UNIT 7

Properties of Matter

1 **Write down the main points of kinetic molecular theory of matter. What is its use?**

Ans. (a) Matter is made up of particles called molecules.

(b) The molecules remain in continuous motion.

(c) Molecules attract each other.

Kinetic molecular model is used to explain the three states of matter – solid, liquid and gas.

2 **What is meant by pressure? Show that atmosphere exerts pressure.**

Ans. **Pressure**

Perpendicular force acting on unit area is called pressure. Atmosphere exert pressure; this can be proved with the help of a simple experiment.

Experiment

Take an empty tin can with a lid. Open its cap and put some water in it. Place it over flame. Wait till water begins to boil and the steam expels the air out of the can. Remove it from the flame. Close the can firmly by its cap. Now place the can under tap water. The can will squeeze due to atmospheric pressure.

Crushing can experiment

When the can is cooled by tap water, the steam in it condenses and the steam changes into water, it leaves an empty space behind it. This lowers the pressure inside the can as compared to the atmospheric pressure outside the can. This will cause the can to collapse from all directions. This experiment shows that atmosphere exerts pressure in all directions.

3 **What is meant by atmospheric pressure? How it is measured?**

Ans. **Atmospheric Pressure**

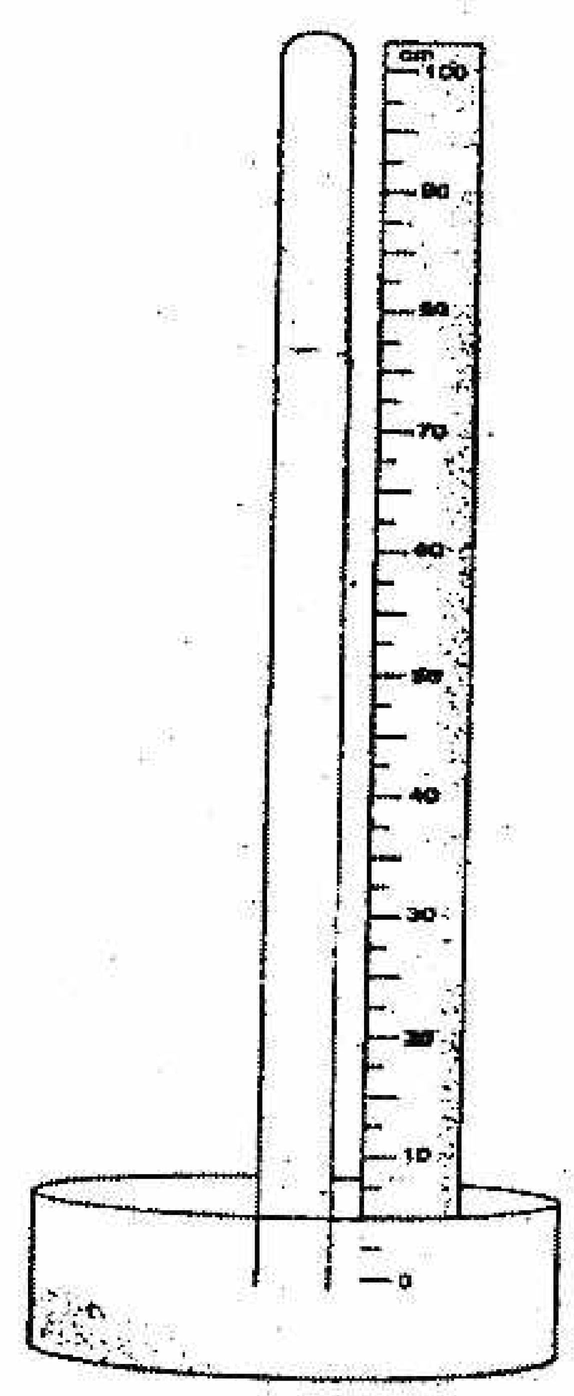
The earth is surrounded by a cover of air called atmosphere. So the pressure exerted by the air is called atmospheric pressure.

Measuring the Atmospheric Pressure

The instruments that measure the atmospheric pressure are called barometers.

Mercury Barometer

One of the simple barometers is a mercury barometer. It consists of a glass tube 1m long closed at one end. After filling it with mercury, it is inverted in a mercury trough. Mercury in the tube descends and stops at a certain height. The column of mercury held in the tube exerts pressure at its base.



