FLUID MECHANICS

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*FLUID MECHANICS

* It is a physical science dealing with the action at rest or in motion and with application and devices in engineering using fluids

vision of Fluid Mechanics

1. FLUID STATICS – deals with fluid at rest

2. FLUID DYNAMICS

   - concerned with fluids in motion

*TYPES OF FLUIDS

1. Ideal Fluids

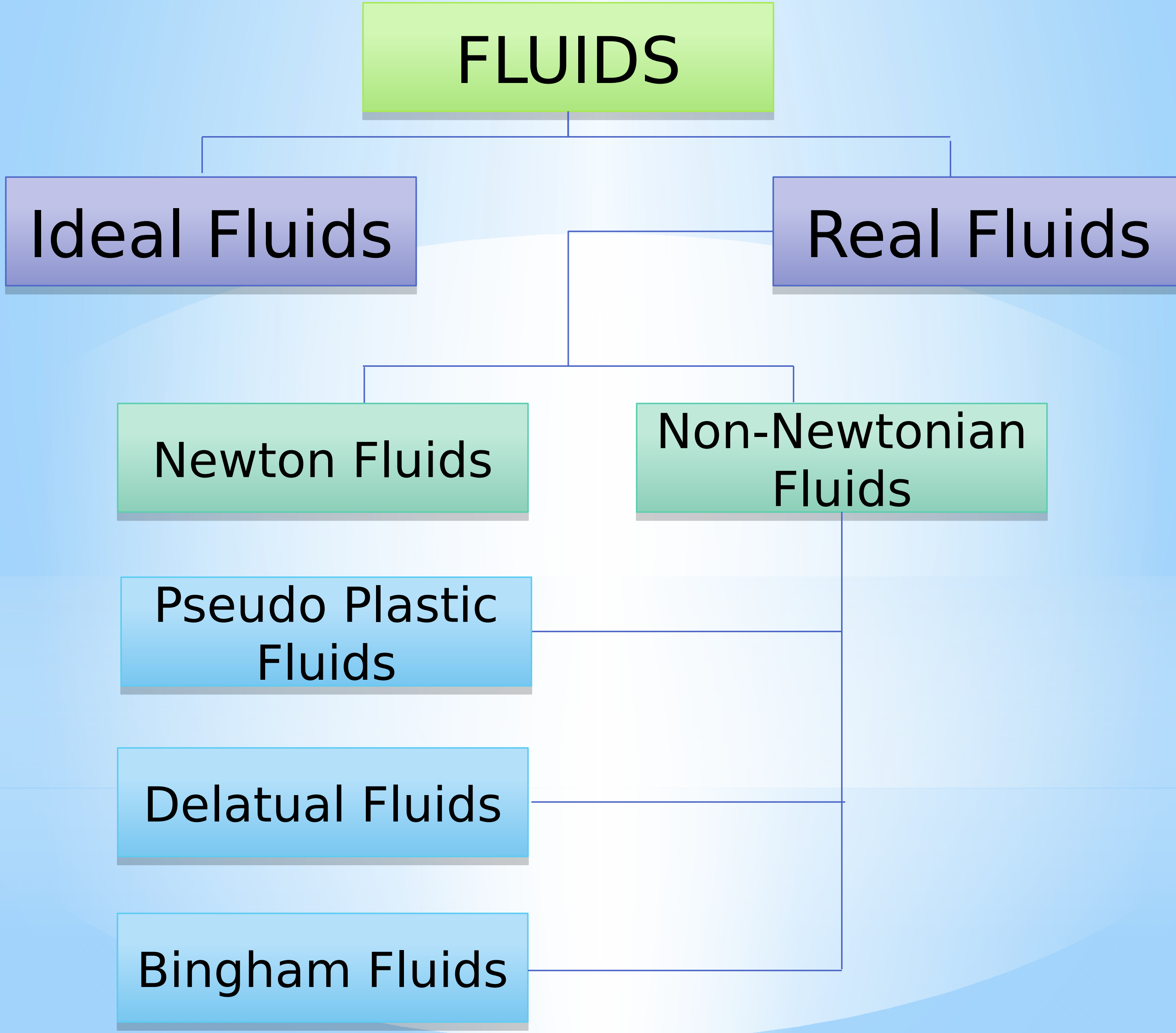
2. Real Fluids

1. Ideal Fluids

* Assumed to have no viscosity
* Incompressible
* Have uniform velocity when flowing
* No eddy currents or turbulence

2. Real Fluids

* Exhibit finite viscosities
* Non-uniform velocity distribution flowing
* Compressible
* Experience friction and turbulence


FLUIDS
Ideal Fluids
Real Fluids
Newton Fluids
Non-Newtonian Fluids
Pseudo Plastic Fluids
Delatual Fluids
Bingham Fluids

*FLUID PROPERTIES

1. Mass Density
2. Specific Volume
3. Specific weight
4. Specific Gravity
5. Absolute Viscosity or Viscosity
6. Kinematic Viscosity
7. Bulk Modulus
8. Compressibility
9. Coefficient Thermal Expansion

