K.N. Toosi
University of Technology

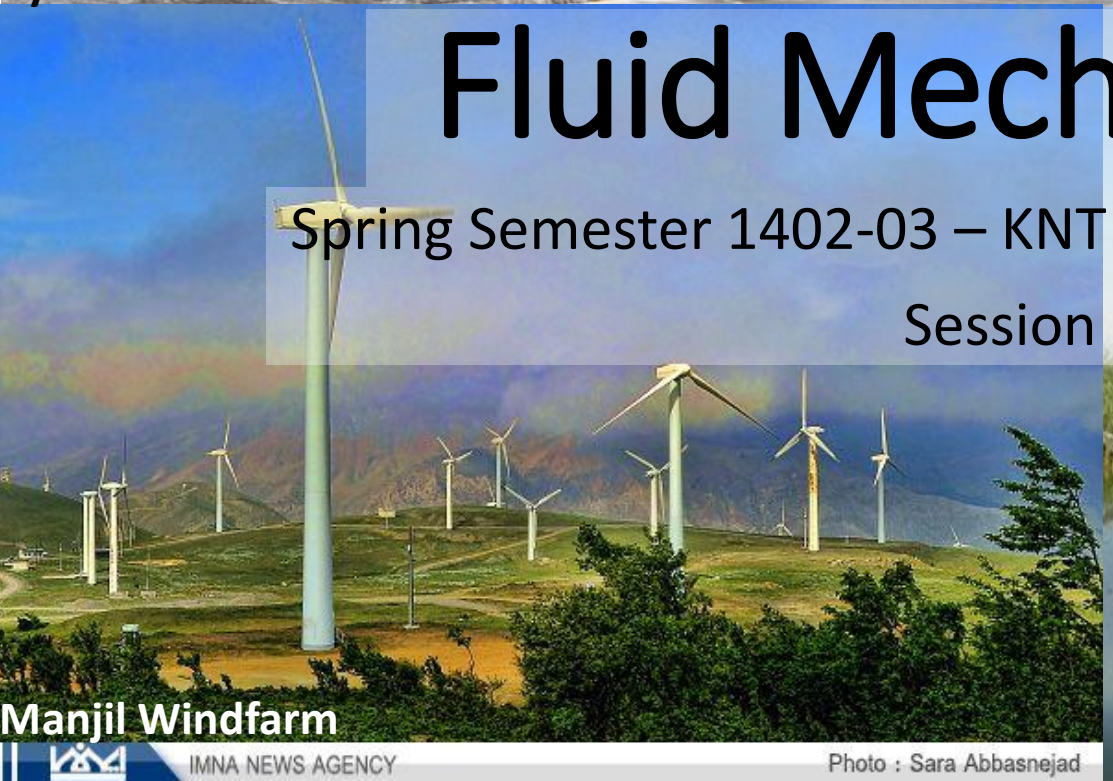

Cyclone Gonu


Shirabad Waterfall, Gorgan

Fluid Mechanics

Spring Semester 1402-03 – KNT University of Technology

Session 2


Manjil Windfarm

IMNA NEWS AGENCY Photo : Sara Abbasnejad


Hooralazim Marsh System


Bakeri Highway flood control System

Outline

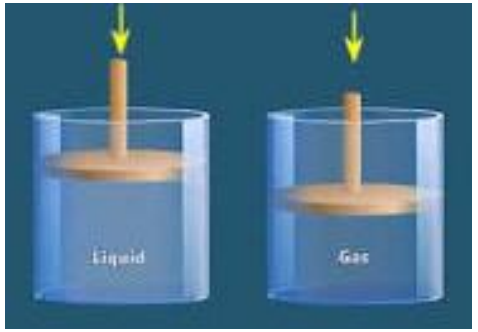
- Compressible vs Incompressible Flow
- Internal vs External Flow
- Laminar vs Turbulent Flow
- Steady vs Unsteady Flow
- Uniform vs Nonuniform Flow
- Natural vs Forced Flow
- One- , Two-, and Three-Dimensional Flow
- System and Control Volume

Classification of Fluid Flows vs Fluid Type

- Compressible vs Incompressible Fluid
  - ✓a compressible fluid can experience a density change during different processes while an incompressible fluid does not experience such a change.

