CHAPTER

2 Properties of Matter

Elasticity and Plasticity

The property of the body to regain its original configuration (length, or shape) when the deforming forces are removed is called ***elasticity***. On the other hand, *if the body does not have any tendency to regain its original configuration on removal of deforming force the body is called plastic body and this property is called* ***plasticity***.

Perfectly elastic body : A body which regains its original configuration immediately and completely after the removal of deforming force from it, is called perfectly elastic body. Quartz and phosphor bronze, are closed to perfectly plastic body.

Perfectly plastic body : A body which does not regain its original configuration at all on the removal of deforming force, however small the deforming force may be is called perfectly plastic body. Putty and mud are closed to perfectly plastic body.

Stress

The internal restoring force acting per unit area of a body is called stress.

i.e., *Stress = Restoring force/ Area*

Strain

The ratio of change in configuration to the original configuration is called strain.

$$i.e.,\ Strain = \frac{Change\ in\ configuration}{Original\ configuration}$$

Strain being the ratio of two like quantities has **no units** and **dimensions**.

Elastic Limit

Elastic limit is the upper limit of deforming force up to which, if deforming force is removed, the body regains its original form completely and beyond which, if deforming force is increased, the body loses its property of elasticity and gets permanently deformed.

Hooke's law

It states that *within the elastic limit stress is directly proportional to strain.*

i.e., $Stress \propto strain$

or $\text{Stress} = E \times \text{strain}$

or $\frac{Stress}{Strain} = E = constant$

Here E is the coefficient of proportionality and is called **modulus of elasticity** or **coefficient of elasticity** of a body.

Materials-Ductile, Brittle and Elastomers

(i) **Ductile materials :** *The materials which have large range of plastic extension* are called ductile materials. They can be drawn into thin wires, e.g., copper, silver, aluminium, iron, etc.

(ii) **Brittle materials :** *The materials which have very small range of plastic extension* are called brittle materials. These materials break as soon as the stress is increased beyond the elastic limit. e.g., glass, ceramics, cast iron, etc.

(iii) **Elastomers :** *The materials which can be stretched to large values of strain* are called elastomers. *e.g.,* rubber, elastic tissue of aorta, etc.

Young's modulus of elasticity (Y) : It is defined as *the ratio of normal stress to the longitudinal strain within the elastic limit.*

Thus, $Y = \frac{Normal\ \ stress}{Longitudinal\ \ strain}$

or, $Y = \frac{F/\pi r^2}{\Delta\ell / L_0} = \frac{MgL_0}{\pi r^2 \Delta\ell}$

Thermal Stress

When a rod is rigidly fixed at its two ends and its temperature is changed, then a thermal stress is set up in the rod. And the corresponding strain developed is called thermal strain.

$$Thermal\ stress = \frac{Force}{Area\ of\ cross\ section} = \frac{F}{A} = Y\alpha\Delta\theta.$$

where α = coefficient of linear expansion of the rod

$\Delta\theta$ = change in temperature.

Fluids

Fluids are the substances that can flow. Therefore liquids and gases both are fluids. The study of fluids at rest is called **fluid statics** or **hydrostatics** and the study of fluids in motion is called **fluid dynamics** or **hydrodynamics**. Both combined are called **fluid mechanics**.

Density (ρ)

Mass per unit volume is defined as density. So density at a point of a fluid is represented as

$$\rho = \lim_{\Delta V \to 0} \frac{\Delta m}{\Delta V} = \frac{dm}{dV}$$

where *m* is the mass and *v* is the volume of the fluid.

Relative Density

It is defined as the ratio of the density of the given fluid to the density of pure water at 4°C.

$$Relative\ density\ (R.D.) = \frac{Density\ of\ \ given\ liquid}{Density\ of\ \ pure\ water\ at\ 4°C}$$

The density of water is maximum at 4°C and is equal to $1.0 \times 10^3\ kgm^{-3}$

Pressure

If a uniform force is exerted normal to an area (A), then *average pressure (p_{av}) is defined as the normal force (F) per unit area.*

$$i.e.,\ p_{av} = \frac{F}{A}$$

In limiting sense, *pressure* $p = \lim_{\Delta A \to 0} \frac{\Delta F}{\Delta A}$. Pressure is a scalar quantity.

SI unit : pascal (Pa), $1\ Pa = 1\ N/m^2$

Practical units: atmospheric pressure (atm), bar and torr

$1\ atm = 1.01325 \times 10^5 Pa = 1.01325\ bar = 760\ torr = 760 mm$ of Hg column pressure.

