Sept. 10/18

$Re = \dfrac{UL}{\mu/\rho}$ $\dfrac{\to \text{ inertial Force}}{\to \text{ viscosity Force}}$

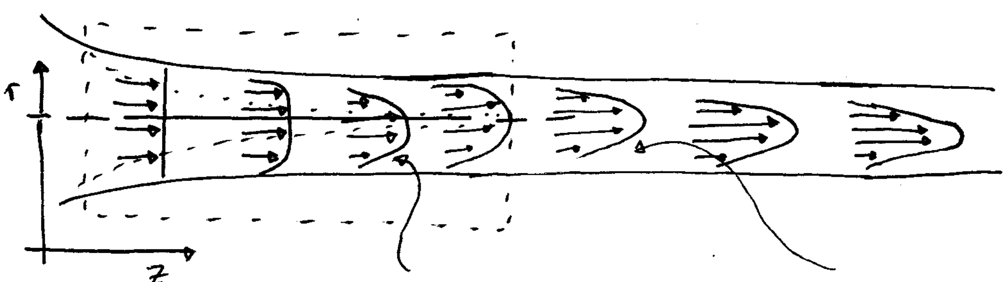
What is Reynold's number? Ratio of inertial Force to viscosity Force.

One, two (typically used inside pipes only), and three-dimensional Flows

- typical Flow is 3D

$V(x, y, z)$ in rectangular or $V(r, \theta, z)$ in cylindrical

Channel Flow:



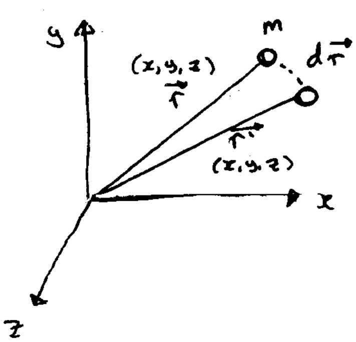
Developing velocity profile $v(r, z)$

Developed velocity profile $v(r)$

Example - Bullet piercing calm air, time-averaged airflow over the bullet during its flight.

→ Should be considered in 2D

↳ if there was crosswind, considered in 3D



$\vec{F} = ma$

Closed system: no mass can cross boundary

- heat and work <u>can</u> cross boundary
- volume doesn't have to be fixed

Open system: can involve moving boundary

- can also be fixed space

- any characteristic of a system is called a property
  - intensive properties : Independent of the mass of system (temp, pressure, density)
  - extensive properties : depends on size - or extent - (total mass, total volume, total momentum)

Specific volume : ($v = V/m$)
Specific total energy : ($e = E/m$)
} extensive properties per unit mass are called specific properties

Density and Specific Gravity

Density = mass per unit volume $\rho = m/V$

$$\left.\begin{aligned} \rho &= \frac{m}{V} \\ v &= \frac{V}{m} \end{aligned}\right\} \quad \rho = 1/v$$

Specific Gravity (or relative density) : ratio of the density of a substance to the density of water @ 4°c

$$\Rightarrow \quad S.G. = \frac{\rho}{\rho_{H_2O}} = \frac{\gamma}{\gamma_{H_2O}}$$

Specific weight : weight of a unit volume of a substance

$$\Rightarrow \quad \gamma_s = \rho g \ (N/m^3)$$

$$\underbrace{P_v = RT \quad \text{or} \quad P = \rho RT}_{\text{Equation on State}}$$

R is the gas constant.

$R = R_u / M$ (where M = molecular mass)

where R_u is universal gas cons.

$R_u = 8.314$ kJ/kmol·K
$= 1.986$ Btu/lbmol

P = absolute pressure
v = specific volume
ρ = density
T = thermodynamic (absolute) temperature

$T(K) = 273.15$
$T(R) = 459.67$

$PV = mRT$ or $PV = NR_uT$ where m = mass

$\left[\begin{array}{l} Pv = RT \\ v = \dfrac{V}{m} \end{array} \right\} \rightarrow PV = mRT \Big]$

N = number of moles (m/M)

$N = \dfrac{m}{M} \Rightarrow PV = NMRT$
$MR \rightarrow R_u$

Example: Determine density, specific gravity, mass of the air in a room with dim. $4m \times 5m \times 6m$ at 100 kPa and $25°C$

where $R = 0.287 \dfrac{kPa \cdot m^3}{kg \cdot K}$

Solution: $P = \rho RT$; $V = 4 \times 5 \times 6 = 120\ m^3$

$\rho = \dfrac{P}{RT} = \dfrac{100\ kPa}{(0.287)(25+273)} \Rightarrow \rho = 1.17\ kg/m^3$

$SG = \dfrac{\rho}{\rho_{H_2O}} = \dfrac{1.17}{1000} = 1.17 \times 10^{-3}$

$v = \dfrac{1}{\rho}$

$v = \dfrac{V}{m} \Rightarrow m = \dfrac{V}{v} \Rightarrow m = V\rho$

$\Rightarrow m = 140\ kg$

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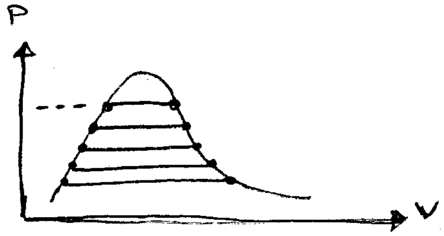
Vapor pressure (P_v) of a pure substance is defined as the pressure exerted by its vapor in phase equilibrium with its liquid at a given temperature. ($P_v = P_{sat}$)
P_v is a property of the pure substance, and turns out to be identical to Saturation pressure P_{sat} of the liquid



