CHAPTER THREE **MECHNICS FLUID**

- **Fluid mechanics** is the branch of **physics** concerned with the **mechanics** of **fluids .**
- Could be: Fluid *dynamics*-which is the study of fluid in motion.

  Fluid *statics*: which is the study of fluid at rest.
- To name a few applications of fluid mechanics : breathing, blood flow, swimming, pumps, fans, turbines, airplanes, ships, rivers, windmills, pipes, missiles, icebergs, engines, filters, jets, and sprinklers.
- The study of fluid mechanics concerns about the following concepts:-**Properties of Bulk Matter.**

  -Fluid statics and Fluid *dynamics*.

Properties of Bulk Matter

- **Elasticity** :- is the property of an object tends to return to its original shape and size.

  -Is the study of elastic behaviors.

  -Materials could be elastic or inelastic based on elasticity.

  -of materials described by Stress, Strain, Strain energy and elastic modulus.

Stress and Strain

- **Stress-** is the feeling of emotional or physical tension.

$$\text{Stress} = \frac{\text{Force}}{\text{Area}}$$

- **Strain**-measures the change in configuration of a body divided by its initial configuration.

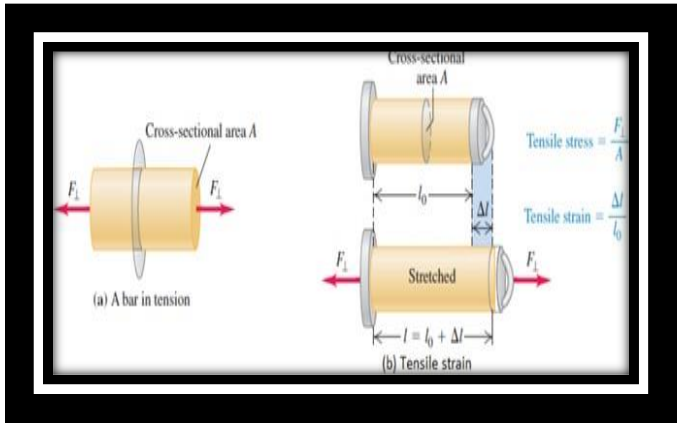
$$Stain = \frac{Change\ in\ configuration}{Orginal\ configuration} = \frac{\Delta l}{l_0}$$

Properties of Bulk Matter

- There are three kinds of strains:

