UNIT 7

PROPERTIES OF MATTER

LONG QUESTIONS

7.1 KINETIC MOLECULAR MODEL OF MATTER

Q.1 Explain different states of matter on the basis of kinetic molecular theory.(LHR 2013)

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

(i) Solid

Solids have fixed shapes and volume. Their molecules are held close together. However, they vibrate about their mean positions but do not move from place to place.

Examples are stone, metal spoon, pencil etc.

(ii) Liquids

The distance between the molecules of a liquid is more than in solids. Thus, attractive forces between them are weaker. Like solids, molecules of a liquid also vibrate about their mean position but are not rigidly held with each other. Due to the weaker attractive forces, they can slide over one another. Thus, the liquids can flow. The volume of a certain amount of liquid remains the same but because it can flow hence; it attains the shape of a container to which it is put.

(iii) Gases

Gases such as air have no fixed shape or volume. They can be filled in any container of any shape. Their molecules have random motion and move with very high velocities. In gases, molecules are much farther apart than solids or liquids. Thus, gases are much lighter than solids and liquids. They can be squeezed into smaller volumes.

Pressure of gases

The molecules of a gas are constantly striking the walls of a container. Thus, a gas exerts pressure on the walls of the container.

(iv) Plasma

The kinetic energy of gas molecules goes on increasing if a gas is heated continuously. This causes the gas molecules move faster and faster. The collisions between atoms and molecules of the gas become so strong that they tear off the atoms. Atoms lose their electrons and become positive ions. This ionic state of matter is called plasma.

Plasma in discharge tubes

Plasma is also formed in gas discharge tubes when electric current passes through these tubes.

Plasma – The Fourth state of Matter

Plasma is also called the fourth state of matter in which gas occurs in its ionic state. Positive ions and electrons get separated in the presence of electric and magnetic field. Plasma also exists in neon and fluorescent tubes when they glow.

Universe formation

Most of the matters that fill the universe are in plasma state. In stars such as our sun, gases exist in their ionic state.

Plasma Good Conductor

Plasma is highly conducting state of mater. It allows electric current to pass through it.

7.4 ATMOSPHERIC PRESSURE

Q.2 What is atmospheric pressure? And explain atmospheric pressure with the help of an experiment.

Ans: The earth is surrounded by a cover of air is called atmosphere. It extends to a few hundred kilometers above sea level. Just as certain sea creatures live at the bottom of ocean, we live at the bottom of a huge ocean of air. Air is the mixture of gases. The density of air in the atmosphere is not uniform. It decreases continuously as we go up.

Atmospheric pressure acts in all directions.

Examples

Soap bubbles expand till the pressure of air in them is equal to the atmospheric pressure. Soap bubbles so formed have spherical shapes because the atmospheric pressure acts on a bubble equally in all directions.

A balloon expands as we fill air into it. The balloon will expand in all directions.

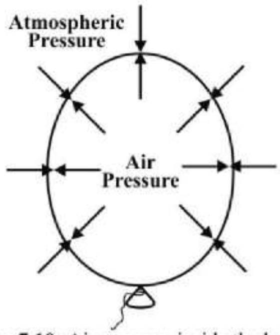

Figure 7.10: Air pressure inside the balloon is equal to the atmospheric pressure.

Experiment

The fact that atmosphere exerts pressure can be explained by simple 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 tape water. The can will squeeze due to atmospheric pressure.

When the can is cooled by tap water, the steam in it condenses. As 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 that can to collapse from all directions. This experiment shows that atmosphere exerts pressure in all directions.

Measuring Atmospheric Pressure (LHR 2014)

Q.3 Which device is used to measure the atmospheric pressure? Explain the measurement of atmospheric pressure by using barometer.

A simple device used to measure the atmospheric pressure is barometer.

Barometer

The instruments that measure atmospheric pressure are called barometers. One of the simple barometers is a mercury barometer. It consists of a glass tube 1 m long closed at one end.

Measurement

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. At the 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 air column is nearly 101,300 Nm^{-2} equal to atmospheric pressure.

