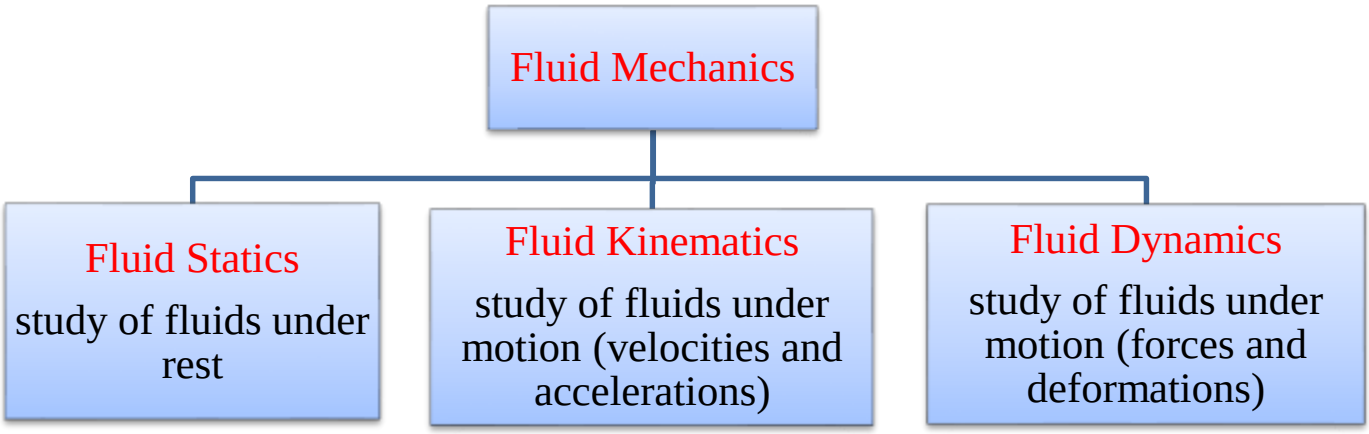
1/ Introduction:

Fluid mechanics is that discipline within the broad field of applied mechanics that is concerned with the behavior of liquids and gases at rest or in motion. It covers a vast array of phenomena that occur in nature (with or without human intervention), in biology, and in numerous engineered, invented, or manufactured situations. There are few aspects of our lives that do not involve fluids, either directly or indirectly.

Fluid is a substance which has no definite shape and will continuously deform or flow whenever an external force is applied to it, e.g.: water, milk, steam, gas, etc. It cannot preserve its shape unless it is restricted into a particular form depending upon the shape of its surroundings.

Fluid Mechanics is the study of fluids either in motion (fluid dynamics/kinematics) or at rest (fluid statics). Gases and liquids (e.g. air, water) come under the category of fluid.

