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**MECHANICS**  
**SUB. CODE-BSPH1102**  
*For B.Sc.(Physics & Chemistry)*  
**(Fluid Motion)**

Kinematics of Moving Fluids,

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# Kinematics of Fluid Motion

When a fluid flows there is relative motion between the adjacent layers of the fluid. The layers exert tangential force on each other which tends to oppose to destroy the relative motion between them. This property of fluid by virtue of which it opposes the relative motion between its different layers is called viscosity.

the force between the layers opposing the relative motion is called force of viscosity



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# Newton's law of viscosity

- Newton showed that the viscous force  $F$ , acting tangentially on any liquid layer, is directly proportional to its surface area  $A$ , and velocity  $v$ , and inversely proportional to its distance  $x$  from the stationary layer. So,
  - $F \propto A$ ,  $F \propto -v$ ,  $F \propto \frac{1}{x}$
  - the -ve sign of  $v$  merely indicates that the direction of the force is opposite to that of velocity.



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$$F \propto -\frac{Av}{x} \quad \text{or,} \quad F = -\eta \frac{Av}{x}$$

where  $\eta$  is a constant, depending upon the nature of the liquid, and is called **coefficient of viscosity**.

Now,  $\frac{v}{x}$  may be put as  $\frac{dv}{dx}$ , which gives the rate of change of velocity with distance, and is called the **velocity gradient**; so that, we have

$$F = -\eta \cdot A \cdot \frac{dv}{dx}$$

This is known as **Newton's law of viscous flow** in streamline motion.



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# Coefficient of Viscosity

It may be defined as the tangential force required per unit area to maintain a unit velocity gradient, i.e., to maintain unit relative velocity between two layers unit distance apart.

## Units of viscosity

M.K.S. System:  $\frac{Kgf.sec}{m^2}$

C.G.S. System:  $\frac{dyne.sec}{cm^2} = \text{poise}$

S.I.:  $\frac{N.S}{m^2} = \text{Pa. S}$



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# Kinematic Viscosity:-

It is defined as the ratio between the dynamic viscosity and density of the fluid.

It is represented by Greek symbol  $\nu$  ( $nu$ ).

Mathematically

$$\nu = \frac{\eta}{\rho}$$

Unit:  $\frac{m^2}{sec}$



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# Variation of Viscosity with Temperature

- The viscosity of liquids decreases with increase of temperature while viscosity of gases increases with increase of temperature.
- The viscos force is mainly due to cohesive forces and molecular momentum transfer.
- In liquids, cohesive forces dominates molecular momentum transfer due to closely packed molecule.
- Due to increase in temperature, cohesive force decreases. So viscosity of liquid decreases .



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- For liquids
- $$\mu = \mu_o \left( \frac{1}{1 + \alpha t + \beta t^2} \right)$$
- Where  $\mu$ =viscosity at  $t^\circ\text{C}$
- $\mu_o$ = viscosity at  $0^\circ\text{C}$
- $\alpha$  &  $\beta$  are constants for liquids
- For water,  $\alpha=0.03368$  and  $\beta=0.000221$





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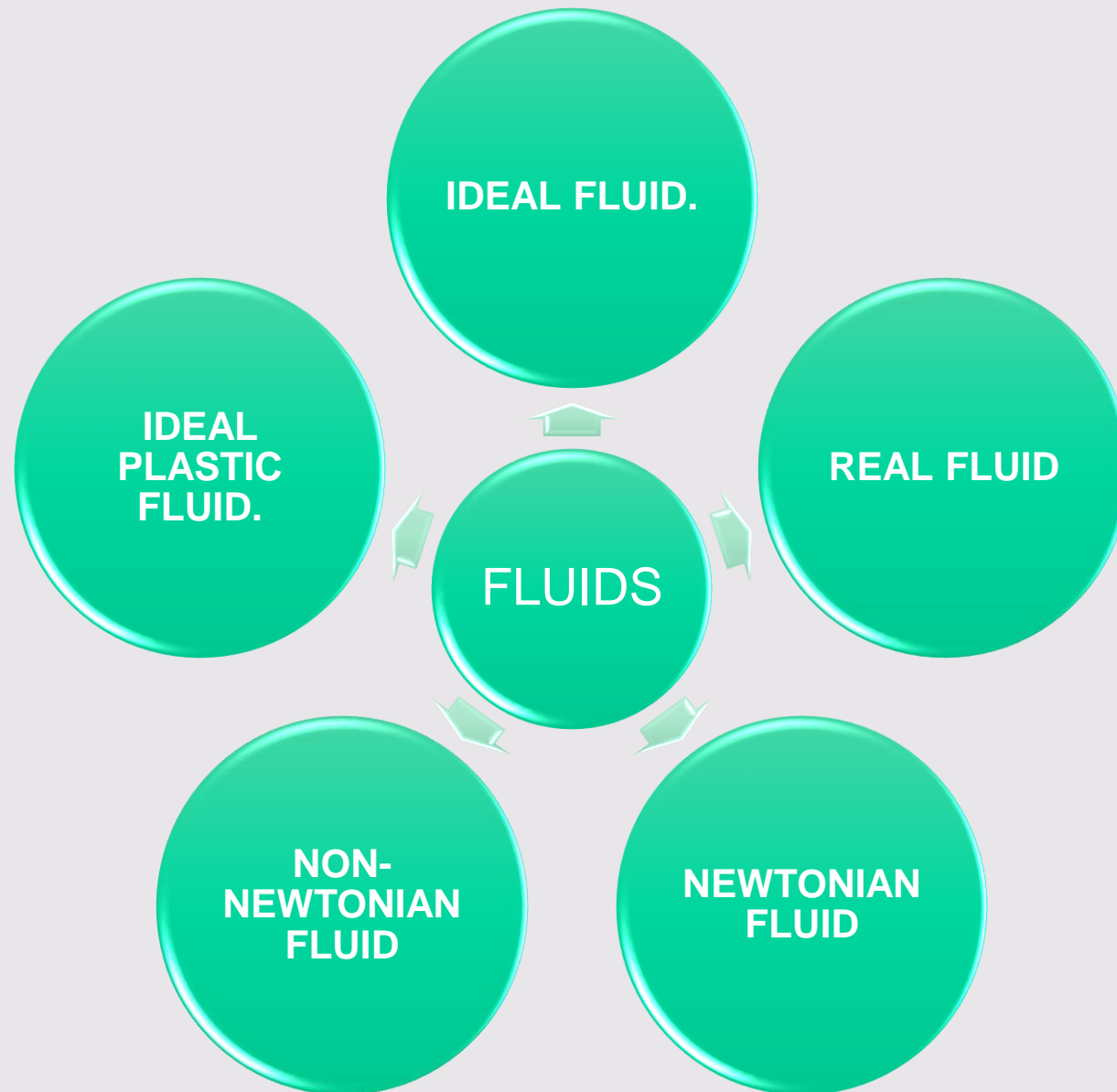
- In gases, molecular momentum transfer predominates cohesive force.
- With increase in temperature, molecular momentum transfer increase. So, viscosity of gases increases with increase of temperature.
- For gases,  $\mu = \mu_o + \alpha t - \beta t^2$
- For air,  $\mu_o=0.000017$ ,  $\alpha=0.0000000056$
- $\beta=0.1189 \times 10^{-9}$



