UNIT-7 PROPERTIES OF MATTER

MY REVISION TIMELINE:-

SUMMARY:-

- The force between the atoms of an element is called inter-atomic force whereas the force between the molecules of a compound is called inter-molecular force.
- Hooke's law: Within the elastic limit, the stress is directly proportional to strain.
- The force per unit area is known as stress. If F is force applied and A is the area of cross section of the body then the magnitude of stress is equal to $\frac{F}{A}$. Tensile or compressional stress can be expressed using a single term called longitudinal stress.
- The ratio of change in length to the original length of a cylinder is $\frac{\Delta L}{L}$ which is known as longitudinal strain.
- Within the elastic limit, the ratio of longitudinal stress to the longitudinal strain is called the Young's modulus of the material of the wire.
- Within the elastic limit, the ratio of volume stress to the volume strain is called the bulk modulus.
- Within the elastic limit, the ratio of shear stress to the shear strain is called the rigidity modulus.
- The elastic potential energy stored in the wire per unit volume is
  U = ½ × stress × strain
  U = ½ × Y × $(\text{strain})^2$
  where Y denotes Young's modulus of the material.
- If F is the magnitude of the normal force acting on the surface area A, then the pressure is defined as the 'force acting per unit area'.
- The total pressure at a depth 'h' below the liquid surface is $P = P_a + \rho gh$, where P_a is the atmospheric pressure which is equal to 1.013×10^5 Pa.
- Pascal's law states that the pressure in a fluid at rest is the same at all points if they are at the same height.
- The law of floatation states that a body will float in a liquid if the weight of the liquid displaced by the immersed part of the body is equal to or greater than the weight of the body.
- The co=efficient of viscosity of a liquid is the viscous force acting tangentially per unit area of a liquid layer having a unit velocity gradient in a direction perpendicular to the direction of flow of the liquid.
- When a liquid flows such that each particle of the liquid passing a point moves along the same path and has the same velocity as its predecessor then the flow of liquid is said to be streamlined flow.

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- During the flow of a fluid, when the critical velocity is exceeded by the moving fluid, the motion becomes turbulent.
- Reynold's number has a significance as it decides whether the flow of fluid through a cylindrical pipe is streamlined or turbulent.
- Stokes formula F = $6\pi\eta$rv, where F is the viscous force acting on a sphere of radius 'r' and 'v' is the terminal velocity of the sphere.
- The surface tension of a liquid as the force of tension acting on a unit length of an imaginary line drawn on the free surface of the liquid, the direction of the force being perpendicular to the line so drawn and acting parallel to the surface.
- The angle between tangents drawn at the point of contact to the liquid surface and solid surface inside the liquid is called the angle of contact for a pair of solid and liquid.
- The flow of a fluid is said to be steady if, at any given point, the velocity of each fluid particle remains constant with respect to time.
- The equation $a_1v_1 = a_2v_2$ is called the equation of continuity for a flow of fluid through a tube and it is due to the conservation of mass is the flow of fluids. It states that the sum of pressure energy, kinetic energy, and potential energy per unit mass of an incompressible, non-viscous fluid in a streamlined flow remains constant. i.e. $\frac{P}{\rho} + \frac{v^2}{2}$ + gh = constant.

FORMULAS:-

- Stress $\sigma = \frac{Force}{Area} = \frac{F}{A}$
- Normal stress or longitudinal stress $\sigma_n = \frac{F_n}{\Delta A}$
- Tangential stress or shearing stress $\sigma_t = \frac{F_t}{\Delta A}$
- Volume stress $\sigma_v = \frac{F}{A}$
- Strain $\varepsilon = \frac{Change\ in\ size}{Original\ size} = \frac{\Delta L}{L}$
- Longitudinal strain $\varepsilon_l = \frac{\Delta L}{L}$
- Shearing strain $\varepsilon_s = \frac{x}{h} = \tan\theta$
- Volume strain $\varepsilon_v = \frac{\Delta V}{V}$
- Young's modulus Y = $\frac{\sigma_t}{\varepsilon_t}$ or $\frac{\sigma_c}{\varepsilon_c}$
- Bulk's modulus K = $\frac{-\Delta P}{\frac{\Delta V}{V}}$
- Rigidity modulus $\eta_R = \frac{\sigma_s}{\varepsilon_s} = \frac{\frac{F_t}{\Delta A}}{\frac{x}{h}} = \frac{F_t}{\Delta A\theta}$
- Poisson's ratio $\mu = \frac{-L}{l} \times \frac{d}{D}$
- Elastic energy = ½ × stress × strain = ½ × $\frac{F}{A} \times \frac{l}{L}$
- Pascal's law $F_2 = \frac{A_2}{A_1} \times F_1$
- Force of viscosity F = $-\eta A \frac{dv}{dx}$ where η is the co-efficient of viscosity