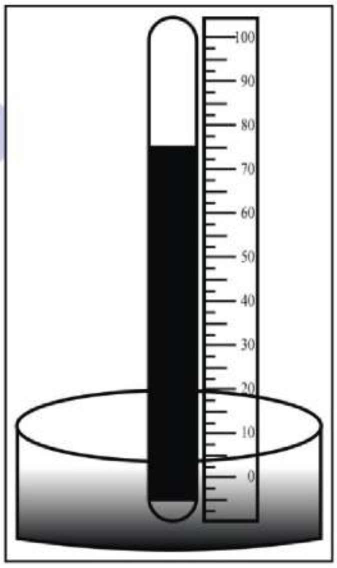

Figure 7.12: A mercury barometer

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.

Atmospheric pressure at sea level

At sea level, the atmospheric pressure is about 101,300 Pa or 101,300 Nm^{-2}.

Mercury in barometer instead of water

Mercury is 13.6 times denser than water. Atmospheric pressure can hold vertical column of water is 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 m x 13.6 = 10.34 m. Thus, a glass tube more than 10 m long is required to make a water barometer.

Variation in Atmospheric Pressure

Q.4 Write a note on variation in atmospheric pressure.

Ans: The atmospheric pressure decreases as we go up. The atmospheric pressure on mountains is lower than at sea level. At a height of about 30 km, the atmospheric pressure becomes only 7 mm of mercury which is approximately 1000 Pa. it would become zero at an altitude where is no air. Thus we can determine the altitude of a place by knowing the atmospheric pressure at that place.

Effect of weather on atmospheric pressure

- On a hot day, air above the Earth becomes hot and expands. This causes a fall of atmospheric pressure in that region.
- During cold chilly nights, air above the Earth cools down. This causes an increase in atmospheric pressure.

Expected weather changes due to variation of atmospheric pressure

The changes in atmospheric pressure at a certain place indicate the expected changes in the weather conditions at that place.

Decrease in atmospheric pressure

- A gradual and average drop in atmospheric pressure means a low pressure in a neighboring locality.
- Minor but rapid fall in atmosphere indicates a windy and showery condition in the nearby region.
- A decrease in atmospheric pressure accompanied by breeze and rain.
- A sudden fall in atmospheric pressure often followed by a storm, rain and typhoon to occur in few hours time.

Increase in atmospheric pressure

- An increasing atmospheric pressure with a decline later on predicts an intense weather conditions.
- A gradual large increase in the atmospheric pressure indicates a long spell of pleasant weather.
- A rapid increase in atmospheric pressure means that it will soon be followed by a decrease in the atmospheric pressure indicating poor weather ahead.

7.5 PRESSURE IN LIQUIDS

Q.5 Define pressure in liquids. Derive its mathematical formula.

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

Mathematical Derivation

Consider a surface area A in a liquid at a depth h as shown 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 the liquid above the surface, then

Mass of the liquid $= m =$ volume x density

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

Force acting on area A $= F = w = mg$

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

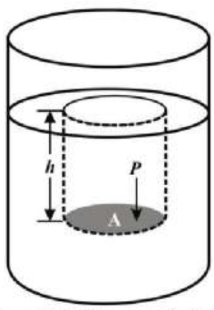

Figure 7.13: Pressure of a liquid at a depth ***h***.

As pressure $= P = F/A$

So $= \dfrac{Ah\rho g}{A}$

Therefore, $P = \rho g h$

The above equation gives the pressure at a depth h in a liquid of density ρ. It show that its pressure in a liquid increases with depth.

Pascal's Law **(GRW 2014)**

Q.6 State Pascal's Law. Write down the application of Pascal's law.

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

An external force applied on the surface of a liquid increases the liquid pressure at the surface of the liquid. This increase in liquid pressure is transmitted equally in all direction and to the walls of the container in which it is filled.

Applications of Pascal's Law (Hydraulic Press) **(LHR 2014)**

Hydraulic press is a machine which works on the principle of Pascal's law. It consists of two cylinders which are fitted with pistons of cross – sectional area a and A. The object is to be compressed is placed over the piston of large cross – sectional area A. the Force is applied on the piston of cross – sectional area a.

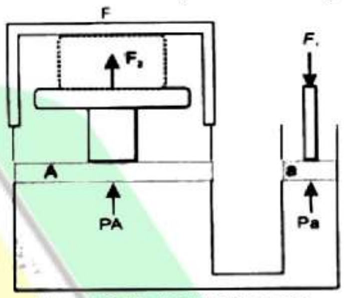

Figure 7.16: A hydraulic press

The pressure P produced by small piston is transmitted through the liquid and acts on the on the large piston and a force F_2 acts on A which is much larger than F_1.