Pascal's Law of Transmission of Fluid Pressure

Pascal's law is stated in following ways :

- The pressure in a fluid at rest is same at all the points if gravity is ignored.
- A liquid exerts equal pressures in all directions.
- If the pressure in an enclosed fluid is changed at a particular point, the change is transmitted to every point of the fluid and to the walls of the container without being diminished in magnitude.

  Applications of Pascal's law : Hydraulic machines, lifts, presses and brakes, are based on the Pascal's law.

Atmospheric Pressure

Force exerted by air column on unit cross-section area of sea level is called atmospheric pressure (P_0)

$$P_0 = \frac{F}{A} = 101.3\ kN/m^2$$

Barometer is used to measure atmospheric pressure which was **discovered by Torricelli**.

Atmospheric pressure varies from place to place and at a particular place from time to time.

Buoyancy and Archimed Principle

If a body is partially or wholly immersed in a fluid, it experiences an upward force due to the fluid surrounding it. This phenomenon of force exerted by fluid on the body is called **buoyancy** and force is called **buoyant force** or **upthrust**.

Archimedes' Principle : *It states that the buoyant force on a body that is partially or totally immersed in a fluid equal to the weight of the fluid displaced by it.*

Bernoulli's Principle

When incompressible, non-viscous, irrotational liquid i.e., ideal liquid flow from one position to other in streamline path then in its path at every point, the sum of pressure energy, kinetic energy and potential energy per unit volume remains constant.

$$i.e.,\ P_1 + \rho g h_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g h_2 + \frac{1}{2}\rho v_2^2$$

$$\therefore \quad P + \rho g h + \frac{\rho v^2}{2} = constant$$

Viscosity

The property of a fluid due to which it opposes the relative motion between its different layers is called viscosity (or fluid friction or internal friction) and the force between the layers opposing the relative motion is called **viscous force**.

According to Newton, the frictional force or viscous force between two layers depends upon the following factors :

$$F \propto A\frac{dv}{dy}$$

or $$F = -\eta A\frac{dv}{dy}$$

where, η is a constant called **coefficient of viscosity** or **simply viscosity** of fluid.

Factors Affecting Viscosity

(1) **Effect of temperature :** On increasing temperature viscosity of a liquid decreases. While it increases in the case of gases.

(2) **Effect of pressure :** On increasing pressure viscosity of a liquid increases but viscosity of water decreases. Viscosity of gases is independent of pressure.

Stoke's Law

According to stoke's law, the viscous drag force F on a spherical body of radius r moving through a fluid of viscosity η with a velocity called terminal velocity v is given by

$$F = 6\pi\eta r v$$

Terminal Velocity

It is maximum constant velocity acquired by the body while falling freely in a viscous medium.

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

Surface Tension

Surface tension is basically a property of liquid. The liquid surface behaves like a stretched elastic membrane which has a natural tendency to contract and tends to have a minimum possible surface area. This property of liquid is called surface tension.

$$Surface\ tension\ T = \frac{Force\ F}{Length\ L}$$

Examples of surface tension

(i) Raindrops are spherical in shape.

(ii) The hair of a shaving brush cling together when taken out of water.

(iii) Oil spread on cold water but remains as a drop on hot water etc.

Angle of Contact (θ)

The angle enclosed between the tangent plane at the liquid surface and the tangent plane at the solid surface at the point of contact inside the liquid is termed as the ***angle of contact****.*

Angle of contact of various solid-liquid pairs

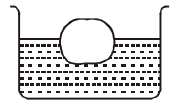
Solid - liquid pair	θ_C	
Glass -normal water	8°	Acute angle
Glass -distilled water	0°	
Glass - alcohol	0°	
Glass - mercury	135°	Obtuse angle
Paraffin wax - water	108°	
Silver - water	90°	Right angle

Capillarity

A glass tube with fine bore and open at both ends is known as **capillary tube**. *The property by virtue of which a liquid rise or fall in a capillary tube is known as* ***capillarity***. Rise or fall of liquid in tubes of narrow bore (capillary tube) is called capillary action. Rise of kerosene in lanterns, rise of ink in fountain pen etc. are due to capillary action.

