NEET Physics

Short Notes

Properties of Solids and Liquids

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Properties of Solids and Liquids is an important topic from NEET Exam Point of view. Every year there are 1-2 questions directly asked from this topic. This short notes on Properties of Solids and Liquids will help you in revising the topic before the NEET Exam.

Properties of Solids and Liquids

Mechanical Properties of Solids

A. Elastic Behaviour of Solids

Elasticity- Elasticity is the property by virtue of which a body regains its original size and shape after the removal of deforming force is called elasticity and the deformation caused is called elastic deformation.

B. Stress and Strain and its Curve

Stress- When a body is subjected to a deforming force, a restoring force is developed in the body. This restoring force is equal in magnitude but opposite in direction to the applied force.

Stress = $\frac{F}{A}$

Types of stress

Longitudinal stress- The restoring force per unit area is known as longitudinal stress.

Tangential or shear stress- The restoring force per unit area developed due to the applied tangential force is known as shear or tangential stress.

Volumetric stress- The restoring force per unit volume is known as volumetric stress.

Strain- It is defined as the ratio of the change in dimension of the body to the original dimension.

Strain = $\frac{\text{Change in dimension}}{\text{Original dimension}}$

Types of strain

Longitudinal strain- The change in the length to the original length of the body is called as longitudinal strain.

Longitudinal strain = $\frac{\Delta L}{L}$

Shearing strain- It is defined as the ration of relative displacement of the faces Δx to the length of the cylinder L.

Shearing strain = $\frac{\Delta x}{L} = \tan\theta$

Where θ is the angular displacement of the cylinder from the vertical.

Volume strain- The strain produced by a hydraulic pressure is called volume strain.

Volume strain- $\frac{\Delta V}{V}$

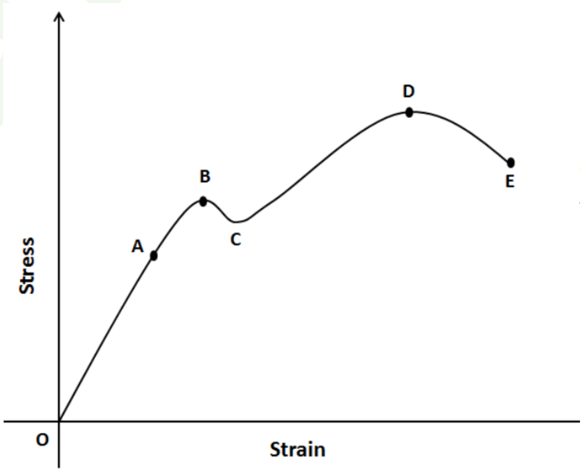
C. Hooke's law- It states that within the elastic limit, stress is proportional to strain.

Stress $\propto$ Strain

Stress = E × Strain

E = $\frac{\text{Stress}}{\text{Strain}}$

D. Stress-Strain Curve – The stress-strain graph provides a graphical measure of the strength and elasticity of a material. Given show a stress-strain curve of a metal wire.



The region between O to A stress is proportional to strain and curve is linear. In this region, Hooke's law is obeyed. The body regains its original dimensions when the applied force is removed. In this region, the solid behaves as an elastic body. The Point A is called the **proportional limit.**

In the region from A to B, stress and strain are not proportional. Nevertheless, the body still returns to its original dimension when the load is removed. The point B in the curve is called **yield point** or **elastic limit.**

If the load is increased further, the stress developed exceeds the yield strength and strain increases rapidly even for a small change in the stress. The portion of the curve between B and D shows this. When the load is removed, at some point C between B and D, the body does not regain its original dimension. In this case, even when the stress is zero, the strain is not zero. The material is said to have a **permanent set.** The deformation is said to be **plastic deformation.** The point D on the graph is the ultimate **tensile strength** of the material. Beyond this point, additional strain is produced even by a reduced applied force and fracture occurs at point E. If the ultimate strength and fracture points D and E are close, the material is said to be **brittle.** If they are far apart, the material is said to be **ductile.**

E. Elastic Moduli

Modulus of elasticity is defined as the ratio of stress to the corresponding strain produced within the elastic limit.

