molecules.
- Rather, we need to describe the macroscopic (≡ **average**) effect over a very large number of molecules.



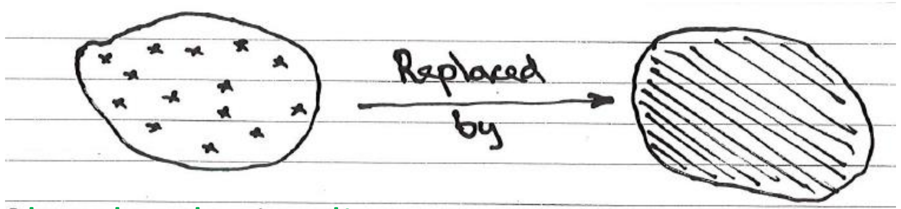
Actual molecular medium

Continuous medium
(≡ **continuum**)

- The model assumes

Fluid Properties:

The Continuum Model (continued)



Actual molecular medium

Continuous medium (≡ **continuum**)

- Limitations of the continuum model at standard temperature and pressure:

Note: Mean Free Path: average distance travelled by molecules between collisions

Fluid Properties: Density (ρ)

Units: kg/m^3

Related quantities:

Specific volume (υ - upsilon)

Specific weight (γ -gamma)

Specific gravity (SG)

Equation of State for Ideal Gases

- Good approximation for many practical cases

R = Gas constant (J/kg-K or m^2/s^2-K)
= 287 J/kg-K for air = $\Re$ / M

$\Re$ = universal gas constant = 8314 J/mole-K

M = Molecular mass of the gas (kg/mole) = 28.97 for air