EXERCISE

1. Kerosene oil rises up in a wick of a lantern because of
   (a) diffusion of the oil through the wick
   (b) surface tension
   (c) buoyant force of air
   (d) the gravitational pull of the wick
2. Two pieces of metal when immersed in a liquid have equal upthrust on them; then
   (a) both pieces must have equal weights
   (b) both pieces must have equal densities
   (c) both pieces must have equal volumes
   (d) both are floating to the same depth
3. If the force on the surface is doubled and area is reduced to half, pressure will
   (a) become 2 times (b) become 3 times
   (c) become 4 times (d) remain unchanged
4. Pressure at a point inside a liquid does not depend on
   (a) the depth of the point below the surface of the liquid
   (b) the nature of the liquid
   (c) the acceleration due to gravity at that point
   (d) the shape of the containing vessel
5. The bulk modulus for an incompressible liquid is
   (a) zero (b) unity
   (c) infinity (d) between 0 and 1
6. An egg when placed in ordinary water sinks but floats when placed in brine. This is because
   (a) density of brine is less than that of ordinary water
   (b) density of brine is equal to that of ordinary water
   (c) density of brine is greater than that of ordinary water
   (d) None of these
7. Water is flowing through a horizontal pipe in streamline flow. At the narrowest part of the pipe
   (a) Velocity is maximum and pressure is minimum
   (b) Pressure is maximum and velocity is minimum
   (c) Both the pressure and velocity are maximum
   (d) Both the velocity and pressure are minimum
8. 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 = 50 cm , diameter = 0.5 mm
   (b) Length = 100 cm, diameter = 1 mm
   (c) Length = 200 cm, diameter = 2 mm
   (d) Length = 300 cm, diameter = 3 mm
9. A man is sitting in a boat which is floating in pond. If the man drinks some water from the pond, the level of water in the pond will
   (a) rise a little (b) fall a little
   (c) remain stationary (d) None of these
10. In solids, interatomic forces are
    (a) totally repulsive
    (b) totally attractive
    (c) combination of (a) and (b)
    (d) None of these
11. A body floats in a liquid containing in a beaker. The whole system as shown in Fig. is falling under gravity. The upthrust on the body due to liquid is



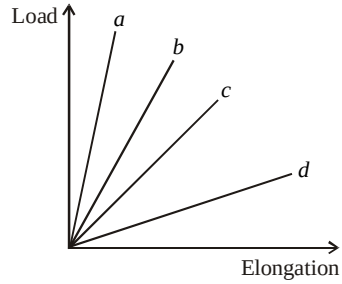
    (a) zero
    (b) equal to weight of body in air
    (c) equal to weight of liquid displaced
    (d) equal to weight of immersed part of the body
12. A water tank of height 10 m, completely filled with water is placed on a level ground. It has two holes one at 3 m and the other at 7 m from its base. The water ejecting from
    (a) both the holes will fall at the same spot
    (b) upper hole will fall farther than that from the lower hole
    (c) upper hole will fall closer than that from the lower hole
    (d) more information is required
13. The lift of an air plane is based on
    (a) Torricelli's theorem
    (b) bernoulli's theorem
    (c) law of gravitation
    (d) conservation of linear momentum
14. The rain drops falling from the sky neither injure us nor make holes on the ground because they move with
    (a) constant acceleration (b) variable acceleration
    (c) variable speed (d) constant terminal velocity
15. Two soap bubbles are held by a tube. What will happen ?
    (a) Air will travel from bigger to smaller bubble
    (b) Air will not travel
    (c) Air will travel through tube
    (d) Nothing can be said
16. With the increase of temperature, the surface tension of the liquid
    (a) may increase or decrease depending on the density of liquid
    (b) remains the same
    (c) always increases
    (d) always decreases
17. According to Hooke's law of elasticity, if stress is increased, then the ratio of stress to strain
    (a) becomes zero (b) remains constant
    (c) decreases (d) increases
18. Liquid pressure at a point in a liquid does not depend on the
    (a) density of liquid
    (b) shape of the vessel in which the liquid is kept
    (c) depth of the point from the surface
    (d) acceleration due to gravity
19. A container partly filled in a liquid is suspended from a spring balance. A small body is gently dropped in the container. The pointer of spring balance will
    (a) read less (b) oscillate
    (c) read the same (d) read more
20. Small droplets of a liquid are usually more spherical in shape than larger drops of the same liquid because
    (a) force of surface tension is equal and opposite to the force of gravity
    (b) force of surface tension predominates the force of gravity

(c) force of gravity predominates the force of surface tension
(d) force of gravity and force of surface tension act in the same direction and are equal

