21ASC203T

APPLIED FLUID MECHANICS

Munson, Bruce R., Young, Donald F., Okiishi, Theodore H., Huebsch, Wade W. Fundamentals of Fluid Mechanics*, 7th ed., John Wiley & Sons, Inc. 2016*

Yunus Çengel, John M. Cimbala - Fluid Mechanics Fundamentals and Applications-McGraw-Hill College

https://nptel.ac.in/courses/112/104/112104118/#

https://nptel.ac.in/courses/112/105/112105171/

- *Introduction to fluid mechanics*
- *Fluids and their properties*
- *Density, viscosity, surface tension*
- *Compressibility and bulk modulus*

Fluid mechanics

Fluid mechanics is the study of fluids either in motion (fluid dynamics) or at rest (fluid statics).

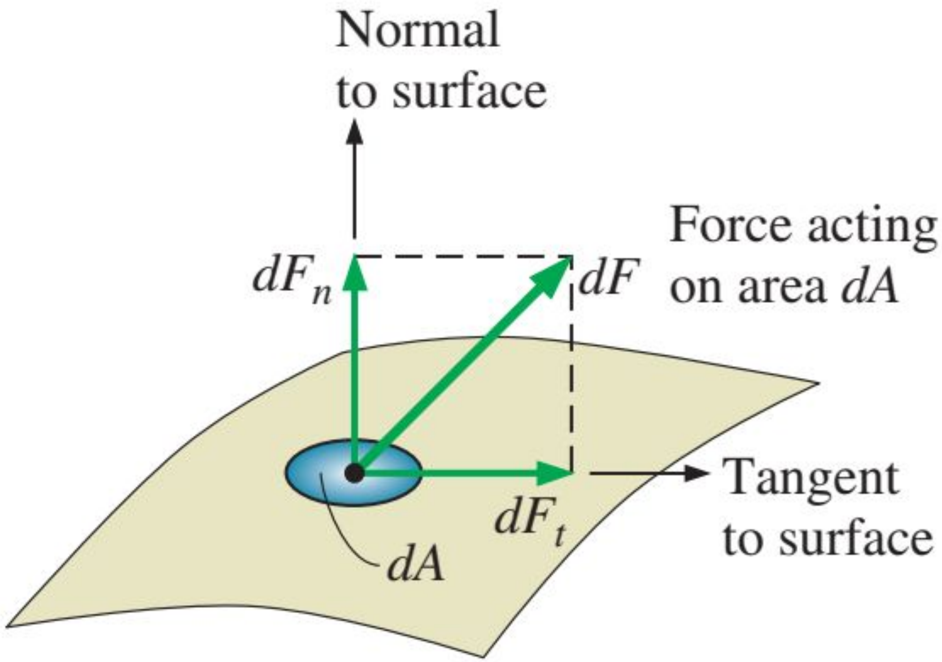
Both gases and liquids are classified as fluids.

The number of fluid engineering applications is enormous:

- breathing, blood flow, swimming, pumps, fans, turbines, airplanes, ships, rivers, windmills, pipes, missiles, icebergs, engines, filters, atmosphere, ocean currents, weather systems, automobiles, cooling, HVAC, jets, and sprinklers, to name a few.

When you think about it, almost everything on this planet either is a fluid or moves within or near a fluid.