Mathematical form

Pressure on piston of small area a is given by,

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

By applying Pascal's law, the pressure on the larger piston of area A will be same as on the small piston.

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

By comparing the above equations, we have

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

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

Since the ratio A/a is greater than 1, hence the force F_2 acts on the larger piston is greater than the force F_1 on the smaller piston. Hydraulic systems working in this way are known as force multipliers.

Braking System in Vehicles

Q.7 Explain the braking system of the vehicles.

Ans: The brakes of cars, buses etc. work on the principle of Pascal's law. In such a type of brakes, when brake pedal is pushed, it exerts pressure on the master cylinder, which increases the liquid pressure in the cylinder. The liquid pressure is transmitted equally through the liquid in the metal pipes. Due to the increase pressure of the liquid pressure, the pistons in the cylinder mover outwards pressing the brakes pad with brake drums. The force of friction between friction the brake pads and the brake drum stops the wheels.

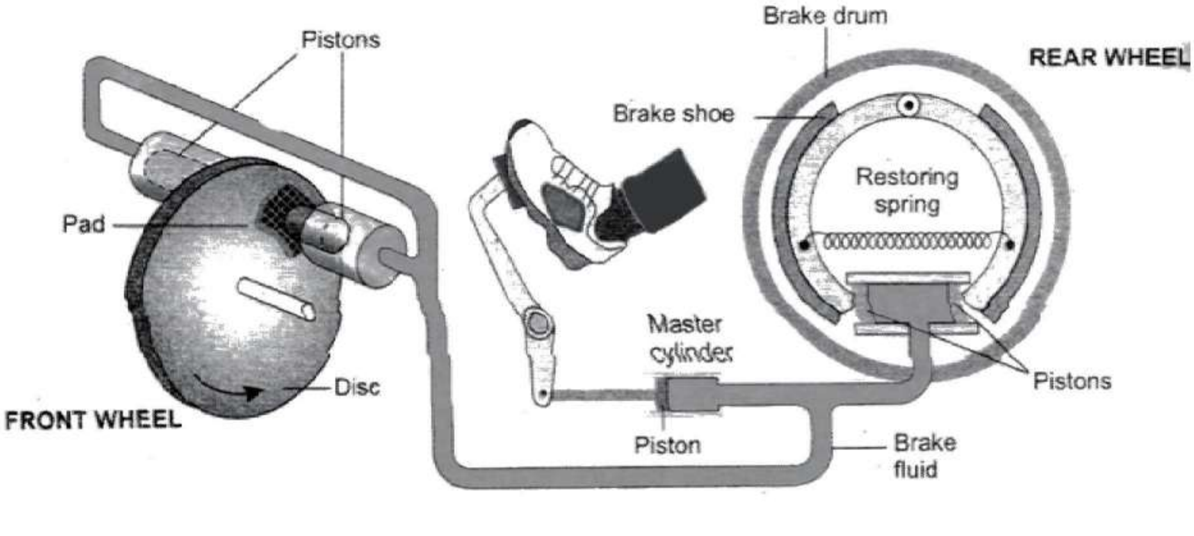

Figure 7.17: A hydraulic brake of a car

7.6 ARCHIMEDES PRINCIPLE

Q.8 State and explain Archimedes Principle. (GRW 2015)

Ans: Introduction

More than two thousands years ago, the Greek scientist, Archimedes noticed the upthrust force of the liquid.

Up thrust force

There is an upward force which acts on an object kept inside a liquid. As a result an apparent loss of weight is observed in the object. This upward force acting on the object is called the upthrust of the liquid.

Statement

When object is totally or partially immersed in a liquid, an upthrust act 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 depth of the top and bottom surfaces of the cylinder respectively from the surface of the liquid.

