11: Mechanics of Solids and Fluids

Key Terms

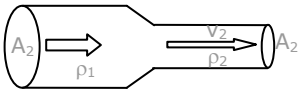
- **Matter:** Anything that has mass and takes up space.
- **States of Matter:** The different forms that matter can take, and whose properties differ due to differences in the motions and forces of the molecules that form the matter.
- **Solid**: Matter with definite shape and volume, which resists changes to these physical properties.
- **Fluid:** Matter with indefinite shape and definite volume Liquids and gases are both fluids.
- **Crystalline Solid:** Solid with ordered molecular-structure and fixed melting point.
- **Amorphous Solids:** Solid with unordered molecular-structure and without melting point.
- **Density:** Mass per unit volume.
- **Pressure:** Force per unit area.
- **Thermal expansion:** An increase in length or volume of matter due to a temperature change.
- **Stress:** The force per unit area that causes deformation.
- **Strain:** The amount by which matter is deformed.
- **Stress-Strain Curve:** A graphical representation of relationship between stress and strain for a solid, usually showing distinct regions of response.
- **Elastic Region**: Material returns to original length when force is removed.
- **Elastic limit:** The maximum stress after which the solid will enter plastic deformation region.
- **Plastic Region:** Material remains permanently deformed even when force is removed.
- **Breaking Point:** Stress at which a material fractures or buckles.
- **Young's modulus:** Ratio of stress to strain when solids is under tension.
- **Shear modulus:** Ratio of stress to strain when solids is under shear.
- **Bulk modulus:** Ratio of stress to strain when solids is under hydraulic pressure.
- **Buoyancy:** The upward force that keeps afloat objects immersed in a fluid, it results from an increase in pressure at greater depth in the fluid.
- **Atmospheric Pressure (atm):** The pressure due to earth's atmosphere, usually taken as that at sea level since it changes with height. 1 atm = 1.013×10^5 N/m^2
- **Hydraulic amplification:** To get a high force on a large piston at one end of a fluid tank by applying small force on a small position at the other end of the fluid tank.
- **Surface tension:** The force to attract surfaced molecular to make the surface area of fluid as small as possible.
- **Capillary action:** The phenomena of fluids automatically rising in open-ended tubes.
- **Contact angle**: The angle from the boundary surface to the tangent line of the fluid drop.
- **Unwettable action:** Fluid-boundary action when the contact angle is large.
- **Wettable action:** Fluid-boundary action when the contact angle is small
- **Continuity:** The net rate of flow of mass inward across any closed surface is equal to the rate of increase of the mass within the surface.
- **Viscosity:** The inter-friction mechanism in fluid to dissipate energy.
- **Laminar flow:** Every particle passing a particular point moves exactly along the smooth path followed by particles passing that point early. Velocity is low.
- **Turbulent flow:** The irregular flow when the velocity of the flow is high.
- **Ideal flow:** Non-viscous & non-compressible laminar flow.

Variables Used and Their Metric Units

- L = Length, m
- P = Pressure, Pa
- h = Depth below surface, m
- A = Area, m^2
- V = Volume, m^3
- T = Temperature, °C or K
- v = Velocity, m/s^2
- ρ = Density, kg/m^3
- g = Acceleration due to gravity = 9.8 m/s^2
- α = Linear expansion coefficient, °C^{-1}
- β = Volume expansion coefficient, °C^{-1}
- γ = Surface tension, N/m
- φ = Contact angle,°
- r = radius, m

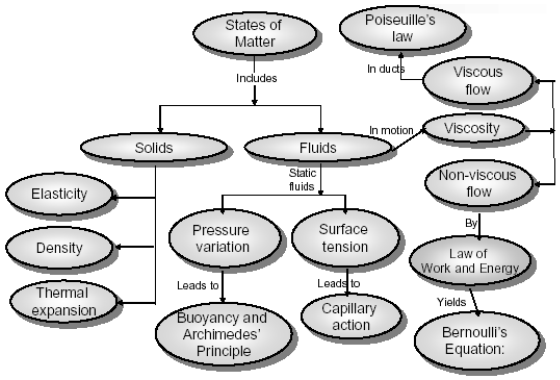
Key Formulas

- Linear thermal expansion: $(L - L_0) = \alpha(T - T_0)$
- Linear thermal expansion: $(V - V_0) = \beta(T - T_0)$
- Stress $= \dfrac{\text{Applied force}}{\text{Loaded area}}$, N/m^2
- Modulus $= \dfrac{\text{Stress}}{\text{Strain}}$, N/m^2
- Fluids:
- Pressure variation with depth: $P = \rho gh$, N/m^2
- Buoyancy (Archimedes' principle): $B = \rho g V_{im}$, N
- Continuity law: $\rho_1 A_1 v_1 = \rho_2 A_2 v_2$



- Bernoulli's equation (along any streamline):
- $P + \frac{1}{2}\rho v^2 + \rho g y = \text{const}$

Solids and Fluids



Fundamental Principles

- **Law of thermal expansion:** The change in dimension of a solid is a linear function with respect to the change in its temperature.
- **Pascal's principle:** The pressure at a depth of **h** below the surface of a fluid open to the atmosphere is greater than atmospheric pressure by the amount **ρgh.**
- **Archimedes' principle:** Any body completely or partially submerged in a fluid is buoyed up by a force whose magnitude is equal to the weight of the fluid displaced by the body.
- **Bernoulli's equation:** For an ideal flow, the sum of the pressure (**P**), the kinetic energy per unit volume **($1/2\rho v^2$)**, and the potential energy per unit volume **(ρgy)** has the same value at all points along a stream line.

How to Use This Cheat Sheet: These are the keys related this topic. Try to read through it carefully twice then recite it out on a blank sheet of paper. Review it again before the exams.