*MASS DENSITY (ρ, rho)

* - The mass per unit volume

$\rho \equiv m/v$

Where: ρ, mass density units; BG slugs/ft^3

m, mass SI kg/m^3

v, volume

For ideal gas

$\rho \equiv \frac{P}{RT}$ where: P, absolute pressure of gas in Pascal

R, gas constant (Air= 287J/kg·K)

T, temperature in Kelvin or Rankine units

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*Specific Volume (Vs)

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$$Vs = \frac{v}{m} = \frac{1}{p}$$

*Specific Weight

* It is the weight per unit volume

- It is the weight per unit volume

$$\gamma = \frac{w}{vol} = \frac{mg}{vol}$$

Units: BG lb/ft^3

SI N/m^3

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SG =

$$SG = \frac{\rho F}{\rho w} = \frac{\gamma F}{\gamma w}$$

*Absolute Viscosity or Viscocity, μ (mu)

*

$$\mu = \frac{T}{dV/dy}$$

Where: T, shear stress

μ, absolute viscosity

γ, distance between plates

V, velocity

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*Kinematic Viscosity, V (nu)

* $V = \mu / \rho$ Where: μ, absolute viscosity Where: μ, absolute viscosity

ρ, density ρ, density

System	Absolute, μ	Kinematic, V
British	lb·sec/ft^2 slug/ft·sec	ft^2/sec
Metric	dyne·s/cm^2 (Poise)	cm^2/s (Stoke)
S.I.	Pa·Sec (N·s/m^2)	m^2/s

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*Note:

1 Poise = 1 dyne·sec/cm^2 = 0.1 Pa·s

1 Stoke = 0.0001 m^2/s

1 dyne = 10^{-5} N

*Bulk Modulus

- It is a measure of fluid compressibility.
- It is the ratio of the change in pressure in the corresponding change in volume

$$Ev = \frac{-dP}{dVol/Vol}$$

where; dP, the change in pressure needed to create a change in volume

dVol, the resulting change in volume

Vol, initial volume

$$Ev = \frac{-dP}{d\rho/\rho}$$

Where: dP, the change in pressure

dρ,the change in fluid density

ρ, initial density

*Compressibility (β)

* Also known as the coefficient of compressibility
- It is the fractional change in volume of fluid per unit change in pressure.
- $$\beta = \frac{1}{Ev} = \frac{\frac{-dVol}{Vol}}{dP} = \frac{-d\rho/\rho}{dP} = \frac{-d\gamma/\gamma}{dP}$$

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- It is the fractional change in volume of fluid per unit change in pressure.

* Coefficient of Thermal Expansion, α_T

- -It represents the ability of fluid to expand or compress under the increase or decrease in temperature

$$\alpha_T = \frac{dVol/Vol}{dT} = \frac{1}{vol} \cdot \frac{dVol}{dT}$$

$$\alpha_T = \frac{d\rho/\rho}{dT}$$

SURFACE TENSION

Liquids have cohesion and adhesion which are forms of molecular attraction. Cohesion permits a liquid to resist tensile stress and adhesion permits it to adhere to another body. The surface tension, σ is defined as the intensity of the molecular attraction per unit length along any line in the surface. It has the dimensions of force per unit length. Its units are dyne/cm or N/m.

CAPPILLARITY

Caused by both cohesion and adhesion. When the effect of cohesion is less than adhesion, the liquid will wet a solid surface which is in contact and rise to the point of contact. If the effect of cohesion is greater than that of adhesion the liquid surface will be depressed.

For clean tube, $\theta = 0°$

For Hg, $\theta = 140°$

For tubes greater than 12mm, the cappillary effects are neglected.

VAPOR PRESSURE

Molecular activity in liquid will allow some of the molecules to escape the liquid surface. Molecules of the vapor also condense back into liquid. The vaporization and condensation at contact temperature as equilibrium processes. The equilibrium exerted by these free molecules is known as vapor pressure or saturation pressure.

PROBLEMS

1. A reservoir of glycerin has a mass of 1200 kg and volume of 0.952m³. Find its (a)weight (b)unit weight (c)mass density and (d)specific gravity.

Given: m = 1200 kg

Vol = 0.952 m^3

(a) W= mg = 1200 (9.81)

= 11, 772 N

(b) $\gamma = \frac{W}{vol}$ = 11,772 N/0.952 m^3

= 12, 365.55 N/m^3

(c) ρ = m/v = 1200 kg / 0.952m^3

(d) SG = $\frac{\rho f}{\rho w}$ = 1260.5 / 1000

= 1.26

2. If the specific volume of certain gas is 0.7848 m^3/kg, what is its specific weight?

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$$\rho = \frac{1}{V_s} = \frac{1}{0.7848} = 1.27 \text{ kg/m}^3$$

$$\gamma = \rho g = 1.27\,(9.81)$$

$$= 12.46 \text{ N/m}^3$$

=ρg = 1.27 (9.81)
= 12.46 N/m^3

3. Find the mass density of helium at 4°C with a pressure of 184KPa if its absolute pressure is 285.92KPa. R = 2079 J/kg · K

$\rho = \frac{P}{RT} = 285.92 \times 10^3 / 2079(4+273)$

$= 0.5 \text{ kg/m}^3$

* 4. Air is kept at a pressure of 200 KPa absolute and a temperature of 30°C in a 500 L container. What is the mass of air?