1. Tensile Strain(S_t):

$$S_t = \frac{\Delta l}{l_0} \; and$$



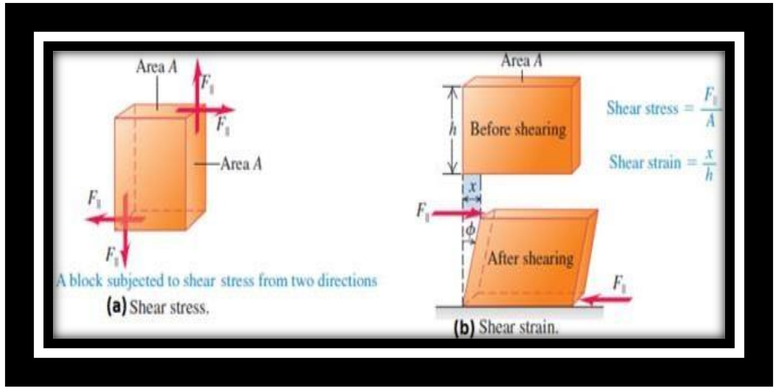
- **Tensile stress(S_T)**

$$S_T = \frac{F_{per}}{A}$$

2. Shear Stress and Strain

$$S_t = \frac{x}{h}$$

$$S_S = \frac{F_{//}}{A}$$

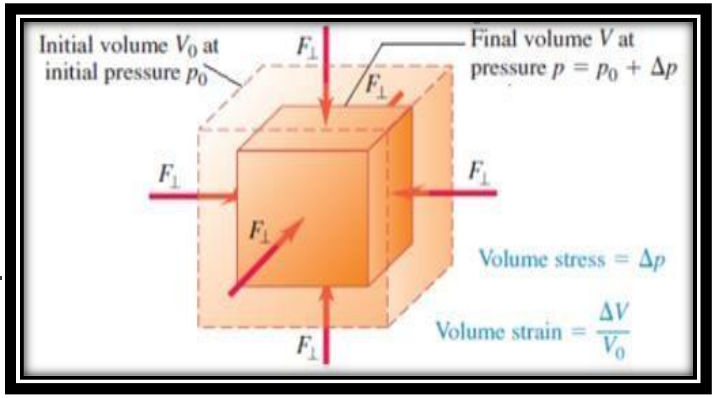


Properties of Bulk Matter

3. Volume Stress and Strain

$$S_v = \frac{\Delta V}{V_0}$$

$$S_T = \frac{F_{per}}{A}$$



Elasticity Moduli

- The stress will be proportional to the strain if the stress is sufficiently small.
- This proportionality constant known as **elastic modulus.**
- Could be Young's modulus(Y), Shear modulus(S) and Bulk modulus(B)

Properties of Bulk Matter

1. Young's Modulus(Y)

$$Y=\frac{S_T}{S_t}=\frac{F\perp/A}{\Delta l/l_0}$$

2. Shear Modulus (S)

$$S=\frac{S_S}{S_s}=\frac{F///A}{\Delta A/A_0}$$

3. Bulk Modulus(B)

$$B=\frac{S_T}{S_t}=-\frac{F\perp/A}{\Delta V/V_0}=-\frac{P}{\Delta V/V_0}$$

Typical Values for Elastic Moduli

Substance	Young's Modulus (N/m^2)	Shear Modulus (N/m^2)	Bulk Modulus (N/m^2)
Tungsten	35×10^{10}	14×10^{10}	20×10^{10}
Steel	20×10^{10}	8.4×10^{10}	6×10^{10}
Copper	11×10^{10}	4.2×10^{10}	14×10^{10}
Brass	9.1×10^{10}	3.5×10^{10}	6.1×10^{10}
Aluminum	7.0×10^{10}	2.5×10^{10}	7.0×10^{10}
Glass	$6.5–7.8 \times 10^{10}$	$2.6–3.2 \times 10^{10}$	$5.0–5.5 \times 10^{10}$
Quartz	5.6×10^{10}	2.6×10^{10}	2.7×10^{10}
Water	–	–	0.21×10^{10}
Mercury	–	–	2.8×10^{10}

- **Strain Energy(S_E)** is energy stored in a stretched wire. If x is the stretch due to applied force F, hence: $S_E = {}^1/_2\, Kx^2$

Properties of Bulk Matter

Examples

1. Suppose that the tension in the cable is 940 N as the actor reaches the lowest point. What diameter should a 10-m-long steel wire have if we do not want it to stretch more than 0.5 cm under these conditions? {Ans:$\Longrightarrow d = 2r = 2(1.7 mm) = 3.4\ mm$ & $A = 9.4 \times 10^{-6} m^2$

2. A solid brass sphere is initially surrounded by air, and the air pressure exerted on it is $1.0 \times 10^5 N/m^2$ (normal atmospheric pressure). The sphere is lowered into the ocean to a depth where the pressure is $2.0 \times 10^7 N/m^2$. The volume of the sphere in air is 0.50 m3. By how much does this volume change once the sphere is submerged

3. A steel wire of diameter 1 mm can support a tension of 0.2 kN. A cable to support a tension of 20 kN should have diameter of what order of magnitude?

4. If the shear stress in steel exceeds$4.0 \times 10^8 N/m^2$, the steel ruptures. Determine the shearing force necessary to (a) shear a steel bolt 1.00 cm in diameter and (b) punch a 1.00-cm-diameter hole in a steel plate 0.500 cm thick.