- Reynold's number $R_c = \frac{\rho v D}{\eta}$
- Terminal velocity $v_t = \frac{2}{9} \times \frac{r^2(\rho-\sigma)}{\eta} g$ => $v_t \alpha r^2$
- Stoke's law $F = 6\pi\eta rv$
- Poiseuille's equation $V = \frac{\pi r^4 \rho}{8\eta l}$
- Surface energy = $\frac{W}{\Delta A}$
- Surface tension $T = \frac{F}{l}$
- Excess pressure inside air bubble $\Delta P = P_2 - P_1 = \frac{2T}{R}$
- Excess pressure inside soap bubble $\Delta P = P_2 - P_1 = \frac{4T}{R}$
- Excess pressure inside liquid drop $\Delta P = P_2 - P_1 = \frac{2T}{R}$
- Surface tension by capillary rise method $T = \frac{r\rho g h}{2\cos\theta}$
- Capillary rise $h = \frac{2T\cos\theta}{r\rho g}$ => $h\ \alpha \frac{1}{r}$
- Equation of continuity: $a_1v_1 = a_2v_2$ = constant
- Kinetic energy per unit mass $\frac{KE}{m} = \frac{1}{2}v^2$
- Potential energy per unit mass $\frac{PE}{m} = gh$
- Pressure energy per unit mass $\frac{E_p}{m} = \frac{P}{\rho}$
- Bernoulli's equation $\frac{P}{\rho} + \frac{v^2}{2}$ + gh = constant

MULTIPLE CHOICE QUESTIONS:-

1. Consider two wires X and Y. The radius of wire X is 3 times the radius of Y. If they are stretched by the same load then the stress on Y is

c) nine times that of X

Solution:

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

Stress S $= \frac{Force}{\pi r^2}$

$S_1\ \alpha \frac{1}{r_1^2}$ $S_2\ \alpha \frac{1}{r_2^2}$ *[when F is same]*

$\frac{S_1}{S_2} = \frac{r_2^2}{r_1^2}$ *and* r_1 *and* $3r_2$

Let $S_1 = S_x$ *and* $S_2 = S_y$

$\frac{S_x}{S_y} = \frac{r_2^2}{(3r_2)^2}$

$\frac{S_x}{S_y} = \frac{1}{9}$

$\boxed{S_y = 9S_x}$

2. If a wire is stretched to double of its original length, then the strain in the wire is

a) 1

Solution:

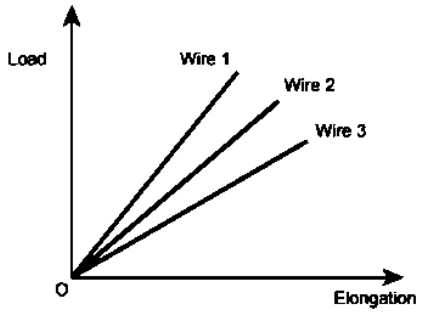
Strain = $\frac{Change\ in\ length}{Original\ length}$

Strain = $\frac{2l-l}{l}$

Strain = $\frac{l}{l}$

Strain = 1

3. The load-elongation graph of three wires of the same material are shown in figure. Which of the following wire is the thickest?



a) wire 1

Solution:

For the wire 1, Young's modulus is less

Young's modulus Y $\alpha \frac{F}{A}$

∴ Area is more

∴ ***Wire 1*** *is* ***thickest.***

4. For a given material, the rigidity modulus is $\left[\frac{1}{3}\right]^{rd}$ **of Young's modulus. Its Poisson's ratio is**

d) 0.5

Solution:

Rigidity modulus = $\frac{1}{3}$ × *Young's modulus*

Poisson's ratio = $\frac{lateral\ strain}{longitudinal\ strain}$

5. A small sphere of radius 2 cm falls from rest in a viscous liquid. Heat is produced due to viscous force. The rate of production of heat when the sphere attains its terminal velocity is proportional to [NEET model 2018]

d) 2^5

Solution:

Rate of heat production = $\frac{Work\ done}{Time\ taken}$

Terminal velocity v = $\frac{2}{9} \times \frac{r^2(\rho-\sigma)}{\eta} g$ => v α r^2