Types of modulus of elasticity

a. Young's modulus- It is defined as the ratio of longitudinal stress to corresponding longitudinal strain.

Young's modulus, $$Y = \frac{\text{Longitudinal Stress}}{\text{Longitudinal Strain}}$$

$$Y = \frac{F/A}{\Delta L/L}$$

$$Y = \frac{FL}{A\Delta L}$$

b. Bulk Modulus- It is defined as the ratio of hydraulic stress to the volumetric strain.

Bulk modulus, $$B = \frac{\text{Hydraulic Stress}}{\text{Volumetric Strain}}$$

$$B = \frac{F / A}{\Delta V / V}$$

$$B = \frac{PV}{\Delta V}$$

Compressibility- The reciprocal of bulk modulus is called compressibility.

$$\text{Compressibility} = \frac{1}{B}$$

$$\text{Compressibility} = \frac{\Delta V}{PV}$$

c. Shear Modulus- It is defined as the ratio of shearing stress to the corresponding shearing strain.

$$\text{Shear modulus, } G = \frac{\text{Shearing Stress}}{\text{Shearing Strain}}$$

$$G = \frac{F / A}{\theta}$$

$$G = \frac{F}{A\theta}$$

$$G = \frac{FL}{A\Delta x}$$

Poisson's ratio- It is defined as the ratio of lateral strain to longitudinal strain.

$$\text{Poisson's ratio, } \sigma = \frac{\text{Lateral Strain}}{\text{Longitudinal Strain}}$$

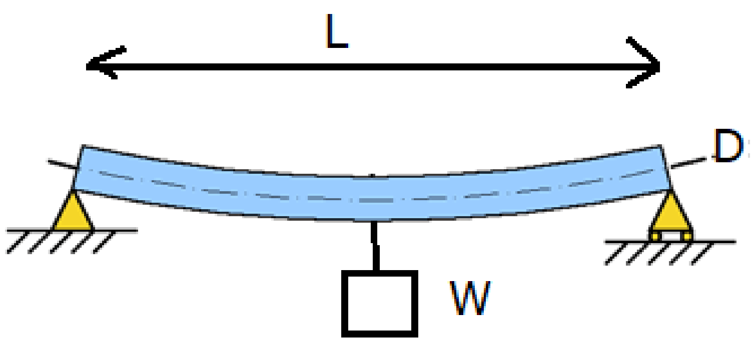
$$\sigma = \frac{\Delta D / D}{\Delta L / L}$$

F. Applications of Elastic Behaviour of Metals

a. Elongation in a wire by its own weight- If a wire of length L and cross-sectional area A is stretched by a force F, then elongation is $\Delta L = \frac{FL}{AY}$

b. Bending of beams- Beams are used in bridges and buildings to support the load. These beams are designed such that they should neither bend too much nor break. When a load W is placed at the centre of a beam of length L , breadth B and thickness D, then the beam supported at the ends sags at the centre by

$$\delta = \frac{WL^3}{4YBD^3}$$



Mechanical Properties of Fluids

Density – Density of a substance is defined as the mass per unit volume of the substance.

Density, $$\rho = \frac{\text{Mass (M)}}{\text{Volume (V)}}$$

1. If two liquids of masses m_1 and m_2 and densities ρ_1 and ρ_2 are mixed together, then the density of the mixture is

$$\rho = \frac{m_1 + m_2}{\frac{m_1}{\rho_1} + \frac{m_2}{\rho_2}}$$

2. If volume V_1 of liquid of density ρ_1 and V_2 volume of density ρ_2 are mixed, then the density of the mixture is,

$$\rho = \frac{\rho_1 V_1 + \rho_2 V_2}{V_1 + V_2}$$

Relative density- Relative density if a substance is defined as the ratio of its density to the density if water at 4°C.