Density and Pressure in Static Fluids

- **Density** (ρ):is the quantity of mass (m) per unit volume (V) of a body with SI unitkg⁄m³

$$\rho = \frac{m}{V}$$

Specific gravity (SG): is the ratio of the density of the substance to the density of another substance (commonly water)

$$SG = \rho_r = \frac{\rho}{\rho_w}$$

Eg : SG of aluminum is 2.7

Example: (1). A solid sphere made of wood has a radius of 0.1 m. The mass of the sphere is 1.0 kg. Determine : a) density and b) specific gravity of the wood. {Ans:ρ= 239 kg/m^3.$V =$ $4.18 \times 10^{-3} m^3$

2. A submerged wreck is located 18.3 m beneath the surface of the ocean off the coast of South Florida. Determine the a) gauge pressure and b) absolute pressure on a scuba diver who is exploring the wreck. Note: the density of sea water is 1025 kg/m^3.{Ans:$Pgauge$= 182 kPa; P_{abs} =2.84kPa }

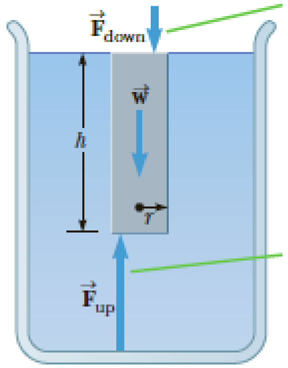
Density and Pressure in Static Fluids

- **Pressure:** is the ratio of the force acting perpendicular to s surface to the surface area (A) on which the force acts. SI unit of pressure is N/m^2, called Pascal (Pa)

$$P = \frac{F}{A}$$

- The pressure produced by the column of fluid of height h and density ρ is given by:

$$P_{fluid} = \rho g h$$



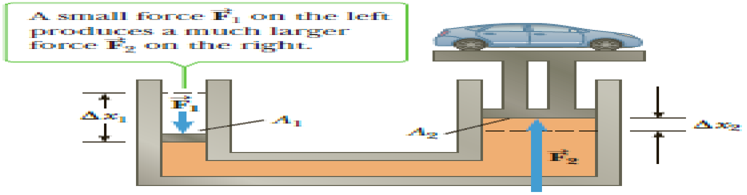
- Pressure could be:- **Absolute Pressure:** $P_{atmospheri}$ **=** $\boldsymbol{P_0}$**=101000kPa=101kPa**

  - Guage pressure: $P_{guage} = P_{system} - P_0$

  Absolute Pressure: P=$P_{absolute} = P_{gauge} + P_0$

Pascal's Principle - sates that pressure applied to a confined fluid in a container is transmitted equally to all regions of the fluid and to the walls of the container.

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$



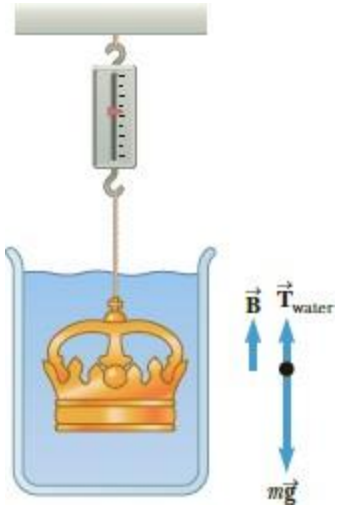
Density and Pressure in Static Fluids

Archimedes' principle:

Archimedes' principle can be stated as anybody completely or partially submerged in a fluid is buoyed up by a force equal to the weight of the fluid displaced by the body.

$$F_{buoyant} = W_{fluid} = \rho_{fluid} V_{displaced} g$$

$$\overrightarrow{F_B} = W - W_{app}$$



Example (1): A sample of an unknown material weighs 300 N in air and 200 N when submerged in an alcohol solution with a density of $0.70 \times 10^3\ kg/m^3$. What is the density of the material? {Ans: $\rho 0 = 2.1 \times 10^3\ kg/m^3$

Moving Fluids and Bernoulli Equations (Fluid Dynamics)

Fluid flow: could be- ***Streamline or laminar***: flow is not smooth.

- ***Turbulen***t: the flow is not smooth.

Moving Fluids and Bernoulli Equations (Fluid Dynamics

- **Factors affecting laminar flow:** are density, compressibility, temperature and viscosity of the fluid.
- **Assumptions:** made in the ideal fluid flow to understand the complex motions of real fluids:
  - The fluid is non-viscous, i.e there is no internal friction between adjacent layers.
  - The flow is steady; the velocity of the fluid at each point remains constant.
  - The fluid is incompressible; density of the fluid is constant.
  - The flow is irrotational; the fluid has no angular momentum about any point.