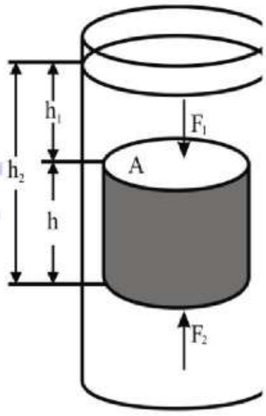

Figure 7.18: Upthrust on a l immersed in a liquid is equa weight of the liquid displace

Then $h_2 - h_1 = h$

If P_1 and P_2 are the liquid pressures at the depth h_1 and h_2 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 due to P_2.

So $F_1 = \rho g h_1 A$

$F_2 = \rho g h_2 A$

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. The net force F on the cylinder is called the upthrust of the liquid.

Therefore, $F_2 - F_1 = \rho g h_2 A - \rho g h_1 A$

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

OR upthrust of liquid $= \rho\, g\, h\, A$

OR $= \rho\, g\, V$

Here Ah is the volume V of the cylinder and equal to the volume of the liquid displaced by the cylinder. Therefore, $\rho\, g\, V$ is the weight of the liquid displaced. The above equation shows that an upthrust acts on the body immersed in a liquid and is equal to the weight of liquid displaced, which is Archimedes principle.

Density of an Object

Q.9 How density of an object can be found by Archimedes principle?

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

7.7 PRINCIPLE OF FLOATATION **(GRW 2015)**

Q.10 Explain the Principle of Floatation.

Ans: An object sinks if its weight is greater than the up thrust force acting on it. An object floats if its weight is equal or less than the up thrust. When an object floats in a fluid, the up thrust acting on it is equal to the weight of the object. In case of floating object, the object may be partially immersed. The up thrust is always equal to the fluid displaced by the object. This is principle of floatation. This states that:

"A floating object displaces a fluid having weight equal to weight of the object."

Archimedes principle is applicable on liquids as well as gases. We find numerous applications of this principle in daily life.

Ships and Submarines

A wooden block floats on water. It is because the weight of an equal volume of water is greater than the weight of the block. According to the principle of floatation, a body floats if it displaces water equal to the weight of the body when it is partially or completely immersed in water.

Ships

Ships and boats are designed on the same principle of floatation. They carry passengers and goods over water. It would sink in water if its weight including the weight of its passengers and goods becomes greater than the upthrust of water.

Submarines

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 the 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 sea water. When these tanks are filled with sea water, 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 sea water.

7.9 HOOKE'S LAW

Q.11 State and explain the Hooke's Law.

Ans: 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.

Mathematical Formula

Stress α strain

Stress = constant x strain

Or $\frac{\text{Stress}}{\text{Strain}}$ = constant

Hooke's law is applicable to all kinds of deformation and all types of matter i.e. solids, liquids or gases within certain limit.

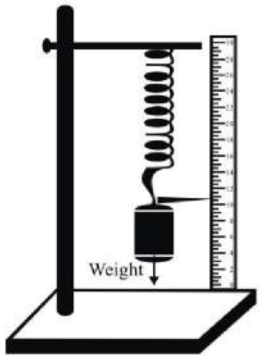

Figure7.23: Extension in the spring depends upon the load

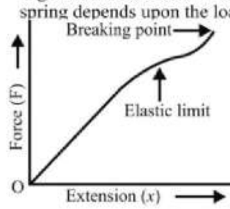

Figure 7.24: Graph between force and extension

Elastic Limit

It is a limit with which a body recovers to original length, volume or shape after deforming force is removed. This limit is called the elastic limit.

When a stress crosses this limit, called the elastic limit, a body is permanently deformed and is unable to restore its original state after the stress is removed.

Young's Modulus **(LHR 2015)**

Q.12 Define Young's Modulus and derive its mathematical formula.

Ans: The ration of stress and strain is a constant within the elastic limit, this constant is called the Young's Modulus.

Mathematical Form

Consider a long bar of length Lo and cross – sectional area A. Let an external force F equal to weight stretches it such that the stretched length becomes L.

Mathematically,

Young's modulus = Y = Stress/Tensile strain

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

$$\Delta L = L - L_o$$

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

And Tensile Strain = $\frac{L - L_o}{L_o}$ = $\Delta L/L_o$

As Young's modulus = Y = Stress/Tensile strain

So $= \frac{F}{A} \times \frac{L_o}{L}$

Therefore, $= \frac{F \times L_o}{A \times L}$

Unit

SI unit of Young's Modulus is Newton per square meter ($N\ m^{-2}$)