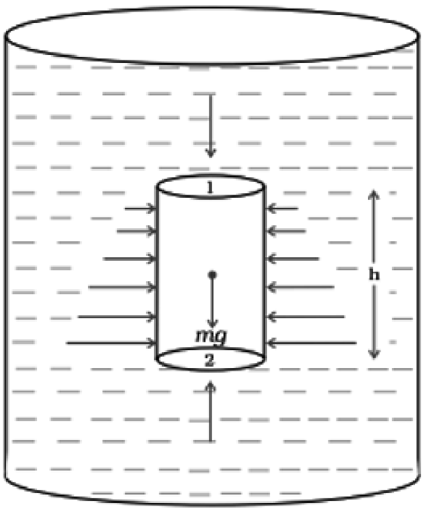
Relative density = $\dfrac{\text{Density of a substance}}{\text{Density of water at } 4^{\circ}\text{C}}$

Pressure- The normal force exerted by a liquid at rest per unit area of the surface in contact with it is called pressure of the liquid on the surface.

Pressure, $P = \dfrac{F}{A}$

A. Pressures due to a Fluid Column

Let us assume that a liquid is at rest in a container. In figure point 1 is at height h above a point 2. The pressures at point 1 and 2 are P_1 and P_2 respectively. Consider a cylindrical element of liquid having area of base A and height h. As the liquid is at rest the resultant vertical forces should balance the weight of the element. The forces acting in the vertical direction due to the liquid pressure at the top is P_1A acting downward, at the bottom P_2A acting upward. If mg is the weight of the liquid in the cylinder, then $P_2 - P_1 = \rho g h$



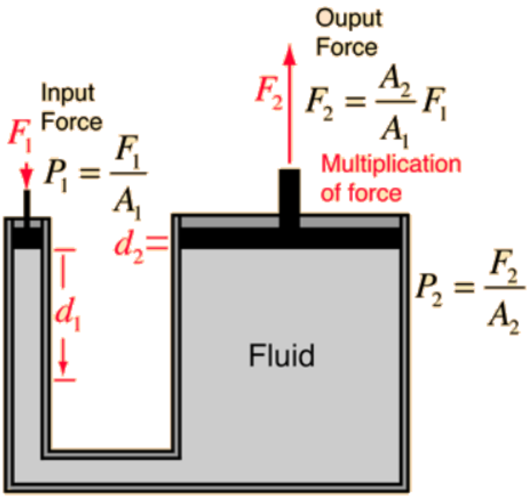
B. Pascal's Law and its Applications

Pascal's law- It states that pressure in a liquid at rest is same at all points which are at the same height. A change in pressure applied to an enclosed liquid is transmitted undiminished to every point of the liquid and the walls of the containing vessel.

Hydraulic lift- It is used to lift heavy loads such as car, truck, etc. It is based on Pascal's law.

In a hydraulic lift, $F_2 = \frac{A_2}{A_1} F_1$

Where A_1 and A_2 are the cross-sectional area of smaller and larger piston of the hydraulic lift. F_1 is the force applied on the smaller piston.



Hydraulic brakes- Hydraulic brakes are used in automobiles to stop automobiles. It is work based on Pascal's law.

C. Viscosity, Stokes' law, Terminal velocity

Viscosity- It is the property of a fluid by virtue of which an internal frictional force comes into play when the fluid is in motion an opposes the relative motion of its different layers. The backward dragging force called viscous drag or viscous force.

The viscous force between two parallel layers each of area A and having velocity gradient dv/dx is

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

Where η is the coefficient of viscosity of the liquid and -ve direction shows that the viscous force acts opposite to the direction of flow of a liquid.