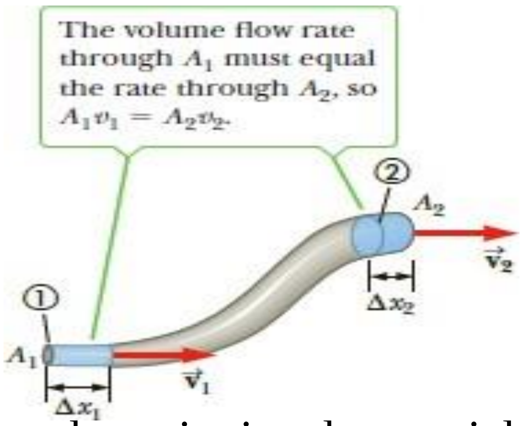
Flow rate(Q): is defined as

$$Q = \frac{Volume}{t} = \vec{A}.\vec{V}$$

Equation of Continuity: states that: "*the product of the area and the fluid speed at all points along a tube is constant for an incompressible fluid*"

Moving Fluids and Bernoulli Equations (Fluid Dynamics

….Contd(**Equation of Continuity**) $A1v1 = A2v2$

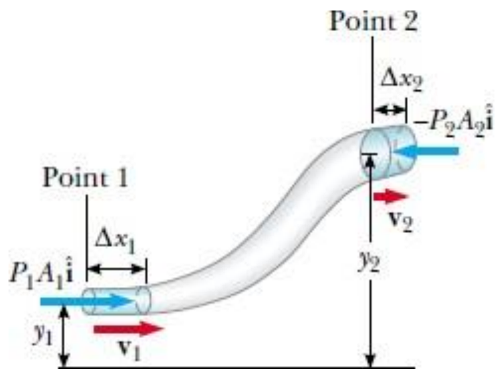


<u>Bernoulli's Equation</u>

- Bernoulli‘s equation is really a consequence of a fundamental principle of physics conservation of energy. It can be derived using energy principles.
- States as: "The sum of the pressure, kinetic energy per unit volume, and gravitational potential energy per unit volume has the same value at all points along a streamline”.
- Mathematically:

$$\boldsymbol{P + \rho g y + \frac{1}{2}\rho v^2 = Constant}$$

$$P_1 + \rho g y_1 + \frac{1}{2}\rho v_2{}^2 = P_2 + \rho\rho g y_2 + \frac{1}{2}\rho v_1{}^2$$



Moving Fluids and Bernoulli Equations (Fluid Dynamics

Example:1. Water circulates throughout a house in a hot water heating system. If the water is pumped at a speed of 0.50 m/s through a 4.0 cm diameter pipe in the basement under a pressure of $3.03 \times 10^5 Pa$, what will be the velocity and pressure in a 2.6 cm diameter pipe on the second floor 5.0 m above?{Ans $P_2 = 1.84 \times 10^5 Pa$.

Chapter Summary

- We can describe the elastic properties of a substance using the concepts of stress and strain
- Three common types of deformation are represented by (1) the resistance of a solid to elongation under a load, characterized by Young's modulus Y; (2) the resistance of a solid to the motion of internal planes sliding past each other, characterized by the shear modulus S; and (3) the resistance of a solid or fluid to a volume change, characterized by the bulk modulus B.
- The pressure P in a fluid is the force per unit area exerted by the fluid on a surface.
- The pressure in a fluid at rest varies with depth h in the fluid according to the expression: $P = P_0 + \rho gh$

Moving Fluids and Bernoulli Equations (Fluid Dynamics

- Pascal‘s law is true for pressure applied to an enclosed fluid.
- Archimedes‘s principle, the magnitude of the buoyant force is equal to the weight of the fluid displaced by the object: $F_b = \rho_f gV$
- The flow rate (volume flux) through the pipe is constant: $A1v1 = A2v2$
- The sum of the pressure, kinetic energy per unit volume, and gravitational potential energy per unit volume has the same value at all points along a streamline. In Bernoulli‘s equation: $\boldsymbol{P + \rho g y + \frac{1}{2}\rho v^2 = Constant}$

Moving Fluids and Bernoulli Equations (Fluid Dynamics