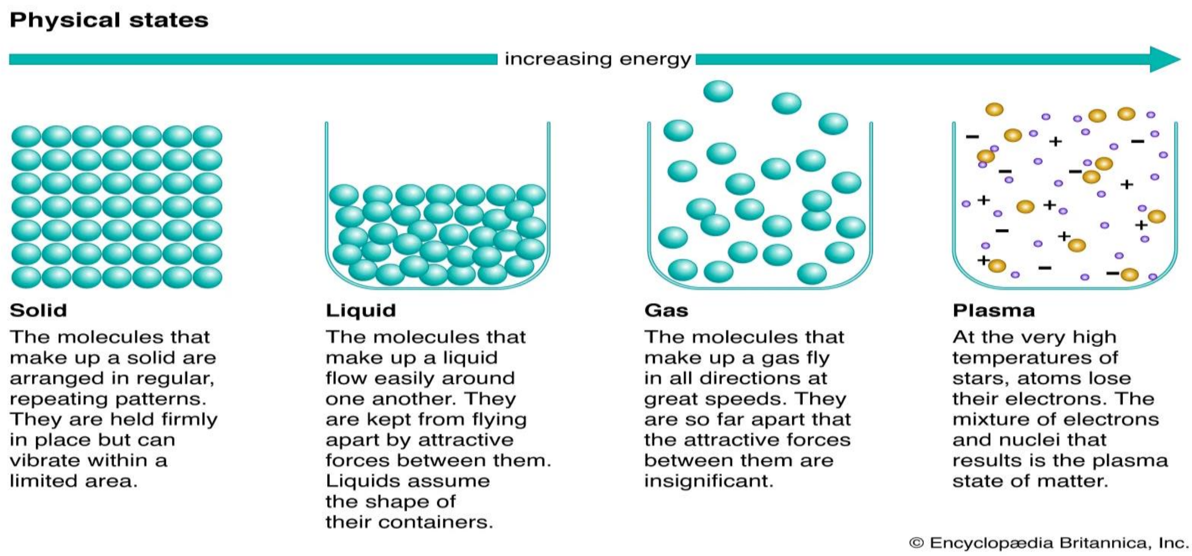
CHAPTER 1
GENERALITIES

1.1 Hydrostatics: from Archimedes to Jefferson

Beginning with Archimedes jumping out of a bath and running down the street shouting "Eureka" because he'd realized how to prove an expensive crown wasn't all it seemed, going on to his Principle of buoyancy and the concept of pressure, then to the much later realization that we live in an ocean of air with its own pressure, finally to Jefferson measuring the altitude of Monticello with a barometer bought in Philadelphia in 1776.

1.2 Solids, Liquids, and Gases. The three states of matter defined

Solids have a definite shape and volume. Liquids have a definite volume, but take the shape of the container. Gases have no definite shape or volume.



1.3 What is a fluid?

A substance that does not possess a definite shape and easily yields to external pressure is known as a fluid.

1.4 Classification of Fluids

Fluids are classified into four types depending on their flow, they are:

- **Steady fluid:** It is the fluid whose density remains constant at each and every point while flowing. Based on the study of fluids, they are classified into two types, they are:

  A. **Fluids statics**: It is the mechanism of fluids at rest or non-motion, and the pressure in fluids exerted by fluids on anybody.
  B. **Fluids dynamics** – It involves the study of the flow of fluids in motion. Popular branches like aerodynamics and hydrodynamics are part of fluid dynamics.

- **Unsteady fluid:** It is the fluid whose velocity differs between any two points while flowing.

- **Compressible fluid and incompressible fluids:** These are classified based on the Mach Number. The incompressible fluid has Mach Number<0.3 and the compressible fluid has Mach Number between 0.3 and 1.

(Mach number, in fluid mechanics, **ratio of the velocity of a fluid to the velocity of sound in that fluid**, named after Ernst Mach (Austrian, 1838–1916))

- **Viscous or Non-viscous**

Fluids with more thickness or viscosity are known as viscous fluids, they are generally very gloppy fluids. Examples: shampoo and motor oil.