Stoke's law- It states that the backward dragging force F acting on a small spherical body (ball) of radius r moving with velocity v through a fluid of viscosity η is given by $F = 6\pi\eta r v$

Terminal Velocity- It is maximum constant velocity attained by a spherical body while falling freely in a viscous medium.

Terminal velocity of a spherical body of radius r, density ρ while falling freely in a viscous medium of viscosity η and density σ is given by

$$v_t = \frac{2}{9}\frac{r^2(\rho-\sigma)g}{\eta}$$

D. Streamline and turbulent flow, Reynolds number

Streamline flow- When a liquid flow such that each particle of the liquid, passing a point, moves along the same path and has the same velocity as its preceding particles, the flow of the liquid is called streamline flow.

Turbulent flow- The flow of the liquid remains to streamline only as long as the velocity doesn't exceed a certain value, called its critical velocity. Beyond its critical velocity, the flow of the liquid ceases to be streamlined but becomes zigzag or sinuous in character and the paths and velocities of the liquid particles change continuously and haphazardly. This unsteady motion of the liquid is called turbulent flow.

Critical velocity - It is that velocity, upto which the flow of liquid is streamlined and above which its flow becomes turbulent. Critical velocity of a liquid (v_c) flowing through a tube $v_c = \frac{K\eta}{\rho r}$

Where ρ is the density of liquid flowing through a tube of radius r and η is the coefficient of viscosity of the liquid.

Reynolds number- It is a pure number which determines the nature of flow of the liquid. For a liquid of viscosity, η density ρ and flowing through a pipe of diameter D, Reynolds number is $R = \frac{\rho v D}{\eta}$

E. Bernoulli's principle and its Applications

Equation of continuity- If an incompressible and non-viscous liquid flowing through a tube of non-uniform cross-section with the steady flow, the product of the area of cross-section and the velocity of flow remains same at every point in the tube.

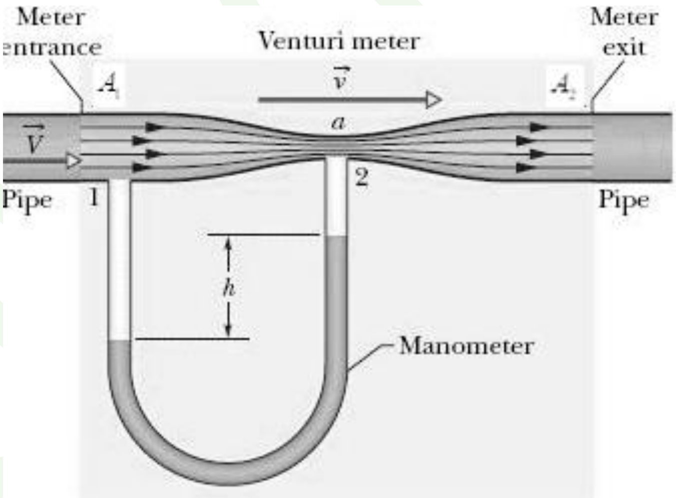
$$A_1 v_1 = A_2 v_2 = \text{constant}$$

Bernoulli's principle- It states that for the streamline flow of an ideal liquid through a tube, the sum of pressure energy, the potential energy and kinetic energy per unit volume remains constant at every cross-section throughout the tube.

$$P + \rho g h + \frac{1}{2}\rho v^2 = \text{constant}$$

Application of Bernoulli's theorem

a. Venturimeter- It is a device used to measure the speed of incompressible liquid and rate if the flow of a liquid through a pipe. It is an application of Bernoulli's principle.