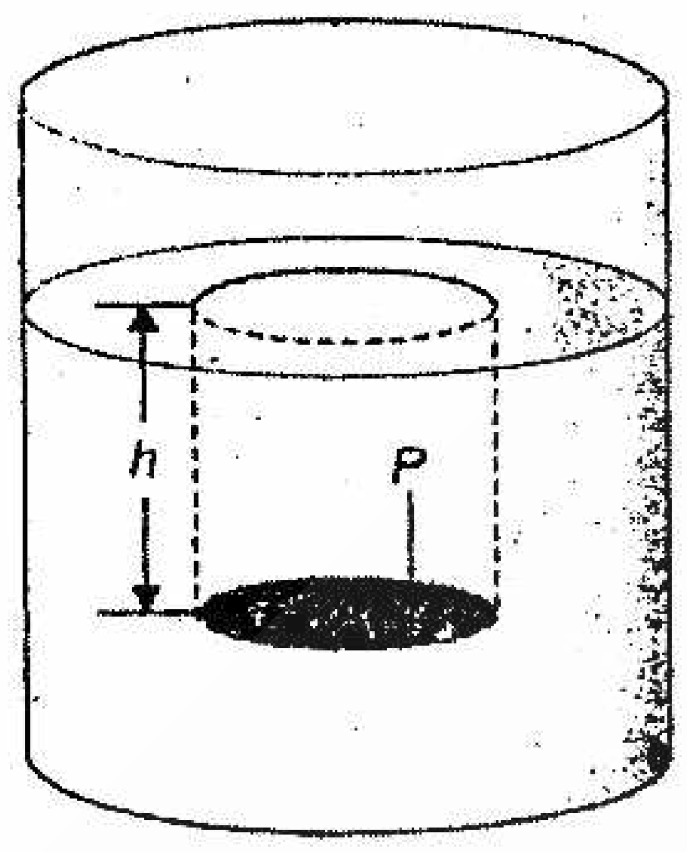
A mercury barometer

At sea level the height of mercury column above the mercury in the trough is found to be about 76 cm. Pressure exerted by 76 cm of mercury column is nearly 101,300 Nm^{-2} equal to atmospheric pressure. It is common to express atmospheric pressure in terms of the height of mercury column. As the atmospheric pressure at a place does not remains constant, hence, the height of mercury column also varies with atmospheric pressure.

4 Prove that liquid pressure is equal to P = ρgh.

Ans. Pressure in Liquids

Liquid exert pressure. The pressure of a liquid acts in all directions. If we take a pressure sensor (a device that measures pressure) inside a liquid, then the pressure of the liquid varies with the depth of sensor.



Pressure of a liquid at a depth h

Consider a surface of area A in a liquid at a depth h as shown by shaded region in figure. The length of the cylinder of liquid over this surface will be h. the force acting on this surface will be the weight w of the liquid above this surface. If ρ is the density of the liquid and m is mass of liquid above the surface, then

Mass of the liquid cylinder

$$m = \text{volume} \times \text{density}$$

$$= (A \times h) \times \rho$$

Force acting on area, A

$$F = w = mgh$$

$$= A\,h\,\rho\,g$$

As pressure, $P = \frac{F}{A}$

$$= \frac{A\,h\,\rho\,g}{A}$$

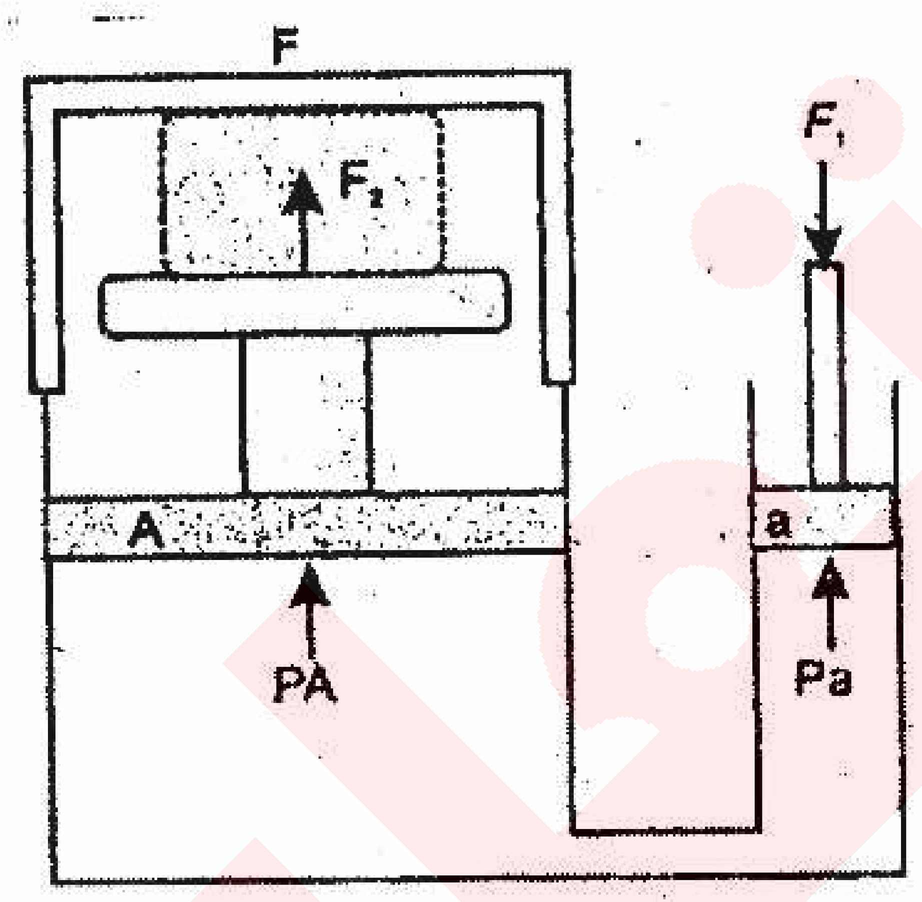
∴ Liquid pressure at depth h $= P = \rho\,g\,h$

Gives the pressure at a depth h in a liquid of density ρ. It shows that the pressure in a liquid increases with depth.

5 Write note on hydraulic press.

Ans. Hydraulic Press

Hydraulic press is a machine which works on Pascal's law. It consists of two cylinders of different cross-sectional area as shown in figure.