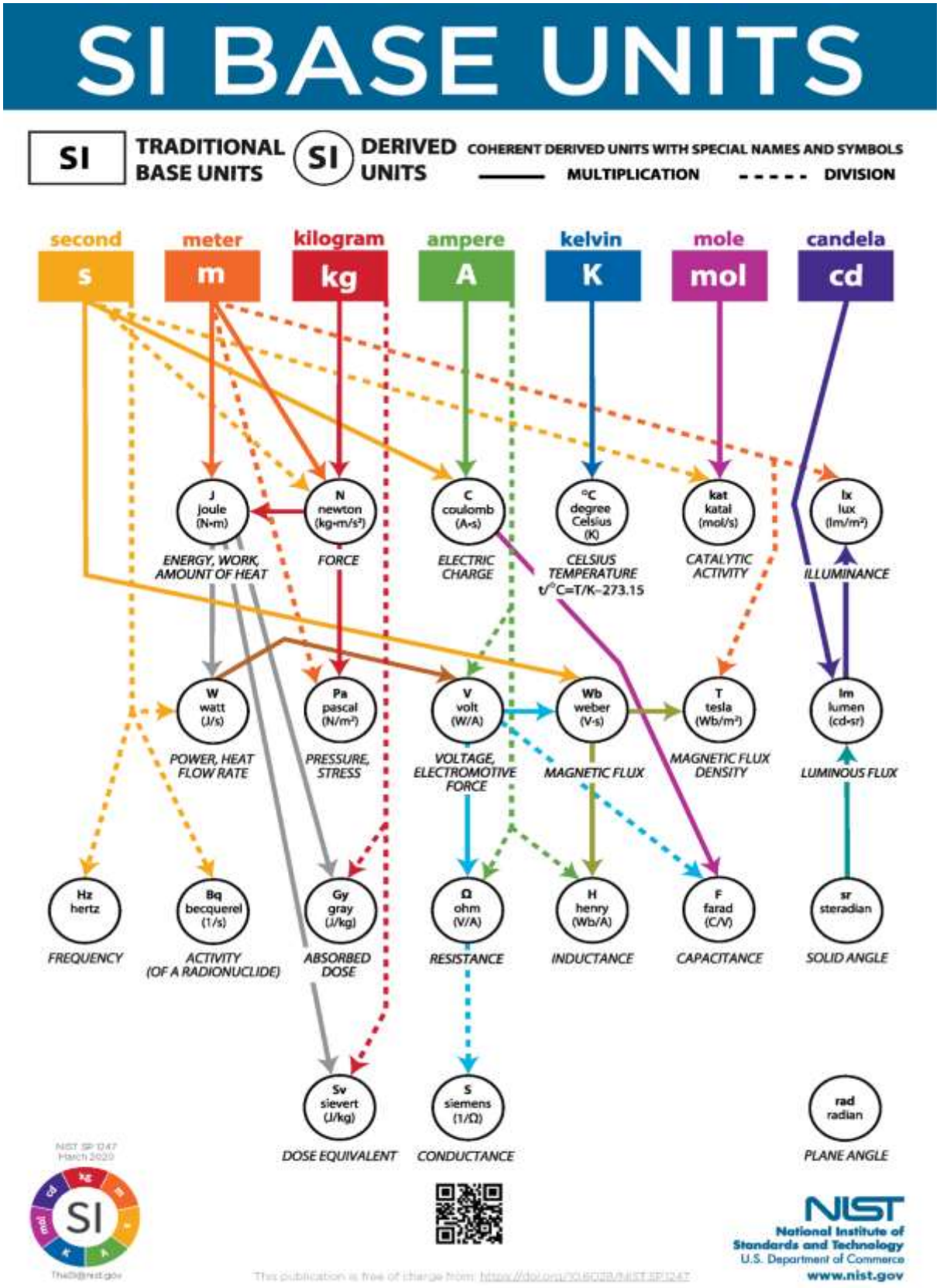
Dairy plants handle various types of fluids such as milk, water, air, refrigerants, steam etc. It is very important to learn the behavior of fluid under various conditions in order to design the system for handling of such fluids in dairy plants.



Quantities and Units

SI Base Units			
Base quantity		**Base unit**	
Name	**Typical symbol**	**Name**	**Symbol**
time	*t*	second	s
length	*l*, *x*, *r*, etc.	meter	m
mass	*m*	kilogram	kg
electric current	*I*, *i*	ampere	A
thermodynamic temperature	*T*	kelvin	K
amount of substance	*n*	mole	mol
luminous intensity	I_v	candela	cd

Source: NIST Special Publication 330:2019, Table 2.