$\rho = Constant$ → Incompressible fluid

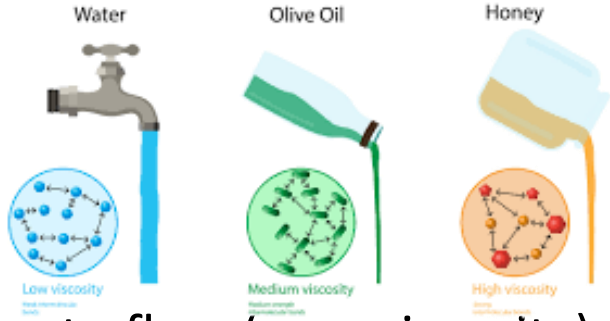
$\rho \neq Constant$ → Compressible fluid



- Viscous and Non-viscous Fluid
  - ✓A fluid with zero viscosity (internal friction) is non-viscous. In reality, viscosity is always present. However, it is often very small compared with other forces (e.g. gravity, pressure).

$\mu = 0$ → Non-viscous fluid

$\mu \neq 0$ → Viscous fluid

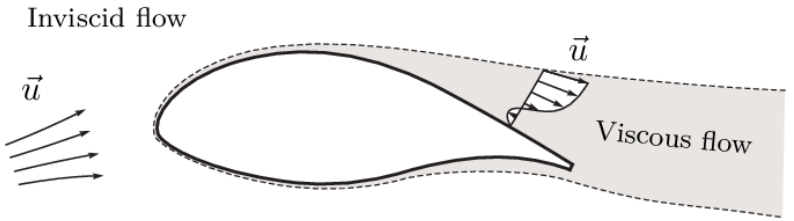


- Ideal Fluid
  - ✓An ideal fluid is a fluid that is incompressible and no internal resistance to flow (zero viscosity)

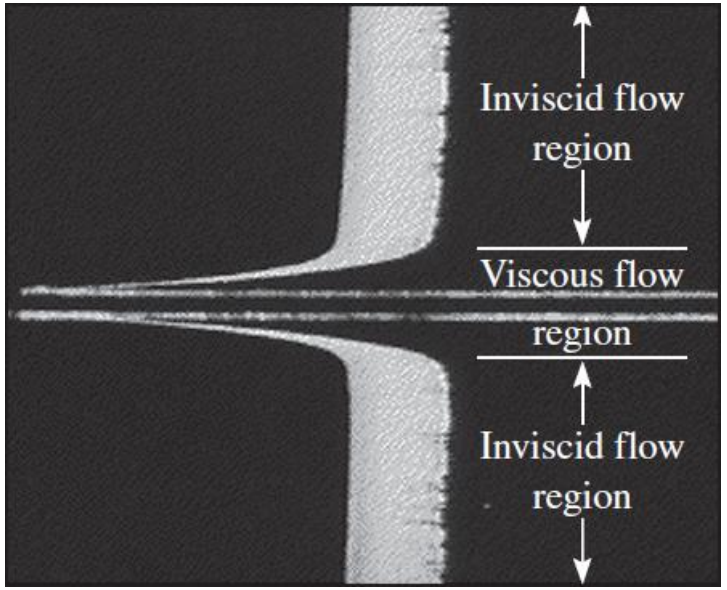
Viscous vs Inviscid Regions of Flow

- **Viscous flow**
  - ✓Flows in which the frictional effects are significant.

$$\tau = \mu \frac{du}{dy}$$



- **Inviscid flow**
  - ✓In many flows of practical interest, there are *regions* (typically regions not close to solid surfaces) where viscous forces are negligibly small compared to inertial or pressure forces.