Fluids with comparatively less thickness or viscosity are known as non-viscous fluids. These are the fluids with no resistance or negligible resistance to internal friction. Non-viscous fluids flow without any loss of kinetic energy. Example: Superfluid liquid helium

- **Rotational or irrotational**

If the angle between the two intersecting lines of the boundary of the fluid element changes while moving in the flow, the flow is a rotational flow. Depending on the angular motion of the fluid, it is classified into rotational fluid or irrotational fluid.

If the fluid rotates as a whole with no change in angles between the boundary lines, the flow of the fluid is classified as irrotational flow.

1.5 The International System of Units (SI)

- Unit of length (meter)
- Unit of mass (kilogram)
- Unit of time (second)
- Unit of electric current (ampere)
- Unit of thermodynamic temperature (kelvin)
- Unit of amount of substance (mole)
- Unit of luminous intensity (candela)

Table 1. SI base units

	SI base unit	
Base quantity	Name	Symbol
length	meter	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd

1.6 Properties of Fluids

After understanding what is fluid and its classification, let us know some of the main properties of fluids. Properties of fluids are:

1.6.1 Density

Density is defined as *mass per unit volume* . Mass is a property and the SI unit for density is [*kg/m*^{3}].

Density can be expressed as

$\rho = m / V$ where
ρ = density [kg/m^3],
m = mass [kg],
V = volume [m^3],

1.6.2 Specific Gravity (Relative Density)

- **SG** - is a *dimensionless* unit defined as the *ratio of the density of a substance to the density of water* - at a specified temperature and can be expressed as

$SG = \rho_{substance} / \rho_{H2O}$

where
SG = Specific Gravity of the substance
$\rho_{substance}$ = density of the fluid or substance [kg/m^3]
ρ_{H2O} = density of water - normally at temperature 4 °C [kg/m^3]

It is common to use the density of water at 4 °C (39 °F) as a reference since water at this point has its highest density of *1000 kg/m^3* .

Since Specific Gravity - SG - is dimensionless,

1.6.3 Specific weight

Specific weight is defined as the ratio between weight and volume. **Specific weight** can also be defined as the product between density and gravitational acceleration. **Specific weight**, unlike density, is not absolute, it depends on the value of the gravitational acceleration (g), which varies depending on altitude and latitude.

$\gamma = G/V = m \cdot g/V$

where:
G [N] – weight
V [m^3] – volume
m [kg] – mass
g [m/s^2] – gravitational acceleration

$\rho = m/V$ $\boldsymbol{\gamma = \rho \cdot g}$

The **SI unit of measurement for specific weight** is [N/m^3].

1.6.4 Viscosity

Viscosity is a measure of a fluid's resistance to flow.

The SI unit of viscosity is poiseiulle (PI). Its other units are newton-second per square metre ($N\ s\ m^{-2}$) or pascal-second (Pa s.) The dimensional formula of viscosity is $[ML^{-1}T^{-1}]$.

The viscosity of liquids decreases rapidly with an increase in temperature, and the viscosity of gases increases with an increase in temperature.

1.6.4.1 Viscosity Formula

Viscosity is measured in terms of a ratio of shearing stress to the velocity gradient in a fluid. If a sphere is dropped into a fluid, the viscosity can be determined using the following formula:

$\eta=2ga^2(\Delta\rho)/9v$

Where $\Delta\rho$ is the density difference between fluid and sphere tested, a is the radius of the sphere, g is the acceleration due to gravity and v is the velocity of the sphere.

1.6.4.2 Viscosity Types

Viscosity is the measure of fluid's friction to its flow. There are two ways to measure the fluid's viscosity as follows:

Dynamic Viscosity (Absolute Viscosity)

Kinematic Viscosity

One way is to measure the fluid's resistance to flow when an external force is applied. This is known as Dynamic Viscosity.

Kinematic viscosity is a measure of a fluid's internal resistance to flow under gravitational forces. It is expressed as the ratio of fluid dynamic viscosity to its density. The unit of measurement is m^2/s.

In reality, they have significant differences between them. For a few applications, kinematic viscosity is more useful than absolute or dynamic viscosity.