SI BASE UNITS
SI TRADITIONAL BASE UNITS
SI DERIVED UNITS
COHERENT DERIVED UNITS WITH SPECIAL NAMES AND SYMBOLS
MULTIPLICATION
DIVISION
second
s
meter
m
kilogram
kg
ampere
A
kelvin
K
mole
mol
candela
cd
J joule (N·m)
ENERGY, WORK, AMOUNT OF HEAT
N newton (kg·m/s²)
FORCE
C coulomb (A·s)
ELECTRIC CHARGE
°C degree Celsius (K)
CELSIUS TEMPERATURE
t/°C=T/K−273.15
kat katal (mol/s)
CATALYTIC ACTIVITY
lx lux (lm/m²)
ILLUMINANCE
W watt (J/s)
POWER, HEAT FLOW RATE
Pa pascal (N/m²)
PRESSURE, STRESS
V volt (W/A)
VOLTAGE, ELECTROMOTIVE FORCE
Wb weber (V·s)
MAGNETIC FLUX
T tesla (Wb/m²)
MAGNETIC FLUX DENSITY
lm lumen (cd·sr)
LUMINOUS FLUX
Hz hertz
FREQUENCY
Bq becquerel (1/s)
ACTIVITY (OF A RADIONUCLIDE)
Gy gray (J/kg)
ABSORBED DOSE
Ω ohm (V/A)
RESISTANCE
H henry (Wb/A)
INDUCTANCE
F farad (C/V)
CAPACITANCE
sr steradian
SOLID ANGLE
Sv sievert (J/kg)
DOSE EQUIVALENT
S siemens (1/Ω)
CONDUCTANCE
rad radian
PLANE ANGLE
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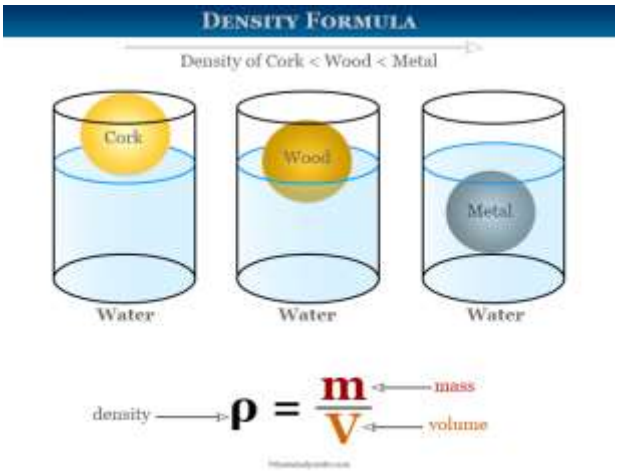
2/ Fluid Properties:

a- **Density:** Mass of fluid per unit of its volume:

$$\rho = \frac{m}{V} \quad [Kg.m^{-3}]$$



b- **Specific Volume:** Volume of substance per unit of its mass.

$$V_S = \frac{1}{\rho} \quad [m^3.Kg^{-1}]$$

c- **Specific Weight:** Weight of fluid per unit of its volume.

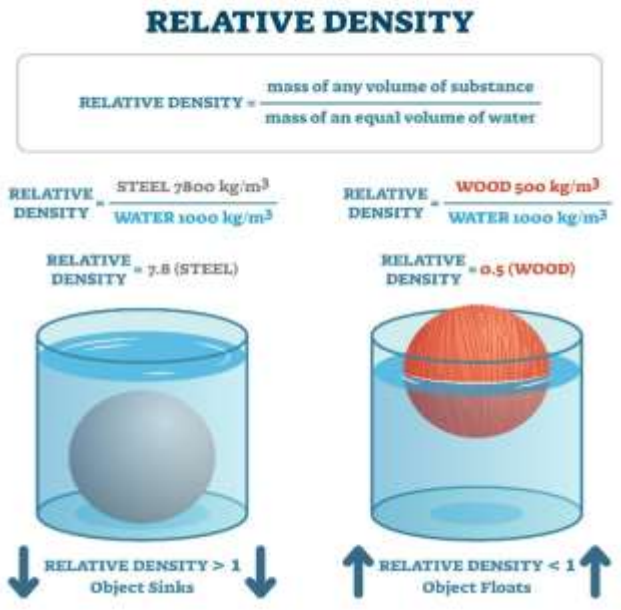
$$\gamma = \frac{mg}{V} = \rho g \quad [N.m^{-3}]$$

d- **Specific Gravity (Relative Density):** Ratio of density of a substance to the density of pure water at 4°C.

$$SG = \frac{\rho_{fluid}}{\rho_{water\ at\ 4°C}}$$

Specific gravities of some substances at 0°C

Substance	SG
Water	1.0
Blood	1.05
Seawater	1.025
Gasoline	0.7
Ethyl alcohol	0.79
Mercury	13.6
Wood	0.3–0.9
Gold	19.2
Bones	1.7–2.0
Ice	0.92
Air (at 1 atm)	0.0013