Compressible vs Incompressible Flow

- **Incompressible flow**
  - ✓ If the density of flowing fluid remains nearly constant throughout (e.g., liquid flow).

$$\mathrm{Ma} = \frac{V}{c} = \frac{\text{Speed of flow}}{\text{Speed of sound}}$$

346 m/s

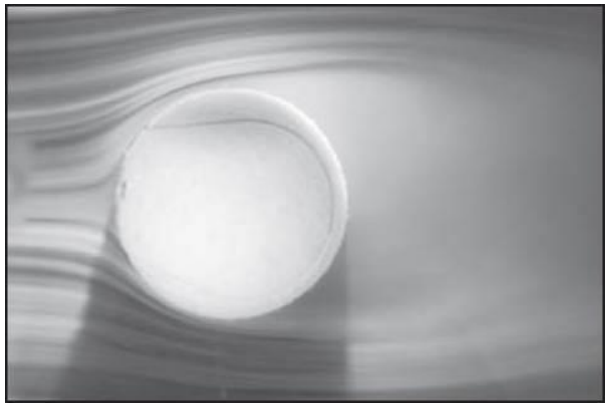
Ma = 1 **Sonic flow**
Ma < 1 **Subsonic flow**
Ma > 1 **Supersonic flow**
Ma >> 1 **Hypersonic flow**

$\rightarrow \quad \frac{d\rho}{\rho} < 5\%$

- **Compressible flow**
  - ✓ If the density of fluid changes during flow (e.g., high-speed gas flow)

Internal vs External Flow

- **External flow**
  - ✓The flow of an unbounded fluid over a surface such as a plate, a wire, or a pipe.
- **Internal flow**
  - ✓The flow in a pipe or duct if the fluid is bounded by solid surfaces.



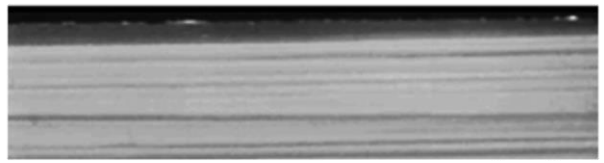
➢ Water flow in a pipe is internal flow, and airflow over a ball is external flow.

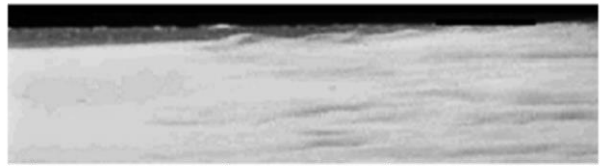
Laminar vs Turbulent Flow

- **Laminar flow**
  - ✓The highly ordered fluid motion characterized by smooth layers of fluid. The flow of high-viscosity fluids such as oils at low velocities is typically laminar.
- **Turbulent flow**
  - ✓The highly disordered fluid motion that typically occurs at high velocities and is characterized by velocity fluctuations. The flow of low- viscosity fluids such as air at high velocities is typically turbulent.
- **Transitional flow**
  - ✓A flow that alternates between being laminar and turbulent.

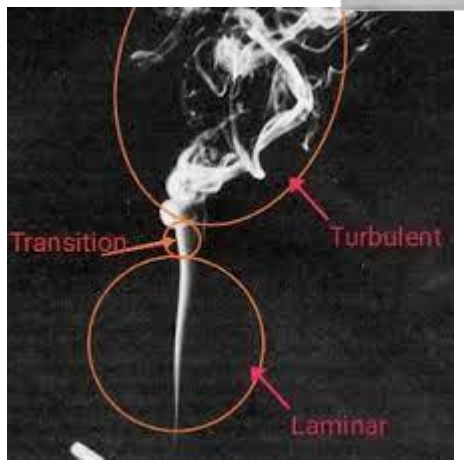
Reynolds Number → $Re = \frac{\rho v L}{\mu}$

