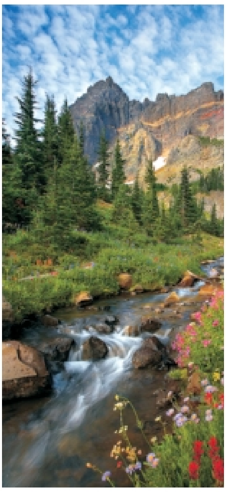
Unit 7

Properties of Matter

STUDENT'S LEARNING OUTCOMES

After studying this unit, the students will be able to:

- state kinetic molecular model of matter (solid, liquid and gas forms).
- describe briefly the fourth state of matter i.e. Plasma.
- define the term density.
- compare the densities of a few solids, liquids and gases.
- define the term pressure (as a force acting normally on unit area).
- explain how pressure varies with force and area in the context of everyday examples.
- explain that the atmosphere exerts a pressure.
- describe how the height of a liquid column may be used to measure the atmospheric pressure.
- describe that atmospheric pressure decreases with the increase in height above the Earth's surface.
- explain that changes in atmospheric pressure in a region may indicate a change in the weather.
- state Pascal's law.
- apply and demonstrate the use with examples of Pascal's law.
- state relation for pressure beneath a liquid surface to depth and to density i.e., (P=ρgh) and solve problems using this equation.



This unit is built on
Matter and its States
- Science -V

This unit leads to:
Fluid Dynamics
- Physics - XI
Physics of Solids
- Physics -XII

- state Archimedes principle.
- determine the density of an object using Archimedes principle.
- state the upthrust exerted by a liquid on a body.
- state principle of floatation.
- explain that a force may produce a change in size and shape of a body.
- define the terms stress, strain and Young's modulus.
- state Hooke's law and explain elastic limit.

Major Concepts

7.1 Kinetic molecular model of matter
7.2 Density
7.3 Pressure
7.4 Atmospheric pressure
7.5 Pressure in liquids
7.6 Upthrust

INVESTIGATION SKILLS

The students will be able to:

- measure the atmospheric pressure by Fortin's barometer.
- measure the pressure of motor bike / car tyre and state the basic principle of the instrument and its value in SI units.
- determine the density of irregular shaped objects.

- state Archimedes principle.
- determine the density of an object using Archimedes principle.
- state the upthrust exerted by a liquid on a body.
- state principle of floatation.
- explain that a force may produce a change in size and shape of a body.
- define the terms stress, strain and Young's modulus.
- state Hooke's law and explain elastic limit.

Major Concepts

7.1 Kinetic molecular model of matter
7.2 Density
7.3 Pressure
7.4 Atmospheric pressure
7.5 Pressure in liquids
7.6 Upthrust
7.7 Principle of floatation
7.8 Elasticity
7.9 Stress, strain and Young's modulus

INVESTIGATION SKILLS

The students will be able to:

- measure the atmospheric pressure by Fortin's barometer.
- measure the pressure of motor bike / car tyre and state the basic principle of the instrument and its value in SI units.
- determine the density of irregular shaped objects.

SCIENCE, TECHNOLOGY AND SOCIETY CONNECTION

The students will be able to:

- explain that to fix a thumb pin, pressure exerted on the top increases thousands time on the pin point.
- explain the use of Hydrometer to measure the density of a car battery acid.
- explain that ships and submarines float on sea surface when the buoyant force acting on them is greater than their total weight.
- state that Hydraulic Press, Hydraulic car lift and Hydraulic brakes operate on the principle that the fluid pressure is transmitted equally in all directions.

- explain that the action of sucking through a straw, dropper, syringe and vacuum cleaner is due to atmospheric pressure.

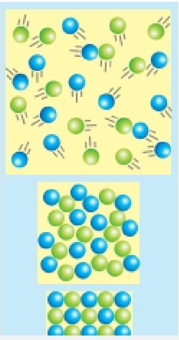
Matter exists in three states, solid, liquid and gas. There are many properties associated with matter. For example, matter has weight and occupies space. There are some other properties which are associated with one state of matter but not with other. For example, solids have shape of their own while liquids and gases do not. Liquids on the other hand have definite volume while gases do not have. Various materials differ in their hardness, density, solubility, flow, elasticity, conductivity and many other qualities. Kinetic molecular model helps in understanding the properties of matter in a simplified way.

Figure 7.1: Water exists in all the three states.

7.1 KINETIC MOLECULAR MODEL OF MATTER

The kinetic molecular model of matter as shown in figure 7.2 has some important features. These are

- Matter is made up of particles called molecules.
- The molecules remain in continuous motion.
- Molecules attract each other.



atmospheric pressure.

Matter exists in three states, solid, liquid and gas. There are many properties associated with matter. For example, matter has weight and occupies space. There are some other properties which are associated with one state of matter but not with other. For example, solids have shape of their own while liquids and gases do not. Liquids on the other hand have definite volume while gases do not have. Various materials differ in their hardness, density, solubility, flow, elasticity, conductivity and many other qualities. Kinetic molecular model helps in understanding the properties of matter in a simplified way.

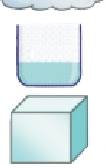


Figure 7.1: Water exists in all the three states.

7.1 KINETIC MOLECULAR MODEL OF MATTER

The kinetic molecular model of matter as shown in figure 7.2 has some important features. These are

- Matter is made up of particles called molecules.
- The molecules remain in continuous motion.
- Molecules attract each other.