A hydraulic press

They are fitted with pistons of cross-sectional areas a and A. The object to be compressed is placed over the piston of large cross-sectional area A. The force F_1 is applied on the piston of small cross-sectional area a. the pressure P produced by small piston is transmitted equally to the large piston and a force F_2 acts on A which is much larger than F_1.

Pressure on piston of small area a is given by

$$P = \frac{F_1}{a}$$

Apply Pascal's law, the pressure on large piston of area A will be the same as on small piston.

$$\therefore \quad P = \frac{F_2}{A}$$

Comparing the above equations, we get

$$\frac{F_2}{A} = \frac{F_1}{a}$$

$$\therefore \quad F_2 = A \times \frac{F_1}{a}$$

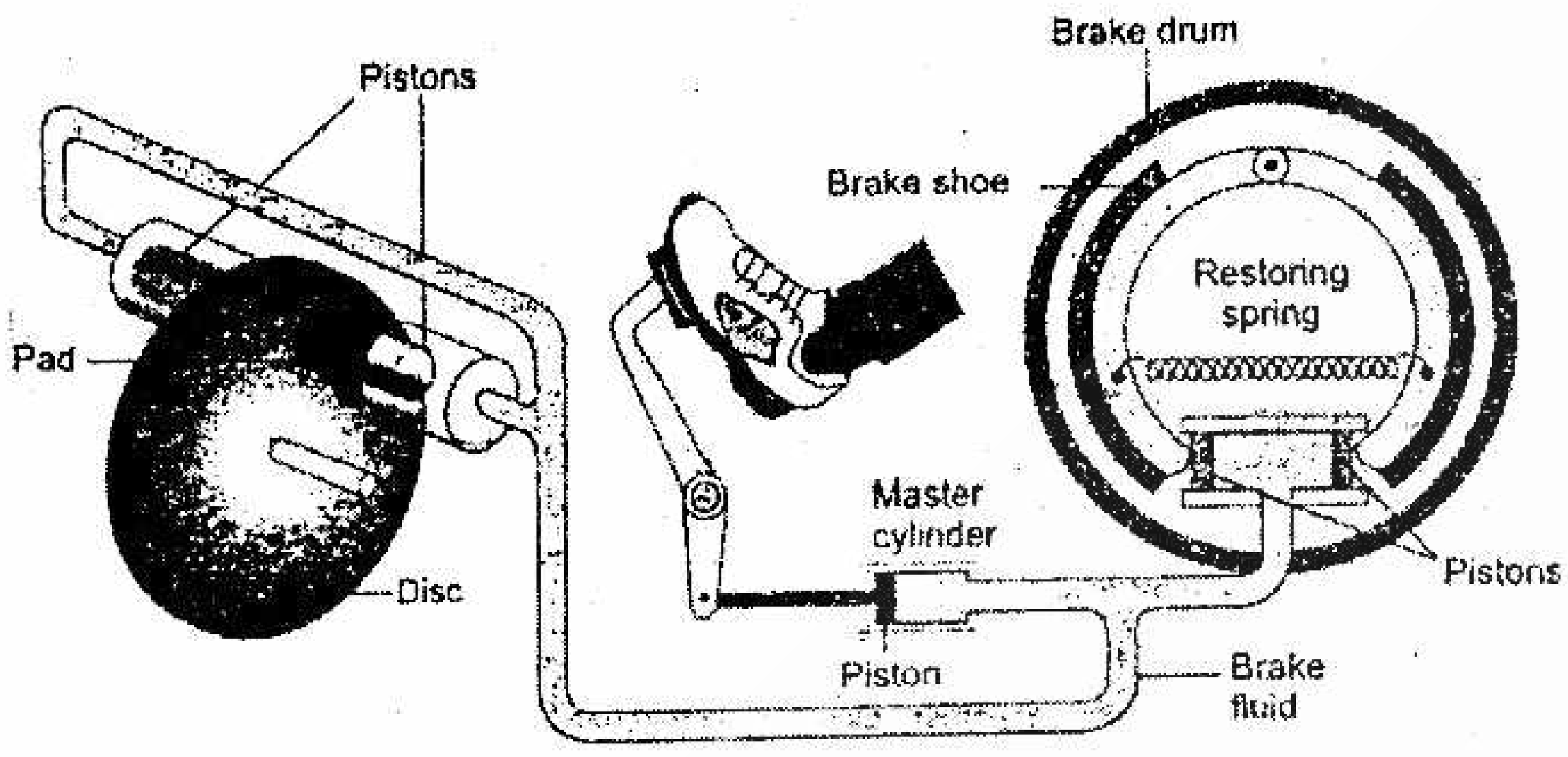
$$\text{or} \quad F_2 = F_1 \times \frac{A}{a}$$

Since the ratio $\frac{A}{a}$ is greater than 1, hence the force F_2 that acts on the larger piston is greater than the force F_1 acting on the smaller piston. Hydraulic system working in this way are known as force multipliers.

6 Write note on Hydraulic brakes.

Ans. Hydraulic Brakes:

The braking systems of cars, buses, etc. also work on Pascal's law. The hydraulic brakes as shown in figure allow equal pressure to be transmitted throughout the liquid. When brake pedal is pushed, it exerts a force on the master cylinder, which increases the liquid pressure in it. The liquid pressure is transmitted equally through the liquid in the metal pipes to all the pistons of other cylinders. Due to the increase in liquid pressure, the pistons in the cylinders move outward pressing the brake pads with the brake drums. The force of friction between the brake pads and the brake drums stops the wheels.