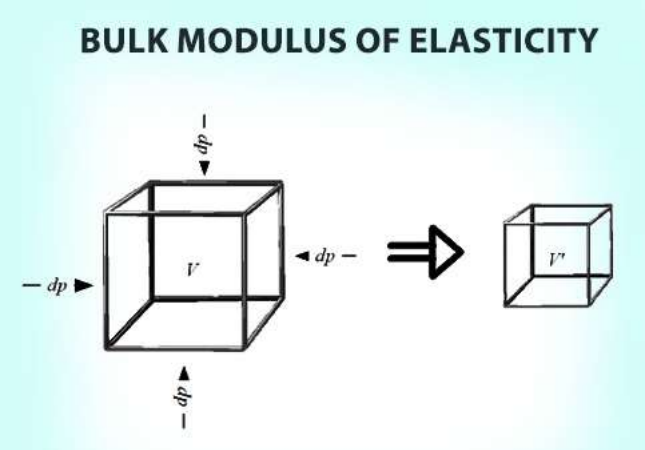


e- Compressibility: is the property of the fluid due to which there will be a change in volume when the fluid is subjected to an external pressure and is reciprocal of Bulk Modulus of Elasticity (E).

e-1- Compressible fluids: The fluids which undergoes a change in volume or density when pressure is applied.

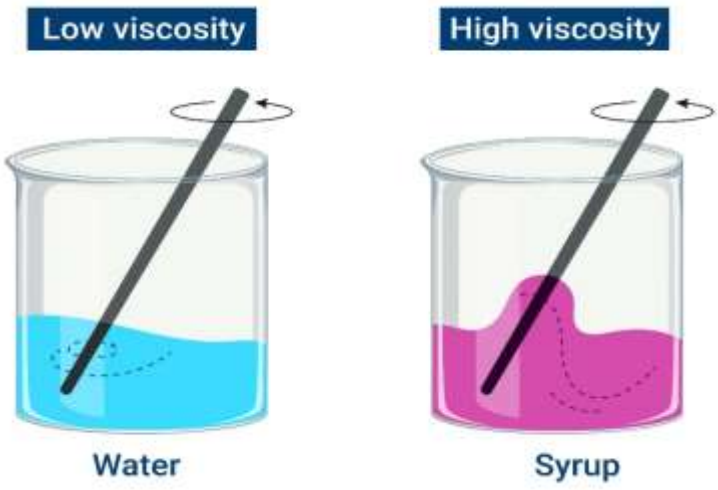
e-2- Incompressible fluids: The fluid which does not show a change in volume or density when pressure is applied.

$$E = \frac{\Delta p}{\frac{\Delta V}{V}} \qquad [Pa]$$



Compressibility Coefficient $\chi = \frac{1}{E}$ $[Pa^{-1}]$

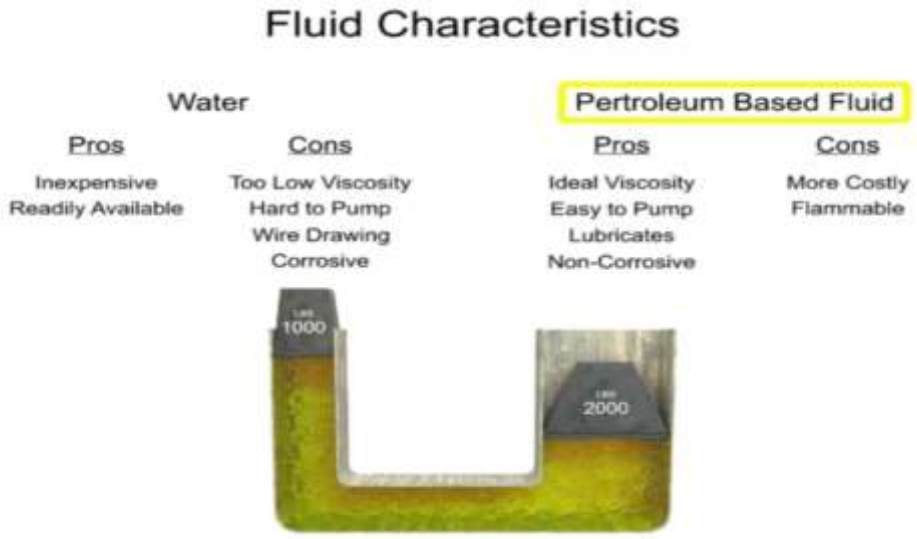
Viscosity: It is property of liquid which provides resistance to flow. For example, flowability of honey is poor as compared to milk. Honey is highly viscous. The viscosity of honey is much higher than milk.



f-1- Newton's Law of Viscosity:

Consider a fluid contained between two parallel plates as shown in the figure01. The fluid layer in contact with the upper plate would move with the plate continuously at the velocity of the plate no matter how small the force *F* is. The fluid velocity decreases with depth because of friction between fluid layers, reaching zero at the lower plate.