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

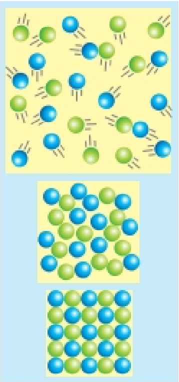


Figure 7.2: Kinetic molecular model of the three states of matter.

SOLIDS

Solids such as a stone, metal spoon, pencil, etc. have fixed shapes and volume. Their molecules are held close together such as shown in figure 7.3 by strong forces of attraction. However, they vibrate about their mean positions but do not move from place to place.

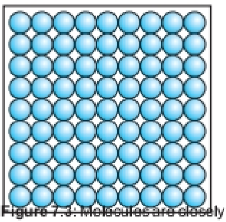


Figure 7.3: Molecules are closely packed in solids.

LIQUIDS

The distances between the molecules of a liquid are 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.

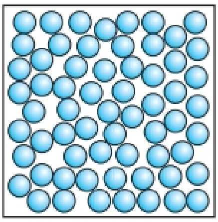


Figure 7.4: Molecules are loosely packed in liquids.

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 such as shown in figure 7.5. Thus, gases are much lighter than solids and liquids. They can be squeezed into smaller volumes. The molecules of a gas are constantly striking the walls of a container. Thus, a gas exerts pressure on the walls of the container.

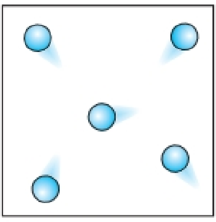


Figure 7.5: Molecules are much farther apart in gases.

PLASMA - THE FOURTH STATE OF MATTER

The kinetic energy of gas molecules goes on increasing if a gas is heated continuously. This causes the gas molecules to 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 is also formed in gas discharge tubes when electric current passes through these tubes.

Plasma is called the **fourth state of matter** in which a gas occurs in its ionic state. Positive ions and electrons get separated in the presence of electric or

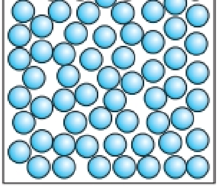


Figure 7.4: Molecules are loosely packed in liquids.

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.

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 such as shown in figure 7.5. Thus, gases are much lighter than solids and liquids. They can be squeezed into smaller volumes. The molecules of a gas are constantly striking the walls of a container. Thus, a gas exerts pressure on the walls of the container.

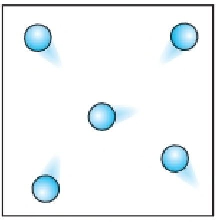


Figure 7.5: Molecules are much fartherapart in gases.

PLASMA - THE FOURTH STATE OF MATTER

The kinetic energy of gas molecules goes on increasing if a gas is heated continuously. This causes the gas molecules to 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 is also formed in gas discharge tubes when electric current passes through these tubes.

Figure 7.6: Aplasma bulb

Plasma is called the **fourth state of matter** in which a gas occurs in its ionic state. Positive ions and electrons get separated in the presence of electric or magnetic fields. Plasma also exists in neon and fluorescent tubes when they glow. Most of the matter that fills the universe is in plasma state. In stars such as our Sun, gases exist in their ionic state. Plasma is highly conducting state of matter. It allows electric current to pass through it.

7.2 DENSITY

Is an iron object heavier than that of wood? Not necessary. It depends upon the quantity of iron and wood you are comparing. For example, if we take equal volumes of iron and wood, then we can easily declare that iron is heavier than wood. In other words, we can say that iron is heavier than wood.

To know which substance is denser or which is lighter we generally compare the densities of various substances. The density of a substance is the ratio of its mass to that of its volume. Thus

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

$$\text{Density} = \frac{\text{mass of a substance}}{\text{volume of that substance}} \quad \ldots \quad \ldots \quad (7.1)$$

SI unit of density is kilogramme per cubic metre (kgm^{-3}). We can calculate the density of a material if we know its mass and its volume. For example, the mass of 5 litre of water is 5 kg. Its density can be calculated by putting the values in equation 7.1.

Since $1 \text{ litre} = 10^{-3} \text{ m}^3$

$\therefore$ $5 \text{ litre} = 5 \times 10^{-3} \text{ m}^3$

$$\text{Density of water} = \frac{5 \text{ kg}}{5 \times 10^{-3} \text{ m}^3}$$

$$= 1000 \text{ kg m}^{-3}$$

The density of water is 1000 kg m^{-3}.

Table 7.1: Density of various substances

Substance	Density (kgm^{-3})
Air	1.3
Foam	89
Petrol	800
Cooking oil	920
Ice	920
Water	1000
Glass	2500
Aluminium	2700
Iron	7900
Copper	8900
Lead	11200
Mercury	13600
Gold	19300
Platinum	21500

USEFUL INFORMATION

you are comparing. For example, if we take equal volumes of iron and wood, then we can easily declare that iron is heavier than wood. In other words, we can say that iron is heavier than wood.

To know which substance is denser or which is lighter we generally compare the densities of various substances. The density of a substance is the ratio of its mass to that of its volume. Thus

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

$$\text{Density} = \frac{\text{mass of a substance}}{\text{volume of that substance}} \quad \ldots\ \ldots\ (7.1)$$

SI unit of density is kilogramme per cubic metre (kgm^{-3}). We can calculate the density of a material if we know its mass and its volume. For example, the mass of 5 litre of water is 5 kg. Its density can be calculated by putting the values in equation 7.1.

$$\text{Since} \quad 1 \text{ litre} = 10^{-3} \text{ m}^3$$

$$\therefore \quad 5 \text{ litre} = 5 \times 10^{-3} \text{ m}^3$$

$$\text{Density of water} = \frac{5 \text{ kg}}{5 \times 10^{-3} \text{ m}^3}$$

$$= 1000 \text{ kg m}^{-3}$$

The density of water is 1000 kg m^{-3}.