A hydraulic brake of a car

Note:

The question can be asked as. Define Pascal law; and give one of its application in our daily life.

The Hydraulic press and hydraulic brakes are the applications of Pascal law. So after definition describe any one of them.

7 State the Archimedes Principle.

Ans. Archimedes Principle

When an object is totally or partially immersed in a liquid, an upthrust acts on it equal to the weight of the liquid it displaces.

Explanation

Consider a solid cylinder of cross-sectional area A and height h immersed in a liquid as shown in figure. Let h_1 and h_2 be the depths of the top and bottom faces of the cylinder respectively from the surface of the liquid.

Then $h_2 - h_2 = h$

If P_1 and P_2 are the liquid pressures at depths h1 and h2 respectively and ρ is its density, then

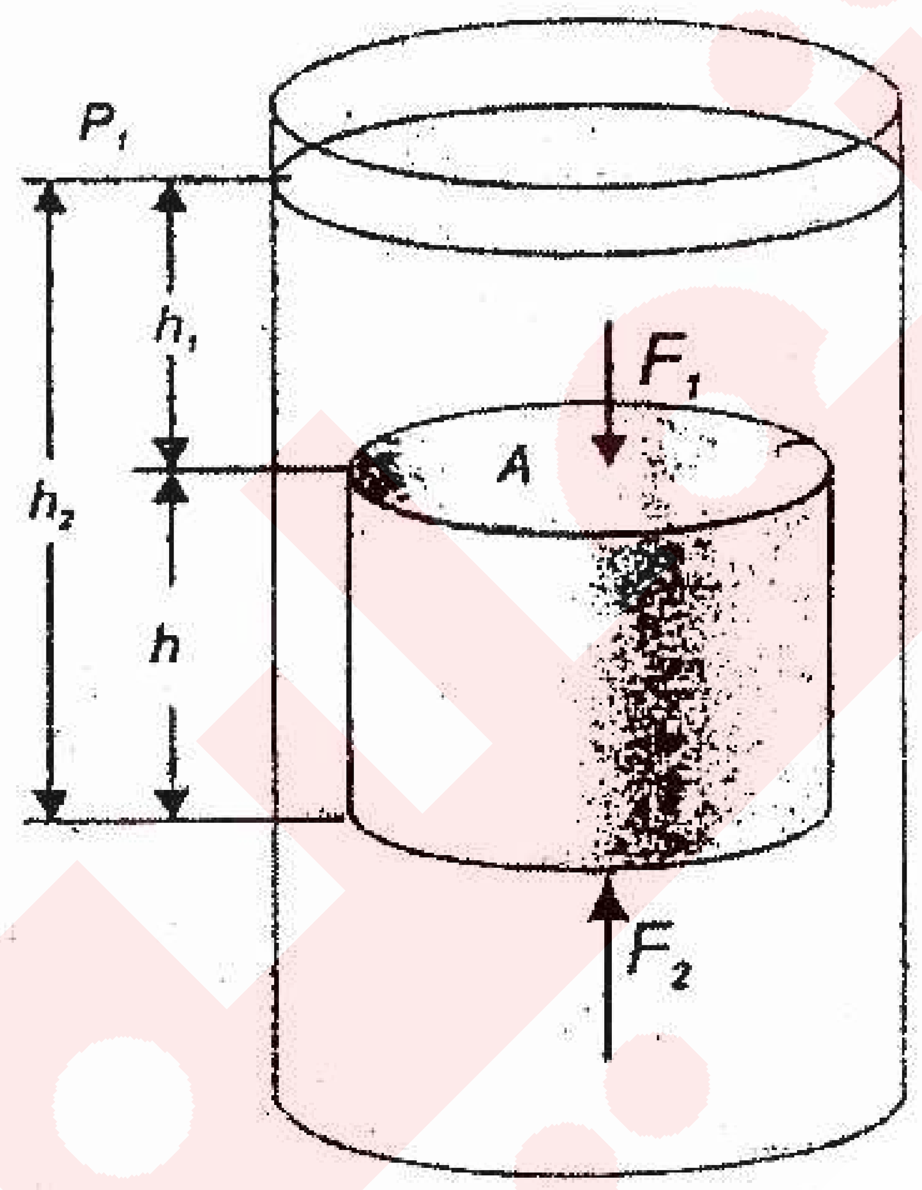
$$P_1 = \rho g h_1$$

$$P_2 = \rho g h_2$$

Let the force F_1 is exerted at the cylinder top by the liquid due to pressure P_1 and the force F_2 is exerted at the bottom of the cylinder by the liquid due to P_2.

$$F_1 = P_1 A = \rho g h_1 A$$

and $$F_2 = P_2 A = \rho g h_2 A$$



Upthrust for a body immersed in a liquid is equal to the weight of the liquid displaced

F_1 and F_2 are acting on the opposite faces of the cylinder. Therefore, the net force F will be $F_2 - F_1$ in the direction of F_2. This net force F on the cylinder is called the upthrust of the liquid.

$$\therefore \quad F_2 - F_1 = \rho g h_2 A - \rho g h_1 A$$

$$= \rho g A (h_2 - h_1)$$

or $$\text{Upthrust of liquid} = \rho g A h$$

or $$= \rho g V$$

Here Ah is the volume V of the cylinder and is equal to the volume of the liquid displaced by the cylinder. Therefore, ρ g V is the weight of the liquid displaced. Equation shows that an upthurst acts on the body immersed in a liquid and is equal to the weight of liquid displaced, which is Archimedes principle.