Definition of stress



$$\text{Normal stress: } \sigma = \frac{dF_n}{dA}$$

$$\text{Shear stress: } \tau = \frac{dF_t}{dA}$$

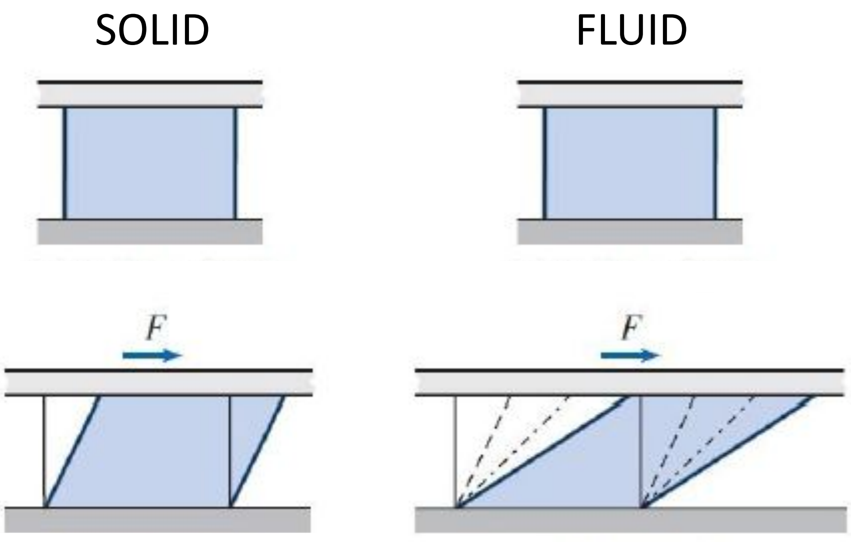
SI Units: N/m^2

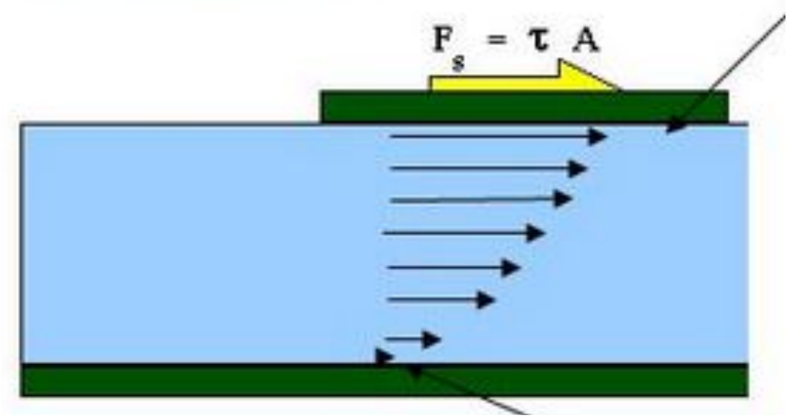
Solid Vs Fluid

Distinction lies with their reaction to an applied shear or tangential stress

A solid can resist a shear stress by a static deflection; a fluid cannot .

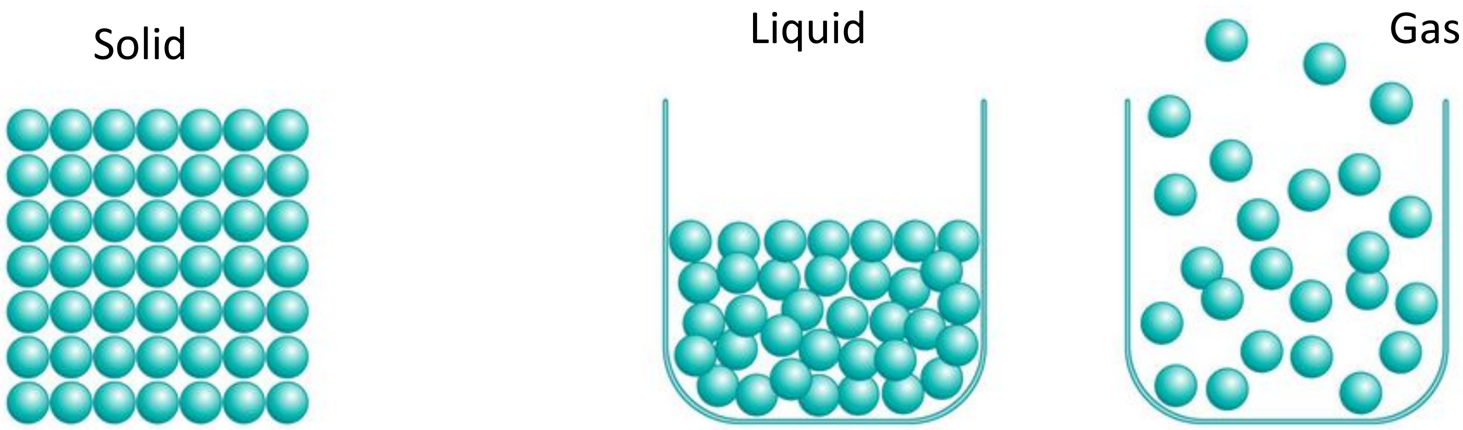
***Any* shear stress applied to a fluid, no matter how small, will result in motion of that fluid. The fluid moves and deforms continuously as long as the shear stress is applied.**