Laminar → Re < 2300
Transitional → 2300<Re<4000
Turbulent → Re>4000


Laminar

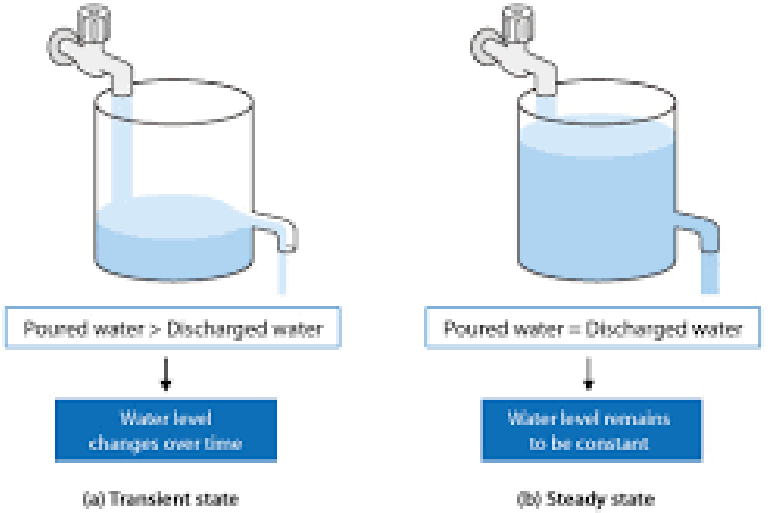

Transitional

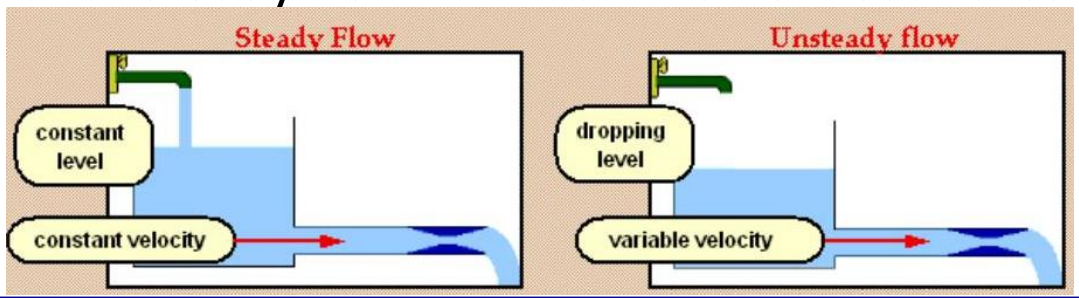

Turbulent



Steady vs Unsteady Flow

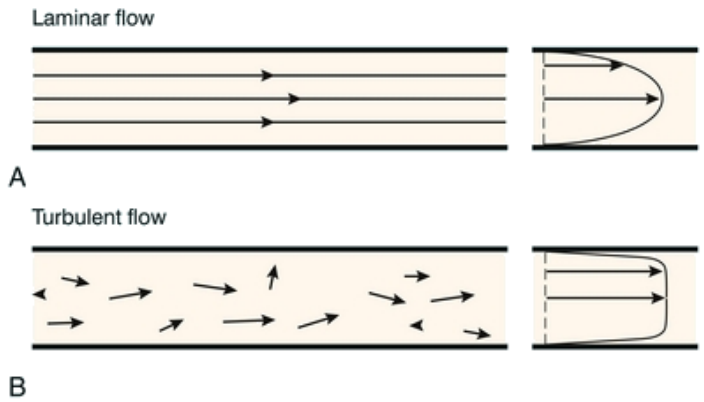
- **Steady Flow**
  - ✓The term **Steady** implies **no change** of properties, velocity, temperature, etc., **at a point with time**.
- **Unsteady Flow**
  - ✓In fluid mechanics, **unsteady** is the most general term that applies to any flow that is not steady.
- **Transient Flow**
  - ✓Flow where the flow velocity and pressure are changing with time.
- **Periodic Flow**
  - ✓This refers to the kind of unsteady flow in which the flow oscillates about a steady mean.