1.6.4.3 Difference Between Kinematic And Dynamic Viscosity

Properties	Kinematic Viscosity	Dynamic Viscosity
Also known as	Diffusivity of momentum	Absolute Viscosity
Represents	Inertia as well as viscous force	The viscous force of the fluid
Symbol	v	μ
Ratio	The ratio of dynamic viscosity to density	The ratio of shear stress to shear strain
Used	When inertia, as well as viscous force, is dominant	When viscous force is dominant
Density	Dependent	Independent
Unit	m^2/s	Ns/m^2

Viscosity

1.6.4.4 Measurement

The elementary way of measuring viscosity is to allow a sphere, such as a metal ball, to drop through a fluid and time the fall of the metal ball. The slower the sphere falls, the greater the viscosity. But, a more accurate measure of viscosity is given by the viscometer.

1.6.5 What is Surface Tension?

Surface tension is the phenomenon that occurs when the surface of a liquid is in contact with another phase (it can be a liquid as well).

· Liquids tend to acquire the least surface area possible.

· The surface of the liquid behaves like an elastic sheet.

“Surface tension is the tension of the surface film of a liquid caused by the attraction of the particles in the surface layer by the bulk of the liquid, which tends to minimise surface area”.

1.6.6 Vapour pressure

The vapour pressure of a liquid is the equilibrium pressure of a vapour above its liquid. The vapour pressure of a liquid varies with temperature. As the temperature increases, the vapour pressure also increases.

1.6.7 Capillarity or meniscus Effect

-Capillarity is defined as a phenomenon of rise or fall of s liquid surface in a small tube relative to the adjacent general level of liquid when tube is held vertically in the liquid.

-The rise of the liquid surface is known as capillarity rise while the fall of liquid surface is known as capillarity depression or fall.

-It is expressed in terms of cm or mm of liquid.

-Its value depends upon the specific weight of the liquid, diameter of the tube and surface tension of the liquid.

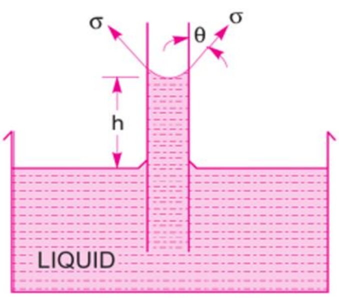


Fig. Capillary Rise

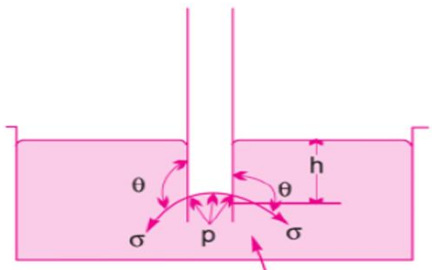


Fig. Capillary fall

- Expression for Capillarity Rise or fall,

$$h = \frac{4\,\sigma\cos\theta}{\rho\, g\, d}$$

-Where, h = Capillarity Rise or fall,

σ = Surface tension Θ = Angle of contact between glass and tube. ρ= Density of fluid d = Diameter of capillary tube

1.6.8 Cavitation

The process of cavitation happens when bubbles or voids form within a fluid. This process takes place when the pressure drops instantaneously below the vapour pressure.

1.7 Types of Fluids

- Ideal fluid: It is a fluid that does not have viscosity and cannot be compressed. This type of fluid cannot exist practically.
- Real fluid: All types of fluids that possess viscosity are classified as real fluids. Examples: Kerosene and castor oil.
- Newtonian fluid: A real fluid that abides by Newton's law of viscosity is known as a Newtonian fluid. Example: Hydrogen and water
- Non-Newtonian fluid: Fluids that do not abide by Newton's law of viscosity are known as Non-Newtonian fluid. Example: Oobleck and flubber
- Ideal plastic fluid: If the shear stress is directly proportional to the velocity gradient, and if the value of shear stress is greater than the resultant, it is referred to as ideal plastic fluid.
- Incompressible fluid: If a fluid's density does not vary with the application of force, it is known as an incompressible fluid. Example: The stream of water flowing at high speed from a garden hose pipe.
- Compressible fluid: If a fluid's density varies with the application of force, it is called a compressible fluid. Example: gas, vapour, and steam.