To resist the shear force, the fluid needs to flow

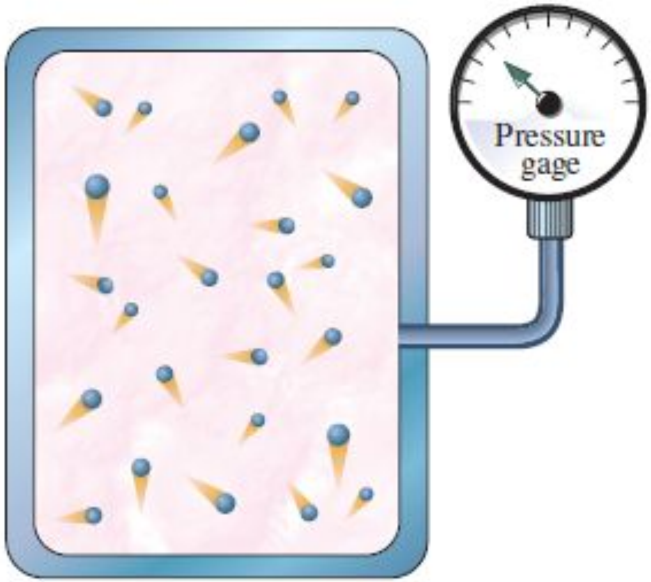
Solid	Fluid
▪ More Compact Structure	▪ Less Compact Structure
▪ Attractive Forces between the molecules are larger therefore more closely packed	▪ Attractive Forces between the molecules are smaller therefore more loosely packed
▪ Solids can resist tangential stresses in static condition	▪ Fluids cannot resist tangential stresses in static condition.
▪ Whenever a solid is subjected to shear stress a. It undergoes a definite deformation α or breaks b. α is proportional to shear stress upto some limiting condition	▪ Whenever a fluid is subjected to shear stress a. No fixed deformation b. Continious deformation takes place until the shear stress is applied
▪ Solid may regain partly or fully its original shape when the tangential stress is removed	▪ A fluid can never regain its original shape, once it has been distorded by the shear stress



Concept of Continuum

- Though matter is composed of several molecules, the concept of continuum assumes a continuous distribution of mass within the matter or system with no empty space
- We don't consider each molecule separately (or) microscopic effects
- We consider the matter to be continuous distribution of mass and study the properties of mass as a whole, i.e., macroscopic effects
- The properties of the matter are considered as continuous functions of space variables.

1 mm^3 of any gas contains 2.7 x 10^{16} molecules – so can be considered as a continuous distribution of mass



Fluid Properties

Density

The **density** (ρ) of a fluid is defined as its mass (m) per unit volume ($\forall$).

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

SI Units: kg/m^3

Specific weight (or) Weight density

The **specific weight** is the weight of fluid per unit volume

$$\gamma = \frac{mg}{\forall} = \rho g$$

SI Units: N/m^3

g is the gravitational acceleration

Specific volume

The **specific volume** of a fluid is the volume occupied by unit mass of fluid.

$$\upsilon = \frac{\forall}{m} = \frac{1}{\rho}$$

SI Units: m^3/kg

Specific gravity

The **specific gravity** of a fluid is the ratio of density of the fluid to the density of a standard fluid

$$s = \frac{\rho}{\rho_{st}}$$

Units: No units

Standard Fluid for liquids – Water at STP (ρ_{st} = 1000 kg/m^3)
Standard Fluid for gases – Air at STP (ρ_{st} = 1.2 kg/m^3)

Problem 1:

Calculate the specific weight, density and specific gravity of one litre of a liquid which weighs 7N

Solution. Given :

$$\text{Volume} = 1 \text{ litre} = \frac{1}{1000} \text{ m}^3 \quad \left(\because\ 1 \text{ litre} = \frac{1}{1000} \text{ m}^3 \text{ or } 1 \text{ litre} = 1000 \text{ cm}^3\right)$$

$$\text{Weight} = 7 \text{ N}$$

(*i*) Specific weight (γ) $= \dfrac{\text{Weight}}{\text{Volume}} = \dfrac{7\text{ N}}{\left(\dfrac{1}{1000}\right)\text{m}^3} = \mathbf{7000\ N/m^3.\ Ans.}$

(*ii*) Density (ρ) $= \dfrac{\gamma}{g} = \dfrac{7000}{9.81} \text{ kg/m}^3 = \mathbf{713.5\ kg/m^3.\ Ans.}$

(*iii*) Specific gravity $= \dfrac{\text{Density of liquid}}{\text{Density of water}} = \dfrac{713.5}{1000}$ $\{\because$ Density of water $= 1000 \text{ kg/m}^3\}$

$= \mathbf{0.7135.\ Ans.}$

Problem 2:

Calculate the density, specific weight and weight of one litre of petrol of specific gravity = 0.7

Solution. Given : Volume = 1 litre = $1 \times 1000 \text{ cm}^3 = \frac{1000}{10^6} \text{ m}^3 = 0.001 \text{ m}^3$

Sp. gravity $S = 0.7$

(*i*) *Density* (ρ)

Density (ρ) $= S \times 1000 \text{ kg/m}^3 = 0.7 \times 1000 = \mathbf{700 \text{ kg/m}^3}$. **Ans.**

(*ii*) *Specific weight* (γ)

$$\gamma = \rho \times g = 700 \times 9.81 \text{ N/m}^3 = \mathbf{6867 \text{ N/m}^3}. \textbf{ Ans.}$$

(*iii*) *Weight (W)*

We know that specific weight $= \frac{\text{Weight}}{\text{Volume}}$

or $$\gamma = \frac{W}{0.001} \text{ or } 6867 = \frac{W}{0.001}$$

$\therefore$ $$W = 6867 \times 0.001 = \mathbf{6.867 \text{ N}}. \textbf{ Ans.}$$