Work α Force α Distance

$$\boxed{Work\ \alpha\ r^2 \times r \Rightarrow 2^5}$$

6. Two wires are made of the same material and have the same volume. The area of cross-sections of the first and the second wires are A and 2A respectively. If the length of the first wire is increased by Δl on applying a force F, how much force is needed to stretch the second wire by the same amount? (NEET model 2018)

b) 4F

Solution:

$\frac{F}{A} = Y\frac{\Delta l}{l} \Rightarrow F = Y\frac{\Delta l}{l} \times A$

$A_1 = A$ *and* $A_2 = 2A$

$\therefore F\ \alpha\ \Delta l \times A$

$F\ \alpha\ \Delta l_1 \times A_1 \qquad F_1\ \alpha\ 2\Delta l_2 \times A_2$

$\frac{F}{F_1} = \frac{\Delta lA}{2\Delta l \times 2A}$

$$\boxed{F_1 = 4F}$$

7. With an increase in temperature, the viscosity of liquid and gas, respectively will

c) decrease and increase

8. The Young's modulus for a perfectly rigid body is

d) infinity

9. Which of the following is not a scalar?

d) Stress

10. If the temperature of the wire is increased, then Young's modulus will

b) decrease

11. Copper of fixed volume V is drawn into a wire of length l. When this wire is subjected to a constant force F, the extension produced in the wire is Δl. If Y represents Young's modulus, then which of the following graphs is a straight line? [NEET 2014 model]

c) Δl versus F

Solution:

Δl versus F

Strain α Stress

Hooke's law is followed.

12. A certain number of spherical drops of a liquid of radius R coalesce to form a single drop of radius R and volume V. If T is the surface tension of the liquid, then

c) energy = $3VT\left[\frac{1}{r} - \frac{1}{R}\right]$ is released

Solution:

$n \times \frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3$

$\therefore$ ***Energy = 3VT*** $\left[\frac{1}{r}-\frac{1}{R}\right]$ ***is released***

13. The following four wires are made of the same material. Which of these will have the largest extension when the same tension is applied?

a) length = 200cm, diameter = 0.5mm

Solution:

$Y = \frac{F/A}{\Delta l/l} = \frac{Fl}{A\Delta l}$

$\Delta l = \frac{Fl}{AY}$

Δl is most when l = 200cm and d = 0.5mm

14. The wettability of a surface by a liquid depends primarily on

d) angle of contact between the surface and the liquid

15. In a horizontal pipe of a non-uniform cross-section, water flows with a velocity of 1 ms^{-1} at a point where the diameter of the pipe is 20 cm. The velocity of water 1.5 (ms^{-1}) at a point where the diameter of the pipe is

b) 16

NUMERICAL PROBLEMS:-

1. Given:

Diameter of capillary tube = d mm

Height of water level $h_1 = 30\ mm = 30 \times 10^{-3} m$

Let the radius of a capillary tube be r mm

Then the radius of a new capillary tube = $\frac{2}{3}r$

Formula used:

Surface tension $T = \frac{r\rho gh}{2\cos\theta}$

Solution:

Let the height of water level in the new capillary tube be h_2.

$h\ \alpha\ \frac{1}{r}$

$\frac{h_1}{h_2} = \frac{r_2}{r_1}$

$\frac{30}{h_2} = \frac{\frac{2}{3}r}{r}$

$h_2 = \frac{3\times30}{2}$

$h_2 = 45mm$

$\therefore$ ***Height of water level in the new capillary tube h_2 = 45mm***

2. Given:

Length of the cylinder l = 1.5m

Diameter of the cylinder d = 4cm

Radius of the cylinder $r = 2 \times 10^{-2} m$

Tangential force $F_1 = 4 \times 10^5 N$

Rigidity modulus of the cylinder = $6 \times 10^{10}\ Nm^{-2}$

Formula used:

$\eta_R = \frac{F_t}{\Delta A \theta}$

Solution:

$\Delta A = \pi r^2 = 3.14 \times 2 \times 10^{-4} = 12.56 \times 10^{-4} m^2$

$\eta_R = 6 \times 10^{10} = \frac{4 \times 10^5}{12.56 \times 10^{-4} \theta}$

$\therefore$ *First produced* $\theta = \frac{4 \times 10^5}{6 \times 10^{10} \times 12.56 \times 10^{-4}}$

$= \frac{0.4}{75.36}$

$\boxed{= 0.005307}$

3. Solution:

Excess of pressure with surface tension of spherical surface of the liquid $\Delta P = \frac{2T}{R}$

where T *– surface tension*

R *– radius*

In case of soap bubble, Excess of pressure $\Delta P_b = \frac{4T}{R}$ *(b-bigger)*