8 What is upthrust? Explain the principle of floatation.

Ans. Upthrust

If an object is kept inside a liquid then an upward force acts on the object this upward force is called the upthrust of the liquid.

Principle of Floatation

The principle of floatation can be state as. A floating object displaces a fluid having weight equal to the weight of the object.

Explanation

An object sinks if its weight is greater than the upthrust acting on it. An object floats if its weight is equal or less than the upthrust. When an object floats in a fluid, the upthrust acting on it is equal to the weight of the object. In case of floating object, the object may be partially immersed. The upthrust is always equal to the weight of the fluid displaced by the object.

9 How the Archimedes principle is helpful to determine the density of an object.

Ans. Archimedes principle is also helpful to determine the density of an object. The ratio in the weights of a body with an equal volume of liquid is the same as their densities.

Let density of the object $= D$

Density of the liquid $= \rho$

Weight of the object $= w_1$

Weight of equal volume of liquid $= w = w_1 - w_2$

Here w_2 is the weight of the solid in liquid. According to Archimedes principle, w_2 is less than its actual weight w_1 by an amount w.

Since $\frac{D}{\rho} = \frac{w_1}{w}$

$\therefore \quad D = \frac{w_1}{w} \times \rho$

or $\quad D = \frac{w_1}{w_1 - w_2} \times \rho$

Thus, finding the weight of the solid in air w_1 and its weight in water w_2, we can calculate the density of the solid by using equation.

10 What is Hook's Law? Give its mathematical form. What is the limitation of this law?

Ans. **Hooks Law**

The strain produced in a body by the stress applied to it is directly proportional to the stress within the elastic limit of the body.

Mathematically:

Thus $\quad$ stress $\propto$ strain

or $\quad$ stress = constant × strain

or $\quad \frac{\text{stress}}{\text{strain}} = \text{constant}$

Limitations

This law is only applicable unter the elastic limits. When a stress crosses the elastic limit, a body is permanently deformed and is unable to restore to original state after the stress is removed.

11 Explain how a submarine moves up in water surface and down into water.

Ans. A submarine can travel over as well as under water. It also works on the principle of floatation. It floats over water when the weight of water equal to its volume is greater than its weight. Under this condition, it is similar to a ship and remains partially above water level. It has a system of tanks which can be filled with and emptied from seawater. When these tanks are filled with seawater, the weight of the submarine increases. As soon as its weight becomes greater than the upthrust, it dives into water and remains under water. To come up on the surface, the tanks are emptied from seawater.

12 What is young's modulus? Also prove that $y = \frac{F\,L_o}{A\,\Delta L}$

Ans. **Young's Modulus**

The ratio of stress to tensile strain is called young's modulus.

Mathematically:

$$\text{Young's modulus } Y = \frac{\text{Stress}}{\text{Tensile strain}}$$

Consider a long bar of length L_o and cross-sectional area A. let an external force F equal to the weight w stretches it such that the stretched length becomes L. According to Hooke's law, the ratio of this stress to tensile strain is constant within the elastic limit of the body.

Let ΔL be the change in length of the rod, then

$$\Delta L = L - L_o$$

Since $\quad \text{Stress} = \frac{\text{Force}}{\text{Area}} = \frac{F}{A}$

And $\quad \text{Tensile strain} = \frac{L - L_o}{L_o} = \frac{\Delta L}{L_o}$

EXERCISE

7.1 Encircle the correct answer from the given choices:

(i) In which of the following state molecules do not leave their position?

(a) solid (b) liquid

(c) gas (d) plasma

(ii) Which of the substances is the lightest one?

(a) copper (b) mercury

(c) aluminum (d) lead

(iii) SI unit of pressure is Pascal, which is equal to:

(a) $10^4\ Nm^{-2}$ (b) $1\ Nm^{-2}$

(c) $10^2\ Nm^{-2}$ (d) $10^3\ Nm^{-2}$

(iv) What should be the approximate length of a glass tube to construct a water barometer?

(a) 0.5 m (b) 1 m

(c) 2.5 m (d) 11 m

(v) According to Archimedes, upthrust is equal to:

(a) weight of displaced liquid

(b) volume of displaced liquid

(c) volume of displaced liquid

(d) none of these

(vi) The density of a substance can be found with the help of:

(a) Pascal's law

(b) Hooke's law

(c) Archimedes principle

(d) Principle of floatation

(vii) According to Hooke's law:

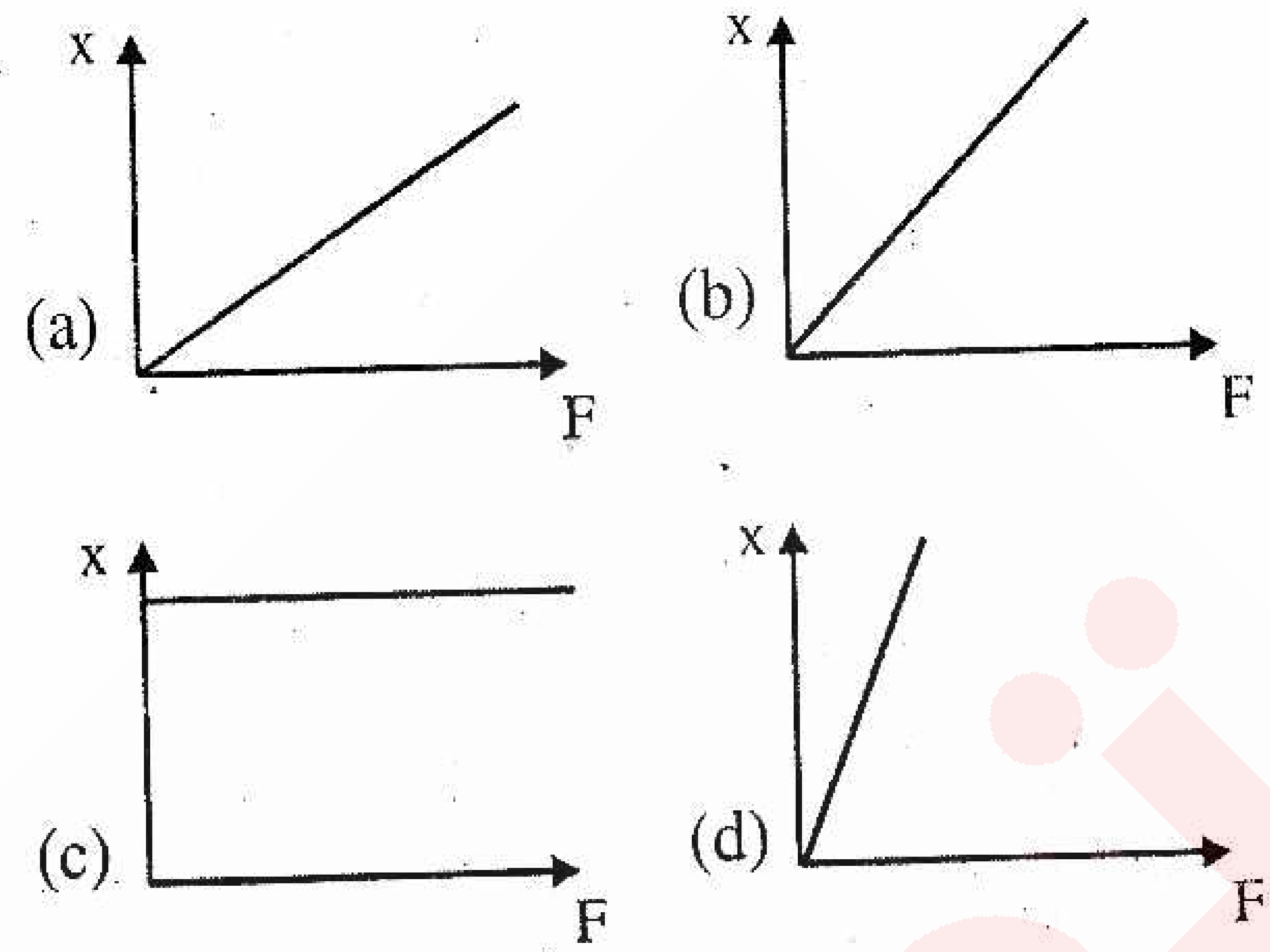
(a) stress × strain = constant

(b) stress / strain = constant

(c) strain / stress = constant

(d) stress = strain

The following force-extension graphs of a spring are drawn on the same scale. Answer the questions given below from (viii) to (x).



(viii) Which graph does not obey Hooke's law?

(a) (b)

(c) (d)

(ix) Which graph gives the smallest value of spring constant?

(a) (b)

(c) (d)

(x) Which graph gives the largest value of spring constant?

(a) (b)

(c) (d)

Answers

(i)	(a)	**(ii)**	(c)	**(iii)**	(b)	**(iv)**	(d)
(v)	(a)	**(vi)**	(c)	**(vii)**	(b)	**(viii)**	(c)
(ix)	(d)	**(x)**	(a)				

7.2. How kinetic molecular model of matte is helpful in differentiating various states of matter?

Ans. According to kinetic model of matter molecules attract each other. The three state of matter have different force of attraction among the molecules. In gases the force of attraction are very weak but in liquids these forces are strong than gases but weaker than solids. So in solids the intermolecular forces are very strong.

7.3. Does there exist a fourth state of matter? What is that?

Ans. Yes, the fourth state of matter also exist and that is plasma.

7.4. What is meant by density? What is its SI unit?

Ans. Mass per unit volume is called density.

$$d = \frac{m}{v}$$

Its unit is g/cm^3 or $kg\ m^{-3}$.

7.5. Can we use a hydrometer to measure the density of milk?

Ans. Yes; a hydrometer can be used to near the density of milk.

7.6. Define term pressure.

Ans. A perpendicular force acting on unit area is called pressure.

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

7.7. Show that atmosphere exerts pressure.

Ans. See Long Question No. 2.

7.8. It is easy to fill air in a balloon but it is very difficult to remove air from a glass bottle. Why?

Ans. It is easy to fill air in a balloon because inside the balloon there is very less air as compare to the atmosphere so air goes in to the balloon easily but iti s difficult to remove air from a glass bottle because the pressure of air outside the bottle is greater than the pressure of air inside the bottle so due to this greater pressure it become difficult to remove air from the bottle.

7.9. What is a barometer?

Ans. Barometer is a 1m long glass tube which is filled with mercury. It is used to measure the atmospheric pressure of any place.