Table 7.1: Density of various substances

Substance	Density (kgm^{-3})
Air	1.3
Foam	89
Petrol	800
Cooking oil	920
Ice	920
Water	1000
Glass	2500
Aluminium	2700
Iron	7900
Copper	8900
Lead	11200
Mercury	13600
Gold	19300
Platinum	21500

DENSITY EQUATIONS

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

$$\text{Mass} = \text{Density} \times \text{Volume}$$

$$\text{Volume} = \frac{\text{Mass}}{\text{Density}}$$

USEFUL INFORMATION

1 metre cube (1 m^3) = 1000 litre

1 litre = 10^{-3} m^3

1 cm^3 = 10^{-6} m^3

1000 kgm^{-3} = 1 gcm^{-3}

DO YOU KNOW?

Earth's atmosphere extends upward about a few hundred kilometres with continuously decreasing density. Nearly half of its mass is between sea level and 10 km. Up to 30 km from sea level contains about 99% of the mass of the atmosphere. The air becomes thinner and thinner as we go up.

EXAMPLE 7.1

The mass of 200 cm^3 of stone is 500 g. Find its density.

SOLUTION

$$m = 500\text{g}$$

$$V = 200 \text{ cm}^3$$

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

$$= \frac{500\text{g}}{200\text{cm}^3} = 2.5 \text{ g cm}^{-3}$$

Thus the density of stone is 2.5 g cm^{-3}.

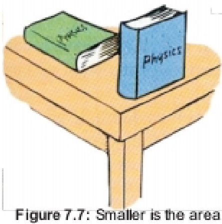
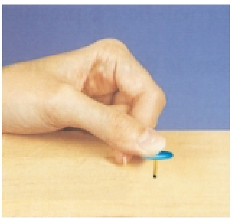


Figure 7.7: Smaller is the area, larger will be the pressure.



7.3 PRESSURE

Press a pencil from its ends between the palms. The palm pressing the tip feels much more pain than the palm pressing its blunt end. We can push a drawing pin into a wooden board by pressing it by our thumb. It is because the force we apply on the drawing pin is confined just at a very small area under its sharp tip. A drawing pin with a blunt tip would be very difficult to push into the board due to the large area of its tip. In these examples, we find that the effectiveness of a small force is increased if the effective area of the force is reduced. The area of the tip of pencil or that of the nail is very small and hence increases the effectiveness of the force. The quantity that depends upon the force and increases with decrease in the area on which force is acting is called pressure. Thus pressure is defined as

The force acting normally per unit area on the surface of a body is called pressure.

into the board due to the large area of its tip. In these examples, we find that the effectiveness of a small force is increased if the effective area of the force is reduced. The area of the tip of pencil or that of the nail is very small and hence increases the effectiveness of the force. The quantity that depends upon the force and increases with decrease in the area on which force is acting is called pressure. Thus pressure is defined as

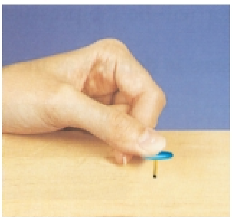


Figure 7.8: A drawing pin with a sharp tip enters easily when pressed on a wooden board.

The force acting normally per unit area on the surface of a body is called pressure.

Thus Pressure $P = \frac{\text{Force}}{\text{Area}}$

or $P = \frac{F}{A}$ ... ... (7.2)

Pressure is a scalar quantity. In SI units, the unit of pressure is Nm^{-2} also called pascal (Pa). Thus

$$1\ Nm^{-2} = 1\ Pa$$

7.4 ATMOSPHERIC PRESSURE

The Earth is surrounded by a cover of air called atmosphere. It extends to a few hundred kilometres 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 a mixture of gases. The density of air in the atmosphere is not uniform. It decreases continuously as we go up.

Figure 7.9: The air pressure inside the bubble is equal to the atmospheric pressure.

Atmospheric pressure acts in all directions. Look at the picture in figure 7.9. What the girl is doing? Soap bubbles expand till the pressure of air in them is equal to the atmospheric pressure. Why the soap bubbles so formed have spherical shapes? Can you conclude that the atmospheric pressure acts on a bubble equally in all direction?

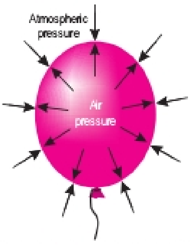


Figure 7.10: Air pressure inside the balloon is equal to the atmospheric pressure.

A balloon expands as we fill air into it. In what direction does the balloon expand? The fact that atmosphere exerts pressure can be explained by 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. Why?

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 the can to collapse from all directions. This experiment shows that atmosphere exerts pressure in all directions.

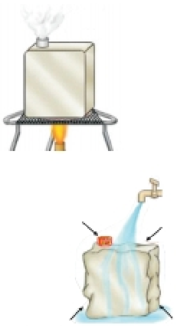


Figure 7.11: Crushing can experiment.

due to atmospheric pressure. Why?

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 the can to collapse from all directions. This experiment shows that atmosphere exerts pressure in all directions.

Figure 7.11: Crushing can experiment.

The fact can also be demonstrated by collapsing of an empty plastic bottle when air is sucked out of it.

MEASURING ATMOSPHERIC PRESSURE

At sea level, the atmospheric pressure is about 101,300 Pa or 101,300 Nm^{-2}. The instruments that measure atmospheric pressure are called barometers. 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. 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.