$\rho = \frac{P}{RT}$ = 200 x 10^3 / 287(30+273)

= 23 kg/m³

$\rho = \frac{m}{v}$; m = ρv = 23(500 x 10^{-3}) = 1.15 kg

* **5. A cylindrical tank 80 cm diameter and 90 cm high is filled with a liquid. The tank of liquid weighed 420 kg. The weight of the tank is 40 kg. What is the unit weight of liquid in KN/m³?**

Mass of liquid = 420 – 40 = 380kg

Vol = $\pi D^2 h/4$ = 0.45m³

$\gamma = \frac{mg}{vol} = 380(9.81)/0.45$

= 8.284 KN/m³

* 6. If the viscosity of water at 70°C is 0.00402 poise and its specific gravity is 0.978. Determine its absolute viscosity in Pa·s and its kinematic viscosity in m^2/s and stoke.

Note: 1 Poise = 0.1 Pa·s

1 Stoke = 0.001 m^2/s

Absolute viscosity,

= 0.00402 Poise x 0.1 Pa·s/Poise

= 0.000402 Pa·s

Kinematic Viscosity

=

V = 4.11 x 10^{-7} /s

6. If the viscosity of water at 70°C is 0.00402 poise and its specific gravity is 0.978. Determine its absolute viscosity in Pa·s and its kinematic viscosity in m^2/s and stoke.

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Absolute viscosity, μ

μ = 0.00402 Poise x 0.1 Pa·s/Poise

μ = 0.000402 Pa·s

Kinematic Viscosity

$V = \mu/\rho = \frac{0.000402}{0.978(1000)}$

V = 4.11 x 10^{-7} m^2/s

*

Converting to stoke

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$$4.11 \times 10^{-7}\ \frac{m^2}{s} \times \frac{1\ \text{stoke}}{0.0001\ m^2/s}$$

4.11×10^{-3} stoke

4.11×10^{-3} stoke

$$V = \mu/\rho = \frac{Pa \cdot s}{kg/m^3} = \frac{N/m^2 \cdot s}{kg/m^3} = m^2/s$$

* 7. Two large surface 25mm apart and the space between them is filled with a liquid of viscosity = 0.958 . Assuming the velocity gradient to be straight line. What force is required to pull a very thin plate of 0.37 area at constant speed v=0.3m/s if the plate is 8.4mm from one of the surface?

7. Two large surface 25mm apart and the space between them is filled with liquid of viscosity μ 0.958 $Pa \cdot s$. Assuming the velocity gradient to be straight line. What force is required to pull a very thin plate of $0.37m^2$ area at constant speed v=0.3m/s if the plate is 8.4mm from one of the surface?

Given: $\mu = 0.958\ Pa \cdot s$

Given: = 0.958

$\rightarrow \sum Fx = 0$

$+\sum Fx = 0$

F = F1 + F2

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$$\mu = \frac{T}{dV/dy}; \quad \mu = \frac{F/A}{V/y}; \quad \mu = \frac{FY}{AV}$$

= = ; =

* $F = \frac{\mu A V}{Y}$

$$F1 = \frac{\mu A V}{Y_1} = \frac{0.958\,(0.37)(0.3)}{16.6\,x\,10^{-3}} = 6.41\ \text{N}$$

$$F2 = \frac{\mu A V}{Y_2} = \frac{0.958\,(0.37)(0.3)}{8.4\,x\,10^{-3}} = 12.66\ \text{N}$$

$$F = 19.07\ \text{N}$$

* 8. An 18 kg slab slides down 15° inclined plane on a 3mm thick film of oil with viscosity of μ = 0.0814 Pa.s. If the contact area is 0.3m^2, find the terminal velocity of the slab. Neglect air resistance.

$+\sum F_x = 0$

$W_x - F = 0$

$F = W_x \sin 15°$

$F = 176.58 \sin 15° = 45.7$ N

$$V = \frac{FY}{\mu A} = \frac{45.1(3 \text{ x } 10^{-3})}{0.0814(0.3)}$$

V = 5.61 m/s

* **9. What is the value of the surface tension of a small deep water 0.3mm in diameter, which is contact with air if the pressure within the droplet is 561 Pascal?**

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$$P = \frac{4\sigma}{d}$$

$$\sigma = \frac{Pd}{4} = \frac{561(0.3)(10^{-3})}{4}$$

$\sigma = 0.042$ N/m

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