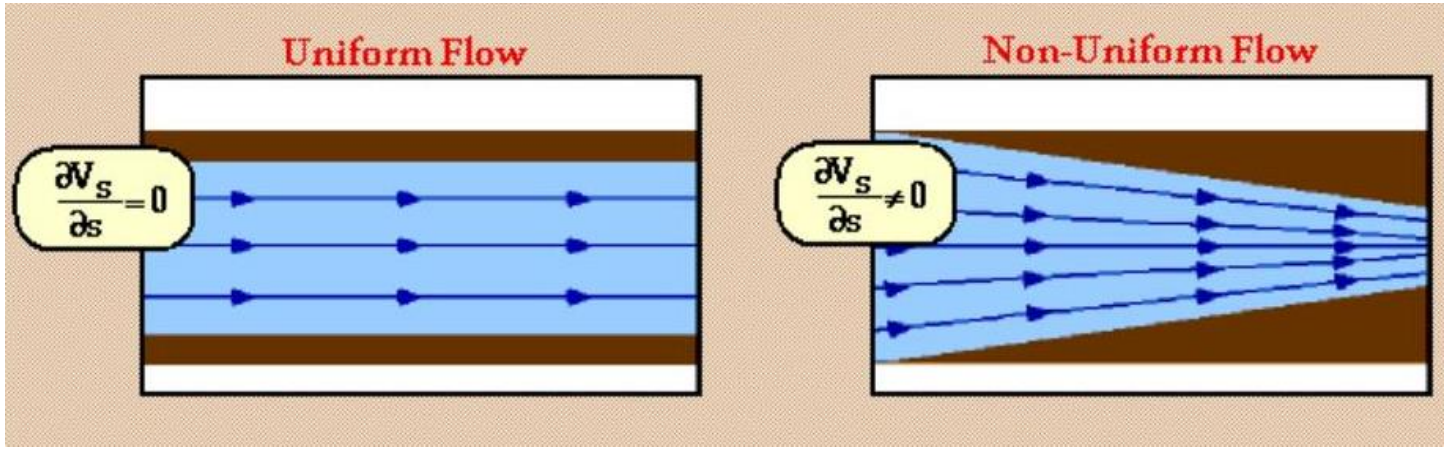




Uniform vs Nonuniform Flow

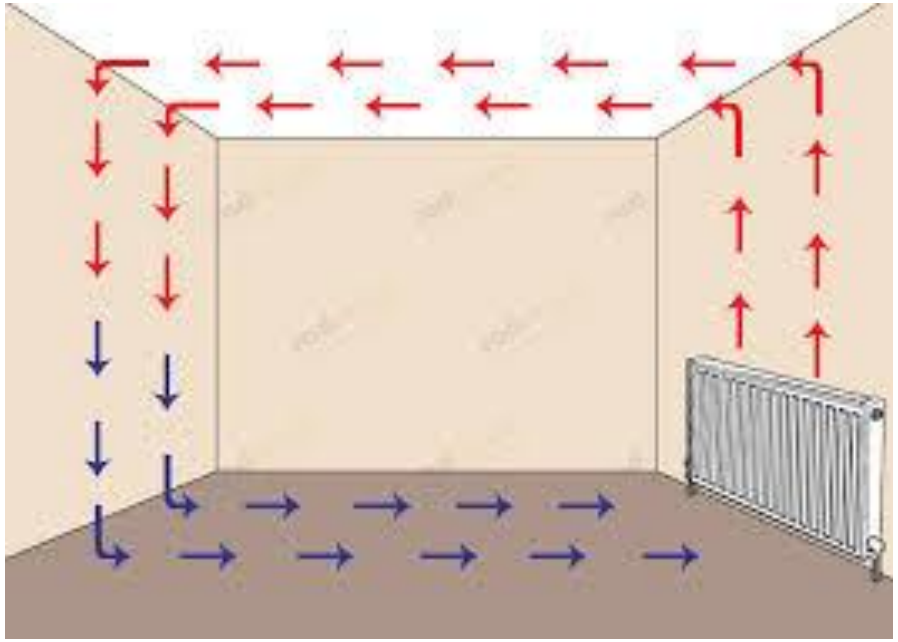
- **Uniform Flow**
  - ✓Uniform flow implies that all fluid properties, such as velocity, pressure, temperature, etc., do not vary with **position**.
- **Non-uniform Flow**
  - ✓If at a given instant, when the parameters are not the same at **every point**, the flow is non-uniform.

