5. Friction In Solids & Liquids

- **Friction** − Friction is the property due to which a force is set up at the surface of contact of two bodies, preventing any relative motion between them.
- **Cause of friction** − Irregularities of the two surfaces get interlocked restricting the motion when one body moves or tends to move over the other.
- **Types of friction:**
  - Sliding friction
  - Rolling friction
- **Sliding friction** − Whenever a body slides or tends to slide over the surface of another body, the friction that comes into play is called sliding friction. It is of two types:
  - Static friction − It is the opposing force that comes into play when a body tends to slide over the surface of another body.
  - Dynamic friction − It is the opposing force that comes into play when a body is actually sliding over the surface of another body. Dynamic friction is also called kinetic friction.

The maximum value of static friction that comes into play when a body is just on the point of sliding is called limiting friction.

Laws of static friction

- The magnitude of the limiting force of static friction (F_s) between any two bodies in contact is given by $F_s = \mu_s N$.

Here, N is the normal reaction between the bodies and μ_s is the proportionality constant and is called the coefficient of static friction.

- The limiting force of static friction depends on the nature of material of the surfaces in contact.

Laws of kinetic friction

- The magnitude of force of kinetic friction (F_k) between any two bodies in contact is directly proportional to the normal reaction (N) between them.

$F_k \propto N$

$F_k = \mu_k N$

- The force of kinetic friction is independent of the area of contact, as long as the normal reaction between two surfaces in contact remains the same.
- The force of kinetic friction depends on the nature and material of the surfaces in contact.
- The force of kinetic friction is approximately independent of the relative velocity between the surfaces in contact.

- **Pressure:** Average pressure (P_{av}) is normal force (F) acting per unit area (A)

$P_{av} = \frac{F}{A}$ (Scalar quantity)

- **Pascal's law :** Pressure exerted at any point on a liquid in a container is transmitted undiminished in all directions.
- Applications of Pascal's law
  - Hydraulic brakes
  - Hydraulic lift

- **Effect of gravity on pressure** →$P = P_a + h\rho g$.

Here,

P→Absolute pressure at any depth h of a liquid

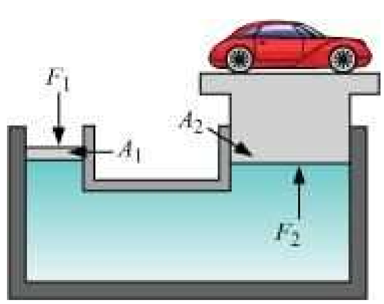
P_a→ Atmospheric pressure

ρ→Density of the liquid

- The liquid pressure at a point in a liquid depends upon the depth of the point below the liquid surface. This is known as hydrostatic paradox.

- **Hydraulic system** → It works on Pascal's Law, according to which, ratio of force exerted to area will be same at all cross-sections.

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



  - Therefore, a large force is experienced in the larger cross-section if a smaller force is applied in the smaller cross-section.

- **Newton's Law of Viscosity:** It states that the shear stress (τ) on fluid layers is directly proportional to the rate of shear strain i.e. **τ=ηdvdl**
- **Viscosity** → The viscous force directly depends on the area of the layer and the velocity gradient.

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

Where, η refers to coefficient of viscosity

- **Poiseuille's Formula** →V=πPr48ηl

- **Stoke's formula** → F=6πηrv,

Where,

r → Radius of the ball

v → Terminal velocity attained by the ball

- **Critical velocity** → Maximum velocity of flow up to which a liquid can have streamlined flow in a tube

$$v_c = \frac{R_e \eta}{\rho r}$$

Where, R_e is Reynolds's number

  - If R_e < 1000, then the flow is streamline.
  - If R_e > 2000, then the flow is turbulent.
  - If $1000<R_e<2000$, then the flow is unstable.

- **Stream-lined flow** → An orderly flow of liquid in which tangents at any point give the direction of flow is called streamlined flow.
- **Equation of continuity** → av = Constant

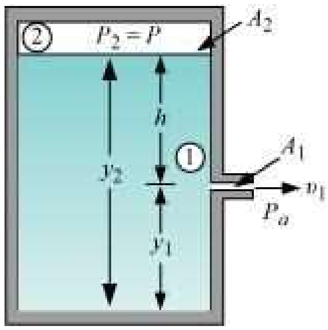
Where,

a = Area of cross-section

v = Velocity of flow

- **Bernoulli's theorem** → $P + \frac{1}{2}\rho v^2 + \rho g h = \text{Constant}$

- **Torricelli's law** → Speed of efflux (fluid out flow) from an open tank is given by a formula identical to that of a freely falling body.



$$v_1 = \sqrt{2gh}$$

- **Magnus effect** →When a ball is given a spin in a streamline of air molecules, it will follow a curved path forming a convex towards the greater pressure side.