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# TYPES OF FLUIDS:-



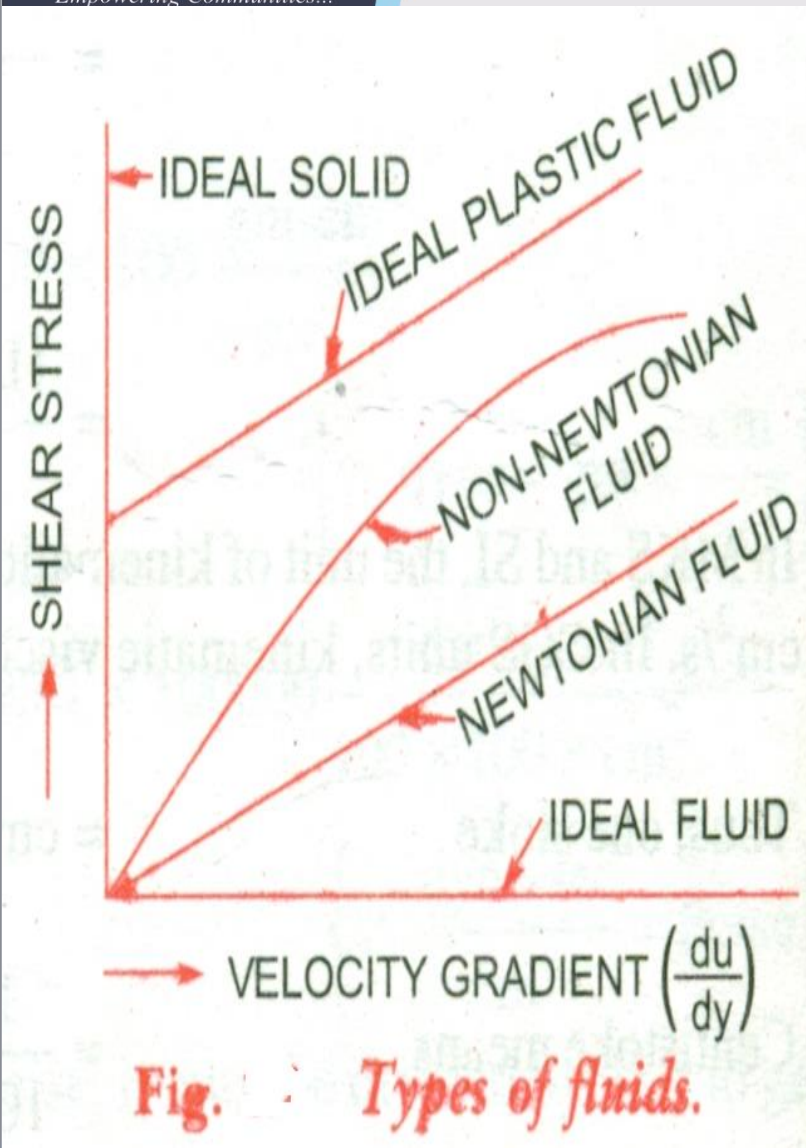


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**Ideal fluid:-** A fluid, which is incompressible and is having no viscosity is known as Ideal fluid. Ideal fluid is only an imaginary fluid as all the fluid, which exist, have some viscosity.

**Real Fluid:-** A fluid, which possesses viscosity is known as Real fluid. All the fluids in actual practice are real fluid.



**Fig. Types of fluids.**



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**Newtonian fluid:-** A real fluid, in which the shear stresses is directly proportional to the velocity gradient (rate of shear strain), is known as Newtonian fluid.

**Non-Newtonian Fluid:-** A real fluid, in which the shear stresses is not directly proportional to the velocity gradient (rate of shear strain), is known as Non-Newtonian fluid.

**Ideal Plastic fluid:-** A fluid in which shear stress is more than the yield value and the shear stress is directly proportional to the velocity gradient, is known as Ideal Plastic fluid.



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# Reference

**Mechanics by *D. S. Mathur*, S. Chand, chp-15.3**