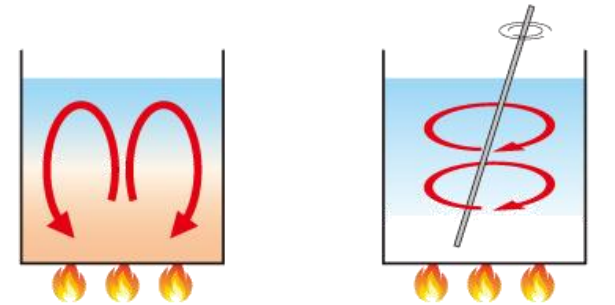




Natural vs Forced Flow

- **Forced flow**
  - ✓A fluid is forced to flow over a surface or in a pipe by external means such as a pump or a fan.
- **Natural flow**
  - ✓Fluid motion is due to natural means such as the buoyancy effect, which manifests itself as the rise of warmer (and thus lighter) fluid and the fall of cooler (and thus denser) fluid.



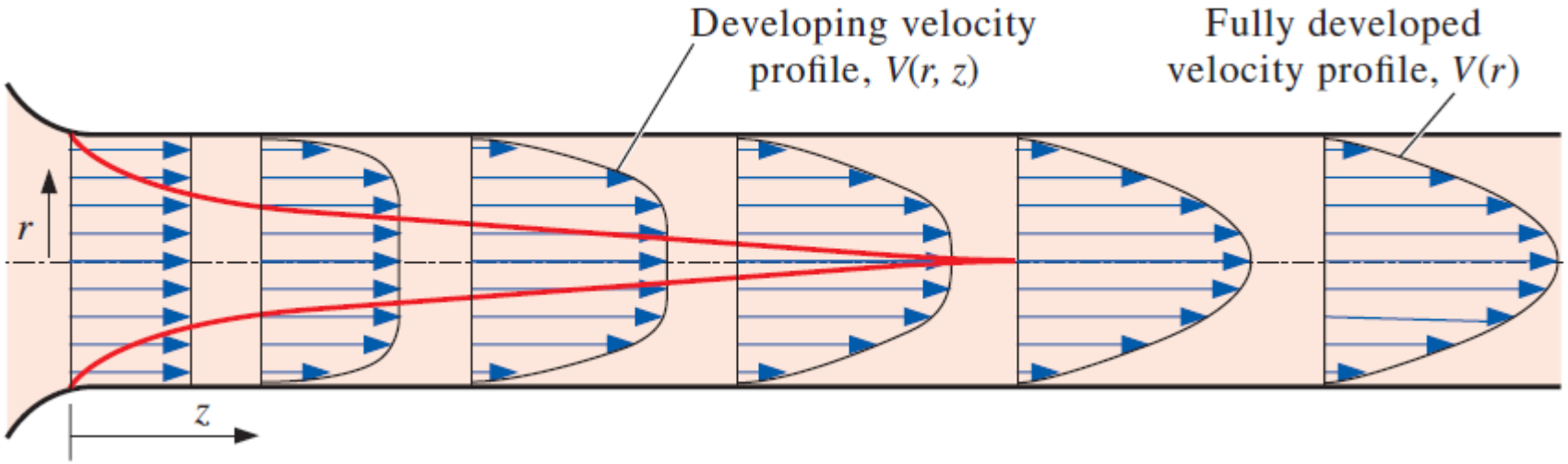


(a) Natural convection (b) Forced convection

One- , Two-, and Three-Dimensional Flow

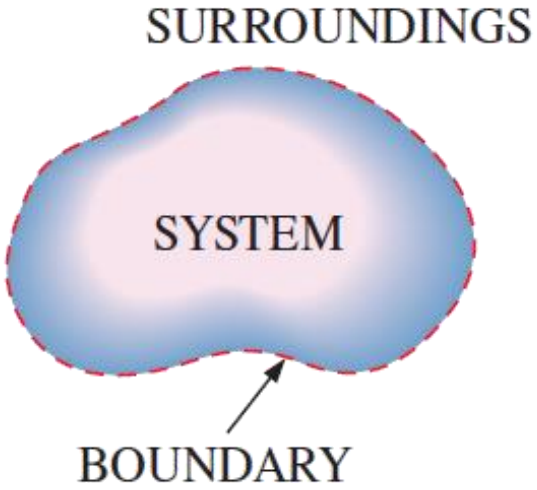
- A flow is said to be one-, two-, or three-dimensional if the flow velocity varies in one, two, or three dimensions, respectively.