7.10. Why water is not suitable to be used in a barometer?

Ans. Mercury is 13.6 times denser than water. Atmospheric pressure can hold vertical column of water about 13.6 times the height of mercury column at a place. Thus, at sea level, vertical height of water column would be 0.76 mx 13.6 = 10.34 m. Thus, a glass tube more than 10 m long is required to make a water barometer. So it is not suitable.

7.11. What makes a sucker pressed on a smooth wall sticks to it?

Ans. The difference in pressure inside and out side the sucker make a sucker pressed on a smooth wall sticks to it. The atmospheric pressure is greater than the pressure in the sucker. So this pressure pressed it on the wall.

7.12. Why does the atmospheric pressure vary with height?

Ans. As we go up the air becomes less dense that is why the atmospheric pressure decreases as we go up.

7.13. What does it mean when the atmospheric pressure at a place fall suddenly?

Ans. If the atmospheric pressure falls suddenly it means there may be a storm, rain and typhoon will occur in few hours time.

7.14. What changes are expected in weather if the barometer reading shows a sudden increase?

Ans. A sudden increase in the barometre reading shows that it will so be followed by a decrease in the atmospheric pressure indicating poor weather a head.

7.15. State Pascal's law.

Ans. Pressure applied at any point of a liquid enclosed in a container, is transmitted without loss to all other parts of the liquid.

7.16. Explain the working of hydraulic press.

Ans. See Long Question No. 5.

7.17. What is meant by elasticity?

Ans. The property of a body to restore its original size and shape as the deforming force ceases to act is called elasticity.

7.18. State Archimedes principle.

Ans. See Long Question No. 7.

7.19. What is upthrust? Explain the principle of floatation.

Ans. See Long Question No.8.

7.20. Explain how a submarine moves up the water surface and down into water.

Ans. See Long Question No.11.

7.21. Why does a piece of stone sink in water but a ship with a huge weight floats?

Ans. If the weight of the object is smaller than buoyant force acting on it, the object will float.

If weight of the object exceeds the buoyant force, the object will sink. The stone sinks in water because the buoyant force acting on the stone is smaller than its weight. The ship of huge weight floats on the surface of water because it is designed in such a way that its volume is so large so the buoyant force balances the weight of the ship.

7.22. What is Hooke;s law? What is meant by elastic limit?

Ans. Hooke's Law:

The strain produced in a body by the stress applied to it is directly proportional to the stress within the elastic limit of the body.

Elastic Limit:

It is a limit within which a body recovers its original length, volume or shape after the deforming force is removed.

PROBLEMS

7.1. A wooden block measuring 40 cm × 10 cm × 5 cm has a mass 850g. Find the density of wood?

Sol. $m = 850\text{ g}$

$\Rightarrow$ 0.850 kg

$v = 40 \times 10 \times 5$

$= 2000\text{ cm}^3$

$= 2 \times 10^{-3}\text{ m}^3$

$d = ?$

$$d = \frac{m}{v}$$

$$d = \frac{850}{1000 \times 2 \times 10^{-3}}$$

$$d = 425\text{ kg m}^{-3}$$

7.2. How much would be the volume of ice formed by freezing 1 litre of water?

Sol. 1 litre = 1 kg

$m = 1\text{ kg}$

$d = 0.920$ kg.litre

$v = ?$

$$d = \frac{m}{v}$$

$$0.920 = \frac{1}{v}$$

$$v = \frac{1}{.920} = \frac{1000}{920} = 1.09\text{ litre}$$

7.3. Calculate the volume of the following objects:

(i) An iron sphere of mass 5 kg, the density of iron is 8200 kg m^{-3}.

(ii) 200 g of lead shot having density 11300 kg m^{-3}.

(iii) A gold bar of mass 0.2 kg. The density of gold is 19300 kg m^{-3}.

Sol. (i) $m = 5\text{ kg}$

$d = 8200\text{ kg m}^{-3}$

$v = ?$

$$d = \frac{m}{v}$$

$$v = \frac{m}{d}$$

$$v = \frac{1}{1650} = 6.1 \times 10^{-4}\text{ m}^3$$

(ii) $m = 200\text{ g}$

$\Rightarrow$ 0.2 kg

$d = 11300\text{ kg m}^{-3}$

$v = ?$

$$d = \frac{m}{v}$$

$$v = \frac{m}{d}$$

$$v = \frac{0.2}{11300}$$

$$v = \frac{2}{11300 \times 10}$$

$$= \frac{2}{113000} = 1.77 \times 10^{-5}\text{ m}^3$$

(iii) $m = 0.2\text{ kg}$

$d = 19300\text{ kg m}^{-3}$

$v = ?$

$$v = \frac{m}{d}$$

$$= \frac{0.2}{19300}$$

$$v = \frac{2}{14300 \times 10}$$

$$v = \frac{2}{193000} = 1.04 \times 10^{-5}\ m^3$$

7.4. The density for air is 1.3 kg m^{-3}. Find the mass of air in a room measuring 8m × 5m × 4m.

Sol. $d = 1.3\ kg\ m^{-3}$

$v = 8m \times 5m \times 4m = 160\ m^3$

$m = ?$

$$d = \frac{m}{v}$$

$$m = d \times v$$

$$= 1.3 \times 160$$

$$m = 208.0\ kg$$

7.5. A student presses her plam by her thum with a force of 75N. How much would be the pressure under her thumb having contact area 1.5 cm^2?