21. Which of the following materials is most elastic ?
(a) Rubber (b) Lead
(c) Wood (d) Steel

22. A stretched rubber has
(a) increased kinetic energy
(b) increased potential energy
(c) decreased kinetic energy
(d) decreased potential energy

23. The load verses elongation graph for four wires is shown. The thinnest wire is

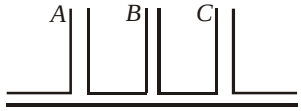


(a) *a* (b) *b*
(c) *c* (d) *d*

24. Elastomers are the materials which
(a) are not elastic at all
(b) have very small elastic range
(c) do not obey Hooke's law
(d) None of these

25. The lift in an aeroplane is based on
(a) Law of gravitation (b) Theorem of continuity
(c) Pascal's low (d) Bernoulli's theorem

26. In the figure below is shown the flow of the liquid through a horizontal pipe. Three tubes *A*, *B* and *C* are connected to the pipe. The radii of the tubes *A*, *B* and *C* at the junction are respectively 2 cm, 1 cm and 2 cms. It can be said that



(a) the height of the liquid in the tube *A* is maximum
(b) height of the liquid in the tube *A* and tube *B* is the same
(c) height of the liquid in all the three tubes is the same
(d) height of the liquid in tube *A* and *C* is the same

27. Houses far from the municipal water tank find it difficult to get water on the top floor even if their ceilings are lower than the level of water filled in tank. Its reason is
(a) pipes are more wide.
(b) pipes are less wide.
(c) when water flows there is loss of pressure.
(d) None of these

28. Working of atomizer is based on
(a) Boyle's law
(b) Bernoulli's law
(c) Newton's laws of motion
(d) Archimedes' principle

29. Ideal liquid is that liquid
(a) whose density is zero (b) whose viscosity is zero
(c) which is compressible (d) None of these

30. Water is flowing through a horizontal pipe line having a restriction. Then
(a) pressure will be the same throughout the length of the pipe.
(b) pressure will be greater at the restriction.
(c) pressure will be greater in the wider portion.
(d) None of these

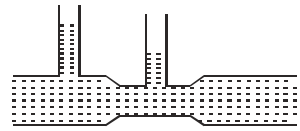
31 Paint-gun is based on
(a) Bernoulli's theorem (b) Archemedes' principle
(c) Boyle's law (d) Newton's laws of motion

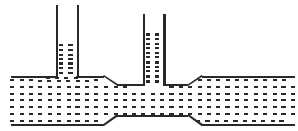
32. A tank filled with water has a hole at a certain height from its bottom. The volume of water emerging out per second from the hole does not depend on
(a) the height of the level of liquid above the hole.
(b) the area of a hole.
(c) the density of a liquid.
(d) the acceleration due to gravity.

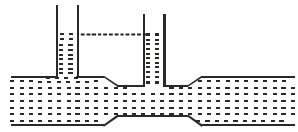
33. A boy carries a fish in one hand and a bucket of water in the other hand. If he places the fish in the bucket, the weight now carried by him.
(a) is less than before (b) is more than before
(c) is the same as before (d) depends upon his speed

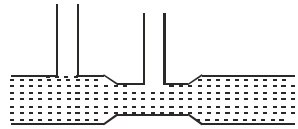
34. A drop of oil is placed on the surface of water. Which of the following statements is correct?
(a) It will remain on it as a sphere
(b) It will spread as a thin layer
(c) It will partly be a spherical droplet and partly a thin film
(d) It will float as a distorted drop on the water surface

35. For a fluid which is flowing steadily, the level in the vertical tubes is best represented by

(a) 

(b) 

(c) 

(d) 

36. Surface tension of a liquid is due to
(a) gravitational force between molecules
(b) electrical force between molecules
(c) adhesive force between molecules
(d) cohesive force between molecules

37. A liquid rises in a capillary tube higher than water does. The difference may be due to the fact that
(a) diameter of the capillary may be different in the two cases
(b) temperature of liquid is higher than that of water
(c) surface tension of water is less than that of the liquid
(d) both (a) and (c)

38. Construction of submarines is based on
(a) Archimede's principle
(b) Bernoulli's theorem
(c) Pascal's law
(d) Newton's laws

39. The action of a nib split at the top is explained by
(a) gravity flow (b) diffusion of fluid
(c) capillary action (d) osmosis of liquid

40. Why the dam of water reservoir is thick at the bottom?
(a) Quantity of water increases with depth
(b) Density of water increases with depth
(c) Pressure of water increases with depth
(d) Temperature of water increases with depth