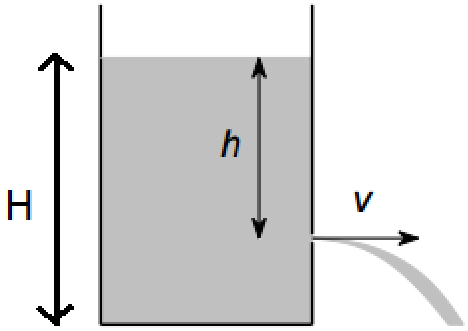


The volume of the liquid flowing per second through the wider tube of area of cross-section A is

$$Q = A_1 V = A_1 A_2 \sqrt{\frac{2\rho_m g h}{\rho\left(A_1^2 - A_2^2\right)}}$$

where ρ_m density of the liquid in U-tube, ρ is the density of liquid flowing through the pipe and h is the difference in height of liquid in two arms of U-tube.

b. Torricelli's' law- It states that the velocity with which the liquid flows out of an orifice (narrow hole) is equal to that which a freely falling body would acquire in falling through a vertical distance equal to the orifice below the free surface of the liquid. The velocity of efflux of a liquid through an orifice at depth h from the liquid surface is $v = \sqrt{2gh}$



c. Airflight- In an airplane wing, the top of the wing is curved, while the bottom of the wing is totally flat. While in the sky, air travels across both the top and the bottom concurrently. Because both the top part and the bottom part of the plane are designed differently, this allows for the air on the bottom to move slower, which creates more pressure on the bottom, and allows for the air on the top to move faster, which creates less pressure. This is what creates lift, which allows planes to fly.

F. Surface energy and Surface Tension, Angle of contact

Surface tension- It is a property by virtue of which the free surface of liquid at rest behaves like stretched membrane tending to contract to possess minimum surface area.

Surface tension, $S = \frac{\text{Force}}{\text{Length}} = \frac{F}{L}$

Surface energy- It is defined as the amount of work done against the force of surface tension in increasing the given surface area of liquid surface at a constant temperature.

Surface energy, $= \frac{\text{Work done in increasing the surface area}}{\text{Increase in surface area}}$

Angle of contact- It is defined as the angle between the tangent to the liquid surface at the point of contact and the solid surface inside the liquid.

Angle of contact is acute for those liquid which wet the walls of the vessel.

Angle of contact is obtuse for those liquid which do not wet the walls of the vessel.

G. Application of Surface Tension - drops, bubbles and capillary rise

1. Work done in forming a liquid drop of radius r, surface tension S is, $W = 4\pi r^2 S$

2. Work done in forming a soap bubble of radius r, surface tension S is, $W = 8\pi r^2 S$

3. Work done in increasing the radius of a liquid drop from r_1 to r_2 is $W = 4\pi S\left(r_2^2 - r_1^2\right)$

4. Work done in increasing the radius of a soap bubble from r_1 to r_2 is $W = 8\pi S\left(r_2^2 - r_1^2\right)$

5. Work done in breaking a liquid drop of radius R into n drops of equal radius is

$W = 4\pi R^2 S\left(n^{1/3} - 1\right)$

Excess Pressure

The pressure on the concave side of the liquid surface is always greater than the pressure on the convex side. The difference of pressure is called as excess pressure.

1. Excess pressure inside a liquid drop is, $P = \frac{2S}{r}$

2. Excess pressure inside a soap bubble is, $P = \frac{4S}{r}$

3. Excess pressure inside an air bubble in liquid is, $P = \frac{2S}{r}$

Capillarity

The phenomenon of rise or fall of liquid in a capillary tube is called capillarity. The height through which liquids falls or rises in a capillary tube is

$$h = \frac{2S\cos\theta}{r\rho g}$$

$$h = \frac{2S}{r\rho g}$$

Where S is the surface tension of the liquid, θ is the angle of contact, ρ is the density of the liquid, r is the radius of the capillary tube, R is the radius of the meniscus and g is the acceleration due to gravity.

1. If $\theta < 90^{o}$ then meniscus is concave, h will be positive, and the liquid will rise in the capillary.

2. If $\theta > 90^{o}$ then meniscus is convex, h will be negative, and the liquid will fall in the capillary.

3. If $\theta = 90^{o}$ then meniscus is concave, h will be plane, so no phenomenon of capillarity.

All the best!

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