Sol. $F = 75\ N$

$$A = 1.5\ cm^2 = \frac{1.5}{100 \times 100} = 1.5 \times 10^{-4}\ m^2$$

$P = ?$

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

$$P = \frac{75}{1.5 \times 10^{-4}}$$

$P = 50 \times 10^4\ Nm^{-2}$

$P = 5 \times 10^5\ Nm^{-2}$

7.6. The head of a pin is a square of side 10mm. Find the pressure on it due to a force of 20 N.

Sol. Side = 10 mm

$$\Rightarrow \quad \frac{1}{1000}\ m$$

$$\text{Area} = \frac{10}{1000} \times \frac{10}{1000} = 10^{-4}\ m$$

$F = 20\ N, \quad P = ?$

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

$$P = \frac{20}{10^{-4}}$$

$$P = 20 \times 10^4 = 2 \times 10^5\ N.m^{-2}$$

7.7. A uniform rectangular block of wood 20 cm × 7.5 cm × 7.5 cm and of mass 1000g stands on a horizontal surface with its longest edge vertical. Find

(i) The pressure exerted by the block on the surface

(ii) Density of the work

Sol. $v = 20\ cm \times 7.5\ cm \times 7.5\ cm$

$$= \frac{20\ m}{100} \times \frac{7.5\ m}{100} \times \frac{7.5\ m}{100} = \frac{9}{8000}\ m^3$$

$$A = L \times w = \frac{7.5}{100} \times \frac{7.5}{100}$$

$$= \frac{9}{1600}\ m^2$$

$P = ?, \quad d = ?$

$m = 1000\ g \quad \Rightarrow \quad 1\ kg$

$F = w = 1 \times 10 \qquad w = mg$

$= 10\ N$

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

$$P = \frac{10}{9} \times 1600 = 1778\ Nm^{-2}$$

(ii) $$d = \frac{m}{v}$$

$$= \frac{1}{9} \times 8000$$

$$d = 889\ kg\ m^{-3}$$

7.8. A cube of glass of 5 cm side and mass 306g. has a cavity inside it. If the density of glass is 2.55 gcm^{-3}. Find the volume of the cavity.

Sol. Side of cube = 5 cm

Volume of cube = 5 × 5 × 5

$= 125\ cm^3$

$m = 308\ g$

$d = 2.55\ gcm^{-3}$

$v = ?$

$d = \frac{m}{v}$

$v = \frac{m}{d} = \frac{308}{2.55} = 120 \text{ cm}^3$

Volume of the cavity = total volume − volume of block with cavity

$= 125 - 120$

Volume of cavity = 5 cm^3

7.9. An object has weight 18N in air. Its weight is found to be 11.4N when immersed in water. Calculate its density. Can you guess the material of the object?

Sol. Weight in air = $w_1 = 18$ N

Weight in water = $w_2 = 11.4$ N

$d = ?$

Density of water P = 1000 kgm^{-3}

$d = \frac{w_1}{w_1 - w_2} \times P$

$d = \frac{18}{18 - 11.4} \times 1000$

$d = \frac{18}{6.6} \times 1000 = \frac{30000}{11} = 2727 \text{ kg m}^{-3}$

7.10. A solid block of wood of density 0.6gcm^{-3} weight 3.06N in air. Determine

(a) volume of the block

(b) the volume of the block immersed when placed freely in a liquid of density 0.9 gcm^{-3}?

Sol. $d = 0.6 \text{ gcm}^{-3}$

$F = w = 3.06$ N

$m = \frac{w}{g}$

$m = \frac{3.06}{10} = 0.306 \text{ kg} = 306 \text{ g}$

$v = ?$

$d = \frac{m}{v}$

$d = \frac{m}{d} = \frac{306}{0.6} = 510 \text{ cm}^3$

(ii) Density of liquid = 0.9 cm^{-3}

$m = 306$ g

volume inside the liquid $v = ?$

$v = \frac{m}{d}$

$\frac{306}{0.9} \Rightarrow 340 \text{ cm}^3$

7.11. The diameter of the piston of a hydraulic press is 30 cm. How much force is required to lift a car weighting 20000N on its piston if the diameter of the piston of the pump is 3cm?

Sol. Diameter = d = 30 cm

$r = \frac{30}{2} \Rightarrow 15 \text{ cm}$

Area of cross section of the piston of press

$a = \pi r^2$

$= \pi \times (15)^2 = \pi \times 225 \text{ cm}^2$

$F_1 = 20000$ N, $F_2 = ?$

Diameter of the piston of pump = d = 3 cm

$R = \frac{3}{2} \Rightarrow 1.5 \text{ cm}$

Area of cross section = $A = 1.5 \times 1.5 \times \pi$

$= 2.25 \times \pi \text{ cm}^2$

$\frac{F_1}{a} = \frac{F_2}{A}$

$F_2 = \frac{F_1}{a} \times A$

$F_2 = 200$ N

7.12. A steel wire of cross-sectional area $2 \times 10^{-5} \text{ m}^2$ is stretched through 2 mm by a force of 4000 N. Find the Young's modulus of the wire. The length of the wire is 2m.

Ans. Solution:

Sol. Area of cross section = $a = 2 \times 10^{-5} \text{ m}^2$

$F = 4000$ N, $L_o = 2$m,

$\Delta L = 2$ mm

$= 2 \times 10^{-3}$ m

$y = ?$

$y = \frac{F \times L_o}{A \times \Delta L} = \frac{2000}{10^{-8}} = 2000 \times 10^8$

$= 2 \times 10^{11} \text{ N.m}^{-2}$