You will recall from statics that stress is defined as force per unit area and is determined by dividing the force by the area upon which it acts. The normal component of the force acting on a surface per unit area is called the normal stress, and the tangential component of a force acting on a surface per unit area is called shear stress (figure 02). In a fluid at rest, the normal stress is called pressure.



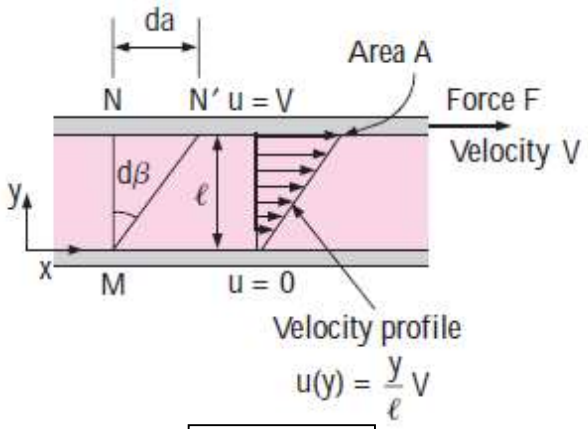
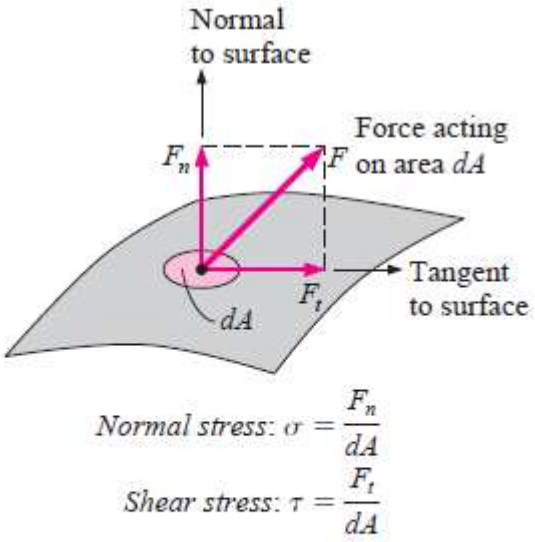


Figure 01

The behavior of a fluid in laminar flow between two parallel plates when the upper plate moves with a constant velocity.



The normal stress and shear stress at the surface of a fluid element.

Figure 02

f-2- Dynamic Viscosity: $\tau = \frac{F}{A}$

$\tau = \mu \frac{dv}{dy}$ τ is pronounced as Tau and is the symbol of shear stress.

$\mu = \frac{F}{A}\frac{y}{v}$ Here, μ is known as coefficient of viscosity or dynamic viscosity.

The SI unit of dynamic viscosity is N.s/m^2.

CGS units of dynamic viscosity is poise: 1 poise = 0.1 N.s/m^2.

f-3- Kinematic Viscosity: $v = \frac{\mu}{\rho}$ $[m^2.s^{-1}]$ or CGS units Stoke=10^{-4} SI.

3/ Classification of Fluids:

a- Ideal Fluid: Ideal fluid is one which has no property other than density. Such fluids have no viscosity, no surface tension and are incompressible. When such fluid flows, no resistance is encountered. Ideal fluid is imaginary fluid as all the fluids have some viscosity.

b- Real Fluid: The fluids which have viscosity, surface tension in addition to density. All the fluids have these properties whether large or small.

c- Newtonion Fluids: Fluids which follow Newton's Law of viscosity are called Newtonian fluid.

d- Non-Newtonion Fluids: Fluids which do not obey Newton's law of viscosity are called non-Newtonian fluids.

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2- Prashant S. Minz, Fluid Mechanics, www.iaritoppers.com.
3- Bruce R. Munson et all, Fundamentals of Fluid Mechanics, John Wiley & Sons, Inc, 6th edition, 2009.