Excess of pressure of air inside the

i) smaller bubble

$\Delta P_s = \frac{4T}{R} = \frac{4T}{2} = 2T$ *(s-smaller)*

ii) bigger bubble

$\Delta P_b = \frac{4T}{R} = \frac{4T}{4} = T$

Pressure difference $\Delta P = \Delta P_s + \Delta P_b = 2T + T = 3T$

Excess of pressure inside a single soap bubble $= \frac{4T}{R} = \frac{4T}{4} = T$

$\therefore T < 3T$

$\therefore$ *Pressure difference of* ***single soap bubble*** *is* ***less*** *than radius of both bubbles A and B.*

4. Given:

Let the mass of Ag block be x kg

Tension in the string $T = 37.12$ *N*

Relative density of liquid $R_l = 0.72$

Relative density of silver $R_{Ag} = 10$

Formula used:

According to the principle of floatation

$V\rho g = mg$

$V\rho = m$

ρ *= density*

Solution:

Weight of Ag block $W = mg = V\rho$

$= R_{Ag} V_g$

$= 10\ V_g$

Force of buoyancy $F_B = R_l\ V_g$

$= 0.72\ V_g$

Apparent weight $W_{app} = 10\ V_g - 0.72\ V_g$

$= 9.28\ V_g$

Tension in the string $= \frac{Apparet\ weight}{Volume}$

$37.12 = 9.28\ g$

$= mg$

$\therefore$ *Mass x = m* $= \frac{37.12}{9.28}$

Mass of Ag block = 4 kg

5. Given:

Before opening the valve $P_1 = 5 \times 10^5 Nm^{-2}$ *and* $v_1 = 0$

After opening the valve $P_2 = 4.5 \times 10^5 Nm^{-2}$ *and* $v_2 = ?$

Formula used:

In the horizontal flow, potential energy remains unchanged. So Bernoulli's theorem can be written as

$$P_2 + \frac{1}{2} \rho v_2^2 = P_1 + \frac{1}{2} \rho v_1^2$$

Solution:

ρ *is the density of water* $= 10^3 kg/m^3$

$P_2 + \frac{1}{2} \rho v_2^2 = P_1 + \frac{1}{2} \rho v_1^2$

$5 \times 10^5 + \frac{1}{2} 10^3 v_2^2 = 4.5 \times 10^5 + \frac{1}{2} 10^3 (0)^2$

$\frac{1}{2} 10^3 v_2^2 = (5 - 4.5) 10^5$

$v_2^2 = \frac{2 \times 0.5 \times 10^5}{10^3}$

$v_2^2 = 100\ ms^{-1}$

$v_2 = 10\ ms^{-1}$

$\therefore$ ***Speed of the water flowing in the pipe*** $= 10 ms^{-1}$

CONCEPTUAL QUESTIONS:-

1. Why coffee runs up into a sugar lump (a small cube of sugar) when one corner of the sugar lump is held in the liquid?

- The sugar lump dissolves **more rapidly** at some points than the others.
- Where it dissolves, the **surface tension** of the liquid is **reduced**.
- As the force of surface tension reduces by different amounts in different points of the sugar lump, coffee runs up into a sugar lump when **one corner of it is held** in the liquid.

2. Why two holes are made to empty an oil tin?

- When oil comes out through a tin with **one hole**, the **pressure** inside the tin becomes **less than the atmospheric pressure**, soon the oil stops flowing out.
- When **two holes** are made in the tin, **air keeps** on **entering** the **tin** through the other hole and **maintains** the **pressure** inside.

3. We can cut vegetables easily with a sharp knife as compared to a blunt knife. Why?

When we cut vegetables with a sharp knife the **area of contact is less**. Hence the **stress** applied becomes **more** [Stress = $\frac{Force}{Area} = \frac{F}{\Delta A}$] and the vegetables would be cut easily. So, it is so easy to cut vegetables with a sharp knife rather than a blunt knife.

4. Why the passengers are advised to remove the ink from their pens while going up in an aeroplane?

- We know that **atmospheric pressure decreases** with **height.**
- Since ink inside the pen is filled at the **atmospheric pressure** existing on the **surface of the earth**, it tends to come out to **equalise** the **pressure**.
- This can **spoil the clothes** of the passengers, so they are advised to remove ink from the pen.

5. We use straw to suck soft drinks, why?

- When we suck through the straw, the **pressure** inside the **straw** becomes **less** than the **atmospheric pressure**.
- Due to the pressure difference, the soft drink **rises** in the **straw** and we are able to take the soft drink easily.

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