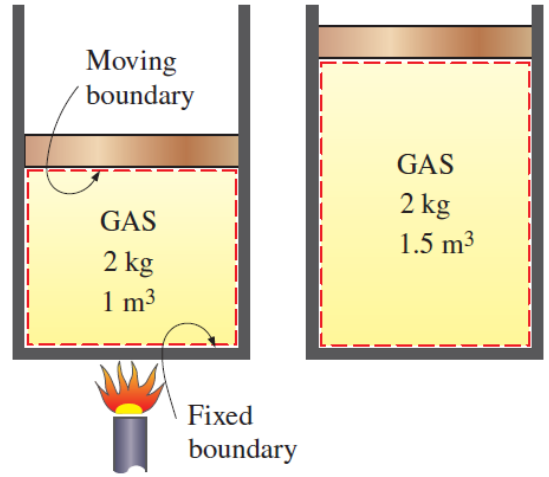
- The variation of velocity in certain directions can be small relative to the variation in other directions and can be ignored.



System

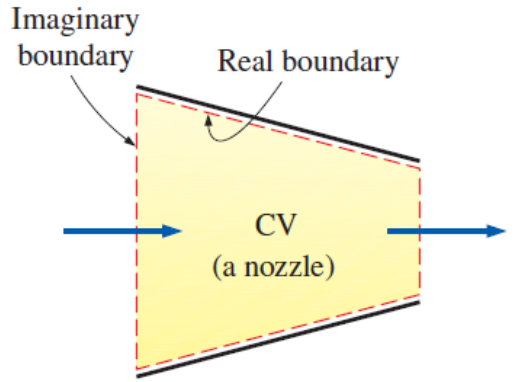
- **System**
  - ✓ A quantity of matter or a region in space chosen for study.
- **Surroundings**
  - ✓ The mass or region outside the system.
- **Boundary**
  - ✓ The real or imaginary surface that separates the system from its surroundings.
  - ✓ The boundary of a system can be *fixed* or *movable.*
- Systems may be considered to be *closed* or *open.*
- **Closed system (Control mass)**
  - ✓ A fixed amount of mass, and no mass can cross its boundary.





Control Volume

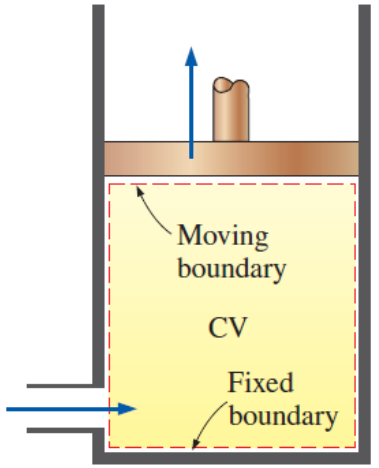
- **Open system (control volume)**
  - ✓ A properly selected region in space. It usually encloses a device that involves mass flow such as a compressor, turbine, or nozzle.



(*a*) A control volume (CV) with real and imaginary boundaries

Both mass and energy can cross the boundary of a control volume.

- **Control surface**
  - ✓ The boundaries of a control volume. It can be real or imaginary.



(*b*) A control volume (CV) with fixed and moving boundaries as well as real and imaginary boundaries

Wrap-up

- Compressible vs Incompressible Flow (Mach Number)
- Internal vs External Flow
- Laminar vs Turbulent Flow
- Steady vs Unsteady Flow
- Uniform vs Nonuniform Flow
- Natural vs Forced Flow
- One- , Two-, and Three-Dimensional Flow
- System and Control Volume