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 m x 13.6 = 10.34 m. Thus, a glass tube more than 10 m long is required to make a water barometer.

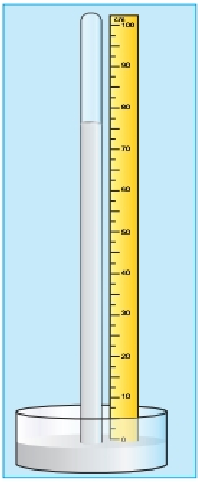
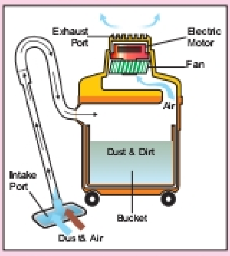


Figure 7.12: A mercury barometer

DO YOU KNOW?



The fan in a vacuum cleaner lowers air pressure in its bucket. The atmospheric air rushes into it carrying dust and dirt with it through its intake port. The dust and dirt particles are blocked by the filter while air escapes out.

VARIATION IN ATMOSPHERIC PRESSURE

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 there is no air. Thus, we can determine the altitude of a place by knowing the atmospheric pressure at that place.

Atmospheric pressure may also indicate a change in the weather. On a hot day, air above the Earth

DO YOU KNOW?

and dirt particles are blocked by the filter while air escapes out.

at an altitude where there is no air. Thus, we can determine the altitude of a place by knowing the atmospheric pressure at that place.

Atmospheric pressure may also indicate a change in the weather. On a hot day, air above the Earth becomes hot and expands. This causes a fall of atmospheric pressure in that region. On the other hand, during cold chilly nights, air above the Earth cools down. This causes an increase in atmospheric pressure.

The changes in atmospheric pressure at a certain place indicate the expected changes in the weather conditions of that place. For example, a gradual and average drop in atmospheric pressure means a low pressure in a neighbouring locality. Minor but rapid fall in atmospheric pressure indicates a windy and showery condition in the nearby region. A decrease in atmospheric pressure is accompanied by breeze and rain. Whereas a sudden fall in atmospheric pressure often followed by a storm, rain and typhoon to occur in few hours time.

DO YOU KNOW?

When air is sucked through straw with its other end dipped in a liquid, the air pressure in the straw decreases. This causes the atmospheric pressure to push the liquid up the straw.

On the other hand, 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

Liquids 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.

Consider a surface of area A in a liquid at a depth h as shown by shaded region in figure 7.13. 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

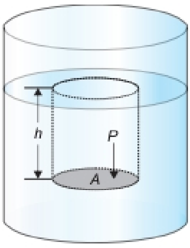


Figure 7.13: Pressure of a liquid at a depth h.

Mass of the liquid cylinder m = volume x density

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

DO YOU KNOW?

The piston of the syringe is pulled out. This lowers the pressure in the cylinder. The liquid from the bottle enters into the piston through the needle.

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

$$= A h \rho g$$

as Pressure $\quad P = \frac{F}{A}$

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

$\therefore$ Liquid pressure at depth h $\quad = P = \rho g h \quad \ldots (7.3)$

Equation (7.3) gives the pressure at a depth h in a liquid of density ρ. It shows that its pressure in a liquid increases with depth.

PASCAL'S LAW

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 directions and to the walls of the container in which it is filled. This result is called Pascal's law which is stated as:

DO YOU KNOW?

The piston of the syringe is pulled out. This lowers the pressure in the cylinder. The liquid from the bottle enters into the piston through the needle.

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

$$= A h \rho g$$

as Pressure $\quad P = \frac{F}{A}$

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

∴ Liquid pressure at depth h $\quad = P = \rho g h \quad \ldots (7.3)$

Equation (7.3) gives the pressure at a depth h in a liquid of density ρ. It shows that its pressure in a liquid increases with depth.

PASCAL'S LAW

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 directions and to the walls of the container in which it is filled. This result is called Pascal's law which is stated as:

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

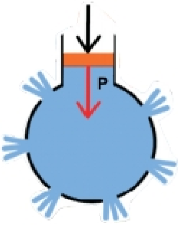


Figure 7.14: Demonstrating Pascal's law.

It can be demonstrated with the help of a glass vessel having holes all over its surface as shown in figure 7.14. Fill it with water. Push the piston. The water rushes out of the holes in the vessel with the same pressure. The force applied on the piston exerts pressure on water. This pressure is transmitted equally throughout the liquid in all directions.

In general, this law holds good for fluids both for liquids as well as gases.

APPLICATIONS OF PASCAL'S LAW

Pascal's law finds numerous applications in our daily life such as automobiles, hydraulic brake system, hydraulic jack, hydraulic press and other hydraulic machine such as shown in figure 7.15.

Figure 7.15 Hydraulic excavator

HYDRAULIC PRESS

Hydraulic press is a machine which works on Pascal's law. It consists of two cylinders of different

cross-sectional areas as shown in figure 7.16. 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

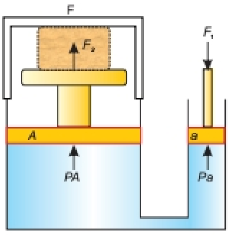


Figure 7.16: A hydraulic press

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

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

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

$$\text{or} \quad F_2 = F_1 \times \frac{A}{a} \quad \ldots\ \ldots\ \ldots (7.4)$$

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 piston.

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

Comparing the above equations, we get

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

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

$$\text{or} \quad F_2 = F_1 \times \frac{A}{a} \quad \dots\ \dots\ \dots (7.4)$$

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 systems working in this way are known as force multipliers.