Vapor pressure is the possibility of the liquid pressure in liquid - Flow systems dropping below the vapor pressure at some locations, and the resulting unplanned vaporization, this Phenomenon is called Cavitation

$\boxed{\text{Example}}$ - In a water distribution system, the temp. of water is observed to be as high as 30°C. Determine the minimum pressure allowed in the system to avoid cavitation.
Solution - $T = 30°c$
From table => $P_v = 4.26$ kPa $< P_{everywhere}$

Energy and Specific heats
Energy can exist in numerous forms, such as thermal, mechanical, kinetic, potential, electric, magnetic, chemical, nuclear, and their sum constitutes total energy (E) of the system,
Macroscopic forms : those of a system w.r.t. outside frame
↳ kinetic, potential (intensive)
Microscopic forms : those related to molecular structure
Internal energy (U) : sum of microscopic
Kinetic energy (KE) : as a result of motion relative to ref. frame
Potential energy (PE) : as a result to elevation in grav. field

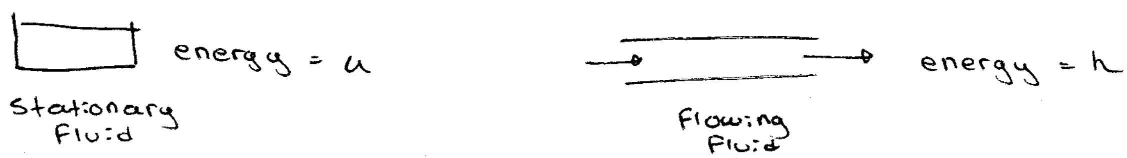
internal energy (u) : microscopic energy of a non-flowing fluid per unit mass

enthalpy (h) : microscopic energy of flowing fluid per unit mass

energy per unit mass needed to move + maintain flow

Flow energy = P/ρ (or flow work)

$h = u + Pv = u + P/\rho$ (enthalpy)



energy of a flowing fluid

$e_{flowing} = P/\rho + e = h + ke + pe = h + \frac{V^2}{2} + gz$ (kJ/kg)

$e = u + KE + PE$; $ke = KE/m$

$du = C_v dT$ and $dh = C_p dT$

Specific heat at a constant volume, C_v ; energy req'd to raise unit mass by one degree as volume is main'd constant

Specific heat at a constant pressure, C_p ; " " " + pressure " "

$\Delta u \cong C_{v,avg} \Delta T$ and $\Delta h \cong C_{p,avg} \Delta T$

$\Delta h = \Delta u + \Delta P/\rho \cong C_{avg} \Delta T + \Delta P/\rho$

$\Delta h \cong \Delta u \cong C_{avg} \Delta T$ for P = const

$\Delta h = \Delta P/\rho$ for T = const

Coefficient of Compressibility

The volume (or density) of a fluid changes with a change in its temp. or pressure

↳ different for different fluids

The bulk modulus of elasticity : K
Coefficient of volume expansion : β

} prop. that help relate volume changes to changes in press. + temp.

Coefficient of compressibility represents the change in pressure corresponding to a fractional change in volume or density of the fluid while the temp. remains const.

$$\kappa = -v\left(\frac{\delta P}{\delta v}\right)_T = \rho\left(\frac{\delta P}{\delta \rho}\right)_T \qquad (Pa)$$

$$\kappa \cong -\frac{\Delta P}{\Delta v/v} \cong \frac{\Delta P}{\Delta \rho/\rho} \qquad (T = \text{const.})$$

A large κ indicates we need a lot of pressure for a small volume change

Coefficient of compressibility (bulk modulus of elas., bulk modulus of comp.)

typical for liquids, helps explain why they are generally considered incompressible

The coefficient of compressibility of an ideal gas is equal to its absolute pressure, and the coefficient of compressibility of the gas increases with increasing power

For an ideal gas, $P = \rho R T$ and $(\delta P/\delta \rho)_T = RT = P/\rho$

thus $K_{\text{ideal gas}} = P \qquad (Pa)$

The percent increase of density of an ideal gas during isothermal compression is equal to percent increase in pressure.

Ideal gas : $$\frac{\Delta \rho}{\rho} = \frac{\Delta P}{P} \qquad (T = \text{const.})$$

Isothermal compressibility : the inverse of the coeff. of compressibility $\rightsquigarrow$ fractional change in volume or density : $\alpha = 1/\kappa = -1/v\left(\frac{\delta v}{\delta P}\right)_T = \frac{1}{\rho}\left(\delta\rho/\delta P\right)_T = (1/Pa)$

Sept. 14/18

FLUID MECHANICS (4TH)

Fundamentals + Applications

CENGAL (Author) → McGraw Hill

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