41. Hydraulic lift is based on the principle of
(a) Pascal's law
(b) Bernoulli's theorem
(c) Toricelli's theorem
(d) Stoke's law

42. A and B are two wires. The radius of A is twice that of B. They are stretched by the same load. Then the stress on B is
(a) equal to that on A (b) four times that on A
(c) two times that on A (d) half that on A

ANSWER KEY											
1	(b)	**8**	(a)	**15**	(a)	**22**	(b)	**29**	(b)	**36**	(d)
2	(c)	**9**	(c)	**16**	(d)	**23**	(b)	**30**	(c)	**37**	(c)
3	(c)	**10**	(c)	**17**	(b)	**24**	(c)	**31**	(a)	**38**	(a)
4	(d)	**11**	(a)	**18**	(b)	**25**	(d)	**32**	(c)	**39**	(c)
5	(c)	**12**	(a)	**19**	(d)	**26**	(d)	**33**	(c)	**40**	(c)
6	(c)	**13**	(b)	**20**	(b)	**27**	(c)	**34**	(b)	**41**	(a)
7	(a)	**14**	(b)	**21**	(d)	**28**	(b)	**35**	(a)	**42**	(b)

HINTS AND SOLUTIONS

5. (c) Bulk modulus $= \frac{\text{Pressure}}{\text{Volume Strain}} = \frac{\text{Pressure}}{0}$

Bulk modulus = ∞

[As liquid is uncompressible, $\Delta V = 0$]

6. (c) Brine due to its high density exerts an upthrust which can balance the weight of the egg.

8. (a) $Y = \frac{T/A}{\Delta\ell/\ell}$

$\Delta\ell = \frac{T \times \ell}{A \times Y} = \frac{T}{Y} \times \frac{\ell}{A}$

Hence, $\frac{T}{Y}$ is constant. Therefore, $\Delta\ell = \frac{\ell}{A}$

$\frac{\ell}{A}$ is largest in the first case.

12. (a) Velocity of water from hole

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

Velocity of water from hole B $= v_2 = \sqrt{2g(H_0 - h)}$

Time of reaching the ground from hole B

$= t_1 = \sqrt{2(H_0 - h)/g}$

Time of reaching the ground from hole A $= t_2 = \sqrt{2h/g}$

13. (b) Apply Bernoulli's theorem.)

15. (a) The excess pressure inside a soap bubble is given by, $p = \frac{4T}{r}$. As the excess of pressure is less in bigger bubble means pressure is more inside bigger bubble. So, air travels from bigger bubble to smaller.

16. (d) Surface-Tension is the property of liquid at rest. As we increase temperature, due to gain in kinetic energy of molecules, surface tension decreases.

17. (b) The ratio of stress to strain is always constant. If stress is increased, strain will also increase so that their ratio remains constant.

19. (d) The pointer of spring balance will read more. The increased reading will be equal to the upthrust given by Archimedes principle.

24. (c) Elastomers do not obey Hooke's law.

26. (d) The rise of water in capillary tube is inversely proportional to radius, $h = \frac{2T}{r\rho g}$. It is given that radius of *A* and *C* are same. So, height of the liquid in tube *A* and *C* is the same.

30. (c) A ↑ v ↑ P ↑ (Area A, Velocity v, Pressure P)

32. (c) Volume per second = $A\sqrt{2gh}$

34. (b) The surface tension of oil is less than that of water, so the oil spreads as a thin layer.

35. (a) From continuity equation, velocity at cross-section (1) is more than that at cross-section (2).
Hence, $P_1 < P_2$.

36. (d) Surface tension of a liquid is due to force of attraction between like molecules of a liquid i.e. cohesive force between the molecules.

37. (c) The height to which liquid rises in a capillary is given by, $h = \frac{2T}{r\rho g}$. Thus, if height to which liquid rises is more, the liquid have greater surface tension than water. Option (a) is not suitable because diameter of capillary tube containing liquid should be smaller than the capillary in which water rises. This is not mentioned clearly in the option (a).

40. (c) A torque is acting on the wall of the dam trying to make it topple. The bottom is made very broad so that the dam will be stable.

41. (a) Hydraulic lift is based on the principle of Pascal's law.

42. (b) Stress = $\frac{\text{force}}{\text{Area}} \therefore \text{Stress} \propto \frac{1}{\pi r^2}$

$\frac{S_B}{S_A} = \left(\frac{r_A}{r_B}\right)^2 = (2)^2 \Rightarrow S_B = 4S_A$