EXAMPLE 7.2

In a hydraulic press, a force of 100 N is applied on the piston of a pump of cross-sectional area 0.01 m^2. Find the force that compresses a cotton bale placed on larger piston of cross-sectional area 1 m^2.

SOLUTION

Here $F_1 = 100N$

$a = 0.01\ m^2$

$A = 1\ m^2$

Pressure P on smaller piston $= \frac{F_1}{a}$

$= \frac{100\ N}{0.01\ m^2}$

$= 10000\ Nm^{-2}$

Applying Pascal's law, we get

Force F_2 acting on the bale $= PA$

$= 10000\ Nm^{-2} \times 1m^2$

$= 10000\ N$

Thus, hydraulic press will compress the bale with a force of 10000 N.

BRAKING SYSTEM IN VEHICLES

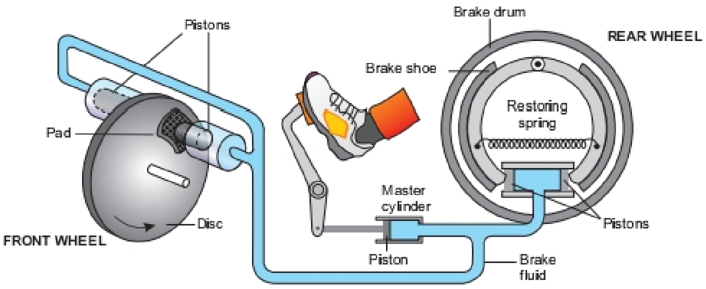


Figure 7.17: A hydraulic brake of a car

The braking systems of cars, buses, etc. also work on Pascal's law. The hydraulic brakes as shown in figure 7.17 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

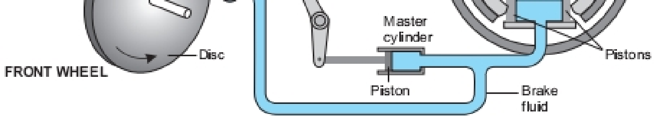


Figure 7.17: A hydraulic brake of a car

The braking systems of cars, buses, etc. also work on Pascal's law. The hydraulic brakes as shown in figure 7.17 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.

7.6 ARCHIMEDES PRINCIPLE

An air filled balloon immediately shoots up to the surface when released under water. The same would happen if a piece of wood is released under water. We might have noticed that a mug filled with water feels light under water but feels heavy as soon as we take it out of water.

More than two thousand years ago, the Greek scientist, Archimedes noticed that 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. Archimedes principle states that:

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.

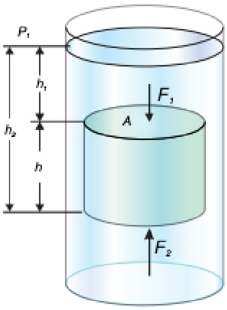


Figure 7.18: Upthrust on a body immersed in a liquid is equal to the weight of the liquid displaced.

Consider a solid cylinder of cross-sectional area *A* and height *h* immersed in a liquid as shown in figure 7.18. 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 $h_2 - h_1 = h$

If P_1 and P_2 are the liquid pressures at depths h_1 and h_2 respectively and ρ is its density, then according to equation (7.3)

$$P_1 = \rho g h_1$$

$$P_2 = \rho g h_2$$

Let the force 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.

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

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

$$\text{and} \quad F_2 = P_2 A = \rho g h_2 A$$

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

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

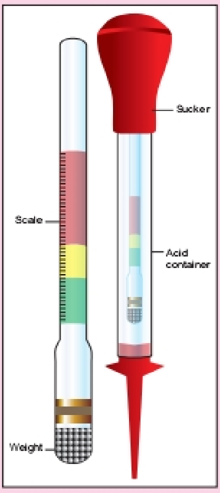
$$= \rho g A (h_2 - h_1)$$

$$\text{or} \quad \text{Upthrust of liquid} = \rho g A h \quad \dots \dots (7.5)$$

$$\text{or} \quad = \rho g V \quad \dots \dots (7.6)$$

Here Ah is the volume V of the cylinder and is equal to the volume of the liquid displaced by the cylinder. Therefore, $\rho g V$ is the weight of the liquid displaced. Equation (7.6) 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.

DO YOU KNOW



Hydrometer is a glass tube with a scale marked on its stem and heavy weight in the bottom. It is partially immersed in a fluid, the density of which is to be measured. One type of hydrometer is used to measure the concentration of acid in a battery. It is called acid meter.

EXAMPLE 7.3

A wooden cube of sides 10 cm each has been dipped completely in water. Calcuclate the upthurst of water acting on it.

SOLUTION

Length of side $L = 10\text{ cm} = 0.1\text{ m}$

Volume $V = L^3 = (0.1\text{ m})^3 = 1\times 10^{-3}\text{ m}^3$

Density of water $\rho = 1000\text{ kgm}^{-3}$

Upthurst of water $= \rho g V$

$= 1000\text{ kgm}^{-3} \times 10\text{m s}^{-2} \times 1 \times 10^{-3}\text{m}^3$

$= 10\text{ N}$

Thus, upthurst of water acting on the wooden cube is 10 N.

DENSITY OF AN OBJECT

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

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

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

$$\text{or} \quad D = \frac{w_1}{w_2 - w_1} \times \rho \quad \dots \dots (7.7)$$

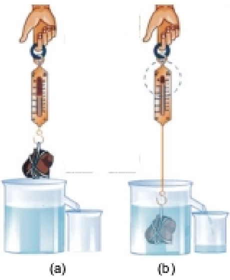


Figure 7.19: (a) weighing solid in air (b) weighing solid in water and measuring water displaced by the solid.

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 7.7 as illustrated in the following example.

EXAMPLE 7.4

DENSITY OF AN OBJECT

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

Since
$$\frac{D}{\rho} = \frac{w_1}{w}$$
$$D = \frac{w_1}{w} \times \rho$$
or
$$D = \frac{w_1}{w_2 - w_1} \times \rho \qquad \ldots\ldots (7.7)$$

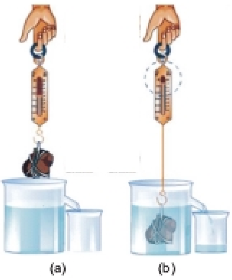


Figure 7.19: (a) weighing solid in air **(b)** weighing solid in water and measuring water displaced by the solid.

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 7.7 as illustrated in the following example.

EXAMPLE 7.4

The weight of a metal spoon in air is 0.48 N. its weight in water is 0.42 N. Find its density.

SOLUTION

Weight of the spoon $= 0.48\ \text{N}$
Weight of spoon in water $w_2 = 0.42\ \text{N}$
Density of water $\rho = 1000\ \text{kg m}^{3}$
Density of spoon $D = ?$
Using equation 7.8,

$$D = \frac{w_1}{w_1 - w_2} \times \rho$$
$$= \frac{0.48\text{N}}{0.48\text{N} - 0.42\text{N}} \times 1000\ \text{kg m}^{-3}$$
$$= 8000\ \text{kg m}^{-3}$$

Thus, density of the material of the spoon is $8000\ \text{kgm}^{-3}$.

7.7 PRINCIPLE OF FLOATATION

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. This is the principle of floatation. It states that:

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

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

EXAMPLE 7.5

An empty meteorological balloon weighs 80 N. It is filled with 10^3 cubic metres of hydrogen. How much maximum contents the balloon can lift besides its own weight? The density of hydrogen is $0.09\ \text{kgm}^{-3}$ and the density of air is $1.3\ \text{kgm}^{-3}$.

SOLUTION

Weight of the balloon $w = 80\ \text{N}$
Volume of hydrogen $V = 10^3\ \text{m}^3$
Density of hydrogen $\rho_1 = 0.09\ \text{kg m}^{-3}$
Weight of hydrogen $w_1 = ?$
Density of air $\rho_2 = 1.3\ \text{kg m}^{-3}$
Weight of the contents $w_2 = ?$
Upthrust $F =$ Weight of air displaced
$= \rho_2 V g$

EXAMPLE 7.5

An empty meteorological balloon weighs 80 N. It is filled with 10^3 cubic metres of hydrogen. How much maximum contents the balloon can lift besides its own weight? Th e density of hydrogen is 0.09 kgm^{-3} and the density of air is 1.3 kgm^{-3}.

SOLUTION

Weight of the balloon $w = 80\text{ N}$
Volume of hydrogen $V = 10^3\text{ m}^3$
Density of hydrogen $\rho_1 = 0.09\text{ kg m}^{-3}$
Weight of hydrogen $w_1 = ?$
Density of air $\rho_2 = 1.3\text{ kg m}^{-3}$
Weight of the contents $w_2 = ?$
Upthrust $F =$ Weight of air displaced

$$= \rho_2 V g$$
$$= 1.3\text{ kgm}^{-3} \times 10\text{ m}^3 \times 10\text{ ms}^{-2}$$
$$= 130\text{ N}$$

Weight of hydrogen
$$w_1 = \rho_1 V g$$
$$= 0.09\text{ kgm}^{-3} \times 10\text{ m}^3 \times 10\text{ ms}^{-2}$$
$$= 9\text{ N}$$

Total weight lifted $= w + w_1 + w_2$

To lift the contents, the total weight of the balloon should not exceed F.

$$\text{Thus}\quad w + w_1 + w_2 = F$$
$$\text{or}\quad 80\text{ N} + 9\text{ N} + w_2 = 130\text{ N}$$
$$\text{or}\quad w_2 = 130\text{ N} - 89\text{ N}$$
$$= 41\text{ N}$$

Thus, the maximum weight of 41 N can be lifted by the balloon in addition to its own weight.

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.

Figure 7.20: A ship floating over water.

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.

Figure 7.21: A submarine travels under water.

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.

EXAMPLE 7.6

A barge, 40 metre long and 8 metre broad, whose sides are vertical, floats partially loaded in water. If 125000 N of cargo is added, how many metres will it sink?

SOLUTION

Area of the barge $A = 40\text{ m} \times 8\text{ m}$
$= 320\text{ m}^2$

Additional load w to carry $= 125000\text{ N}$

$= 320\ \text{m}^2$

Additional load w to carry $= 125000\ \text{N}$

Increased upthrust F of water must be equal to the additional load. Hence

$$F = \rho V g$$

Since $F = w$

$\therefore$ $\rho V g = w$

or $1000\ \text{kg m}^{-3} \times V \times 10\ \text{ms}^{-2} = 125000\ \text{N}$

or $V = 12.5\ \text{m}^3$

Depth h to which barge sinks $= h = \dfrac{V}{A}$

$\therefore$ $h = \dfrac{12.5\ \text{m}^3}{320\ \text{m}^2}$

$= 0.04\ \text{m} = 4\ \text{cm}$

Thus, the barge will sink 4 cm in water on adding 125000 N cargo.

7.8 ELASTICITY

We know that the length of a rubber band increases on stretching it. Similarly, the pointer of a spring balance is lowered when a body is suspended from it. It is because the length of the spring inside the balance increases depending upon the weight of the suspended body. Look at the pictures in figure 7.22. What happens to the objects due to the forces acting on them. The applied force that changes shape, length or volume of a substance is called deforming force. In most of the cases, the body returns to its original size and shape as soon as the deforming force is removed.

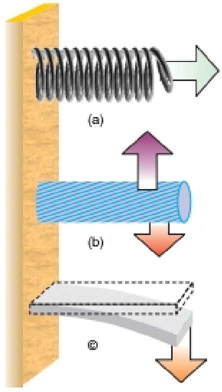


Figure 7.22 (a) A spring is stretched by a force (b) A rod is twisted by the torque produced by a couple (c) A strip is bent by a force.

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

STRESS

Stress is related to the force producing deformation. It is defined as:

The force acting on unit area at the surface of a body is called stress.

Thus $\text{Stress} = \dfrac{\text{Force}}{\text{Area}}$ ... ... (7.8)

In SI, the unit of stress is newton per square metre (Nm^{-2}).

STRAIN

When stress acts on a body, it may change its length, volume, or shape. A ratio of such a change caused by the stress with the original length, volume or shape is called as **strain.** If stress produces a change in the length of an object then the strain is called **tensile strain.**

Tensile strain $= \dfrac{\text{change in length}}{\text{original length}}$ ... ... (7.9)

In SI, the unit of stress is newton per square metre (Nm^{-2}).

STRAIN

When stress acts on a body, it may change its length, volume, or shape. A ratio of such a change caused by the stress with the original length, volume or shape is called as **strain.** If stress produces a change in the length of an object then the strain is called **tensile strain.**

$$\text{Tensile strain} = \frac{\text{change in length}}{\text{original length}} \quad \dots \dots (7.9)$$

Strain has no units as it is simply a ratio between two similar quantities.

7.9 HOOKE'S LAW

It has been observed that deformation in length, volume or shape of a body depends upon the stress acting on the body. Hooke's law states that:

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.

Thus $\quad \text{stress} \propto \text{strain}$

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

or $$\frac{\text{stress}}{\text{strain}} = \text{constant} \quad \dots \dots (7.10)$$

Hooke's law is applicable to all kinds of deformation and all types of matter i.e., solids, liquids or gases within certain limit. This limit tells the maximum stress that can be safely applied on a body without causing permanent deformation in its length, volume or shape. In other words, it is a limit within which a body recovers its original length, volume or shape after the deforming force is removed. 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.

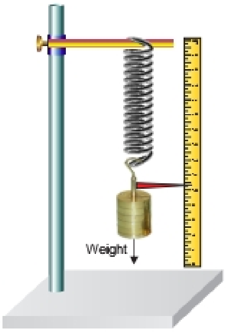


Figure 7.23: Extension in the spring depends upon the load.

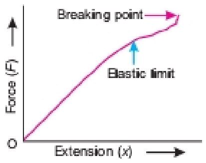


Figure 7.24: Graph between force and extension.

YOUNG'S MODULUS

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.

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

Mathematically,

$$\text{Young's modulus } Y = \frac{\text{Stress}}{\text{Tensile strain}} \quad \dots \dots (7.11)$$

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

As $\quad Y = \frac{\text{Stress}}{\text{Tensile strain}}$

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

Table 7.2: Young's moduli of some common materials

Material	Young's modulus $\times 10^9$ Nm^{-2}

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.

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

Mathematically,

$$\text{Young's modulus } Y = \frac{\text{Stress}}{\text{Tensile strain}} \quad \ldots\ldots (7.11)$$

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

$$\Delta L = L - L_o$$

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

$$\text{and} \qquad \text{Tensile strain} = \frac{L - L_o}{L_o} = \frac{\Delta L}{L_o}$$

$$\text{As} \qquad Y = \frac{\text{Stress}}{\text{Tensile strain}}$$

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

$$\therefore \qquad Y = \frac{F\,L_o}{A\,\Delta L} \quad \ldots\ldots (7.12)$$

SI unit of Young's modulus is newton per square metre (Nm^{-2}) Young's modului of some common materials are given in Table 7.2.

Table 7.2: Young's modului of some common materials

Material	Young's modulus $\times 10^9\ Nm^{-2}$
Aluminium	70
Bone	0.02
Brass	91
Copper	110
Diamond	1120
Glass	60
Iron	190
Lead	16
Nickel	200
Rubber	0.0007
Steel	200
Tungsten	400
Wood (paralel gain)	10
Wood (perpendicular gain)	1

EXAMPLE 7.7

A steel wire 1 m long and cross-sectional area $5 \times 10^{-5} m^2$ is stretched through 1 mm by a force of 10,000 N. Find the Young's modulus of the wire.

SOLUTION

Force $F = 10{,}000$ N

Length $L_o = 1$m

Extension $\Delta L = 1\text{mm} = 0.001$m

Cross sectional Area $A = 5 \times 10^{-5}\ m^2$

$$\text{Since} \qquad Y = \frac{F\,L_o}{A\,\Delta L}$$

$$Y = \frac{10000\ N \times 1\ m}{5 \times 10^{-5}\ m^2 \times 0.001\ m}$$

$$Y = 2 \times 10^{11}\ N\,m^{-2}$$

Thus, Young's modulus of steel is $2 \times 10^{11}\ Nm^{-2}$.

SUMMARY

- Kinetic molecular model explains the three states of matter assuming that
  - matter is made up of particles called molecules.
  - the molecules remain in continuous motion.
  - molecules attract each other.
- At very high temperature, the collision between atoms and molecules tears off their electrons. Atoms become positive ions. This ionic state of matter is called plasma-the fourth state of matter.
- Density is the ratio of mass to volume of a substance. Density of water is 1000 kgm^{-3}.
- Pressure is the normal force acting per unit area. Its SI unit is Nm^{-2} or pascal (Pa).
- Atmospheric pressure acts in all directions.
- The instruments that measure

can determine its altitude.

- The changes in atmospheric pressure at a certain place indicate the expected changes in the weather conditions of that place.
- Liquids also exert pressure given by: $P = \rho g h$
- Liquids transmit pressure equally in all directions. This is called Pascal's law.
- When a body is immersed wholly or partially in a liquid, it loses its weight equal to the weight of the liquid displaced. This is known as Archimedes principle.
- For an object to float, its weight must be equal or less than the upthrust of the liquid acting on it.
- The property of matter by virtue of which matter resists any force which tries to change its length, shape or volume is called elasticity.
- Stress is the deforming force acting

- molecules attract each other.
- At very high temperature, the collision between atoms and molecules tears off their electrons. Atoms become positive ions. This ionic state of matter is called plasma-the fourth state of matter.
- Density is the ratio of mass to volume of a substance. Density of water is 1000 kgm^{-3}.
- Pressure is the normal force acting per unit area. Its SI unit is Nm^{-2} or pascal (Pa).
- Atmospheric pressure acts in all directions.
- The instruments that measure atmospheric pressure are called barometers.
- The atmospheric pressure decreases as we go up. Thus, knowing the atmospheric pressure of a place, we

$P=\rho gh$

- Liquids transmit pressure equally in all directions. This is called Pascal's law.
- When a body is immersed wholly or partially in a liquid, it loses its weight equal to the weight of the liquid displaced. This is known as Archimedes principle.
- For an object to float, its weight must be equal or less than the upthrust of the liquid acting on it.
- The property of matter by virtue of which matter resists any force which tries to change its length, shape or volume is called elasticity.
- Stress is the deforming force acting per unit area.
- The ratio of change of length to the original length is called tensile strain.
- The ratio between stress and tensile strain is called Young's modulus.

QUESTIONS

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)10^2Nm^{-2} (d)10^3Nm^{-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) mass 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

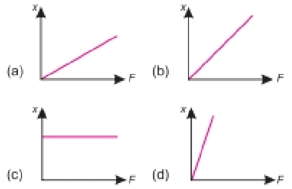
(a) stress x strain = constant

(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)

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

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

found with the help of:

(a) Pascal's law

(b) Hooke's law

(c) Archimedes principle

(d) Principle of floatation

of matter is helpful in differentiating various states of matter?

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

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

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

7.6 Define the term pressure.

7.7 Show that atmosphere exerts pressure.

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

7.9 What is a barometer?

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

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

Suction cup to hang light objects

7.12 Why does the atmospheric pressure vary with height?

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

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

7.15 State Pascal's law.

7.16 Explain the working of hydraulic press.

7.17 What is meant by elasticity?

7.18 State Archimedes principle.

7.19 What is upthrust? Explain the principle of floatation.

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

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

7.22 What is Hooke's law? What is meant by elastic limit?

7.23 Take a rubber band. Construct a balance of your own using a rubber band. Check its accuracy by weighing various objects.

PROBLEMS

7.1 A wooden block measuring 40 cm x 10 cm x 5 cm has a mass 850 g. Find the density of wood. (425 kgm^{3})

7.2 How much would be the volume of ice formed by freezing 1 litre of water? (1.09 litre)

7.3 Calculate the volume of the following objects:

(i) An iron sphere of mass 5 kg, the density of iron is 8200 kgm^{-3}. (6.1x10^{-4}m^{3})

(ii) 200 g of lead shot having density 11300 kgm^{-3}. (1.77x10^{-5}m^{3})

(iii) A gold bar of mass 0.2 kg. The density of gold is 19300 kgm^{-3}. (1.04x10^{-5}m^{3})

7.4 The density of air is 1.3 kgm^{-3}. Find the mass of air in a room measuring 8m x 5m x 4m. (208 kg)

7.5 A student presses her palm by her thumb with a force of 75 N. How much would be the pressure

2.55 gcm^{-3}. Find the volume of the cavity. (5 cm^{3})

7.9 An object has weight 18 N in air. Its weight is found to be 11.4 N when immersed in water. Calculate its density. Can you guess the material of the object? (2727 kgm^{-3}, Aluminium)

7.10 A solid block of wood of density

(iii) A gold bar of mass 0.2 kg. The density of gold is 19300 kgm^{-3}. ($1.04 x 10^{-5} m^3$)

7.4 The density of air is 1.3 kgm^{-3}. Find the mass of air in a room measuring 8m x 5m x 4m. (208 kg)

7.5 A student presses her palm by her thumb with a force of 75 N. How much would be the pressure under her thumb having contact area 1.5 cm^2? ($5x10^5$ Nm^{-2})

7.6 The head of a pin is a square of side 10 mm. Find the pressure on it due to a force of 20 N. ($2x10^5$ Nm^{-2})

7.7 A uniform rectangular block of wood 20 cm x 7.5 cm x 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 wood. (1778 Nm^{-2}, 889 kgm^{-3})

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

7.9 An object has weight 18 N in air. Its weight is found to be 11.4 N when immersed in water. Calculate its density. Can you guess the material of the object? (2727 kgm^{-3}, Aluminium)

7.10 A solid block of wood of density 0.6 gcm^{-3} weighs 3.06 N 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}? (510 cm^3, 340 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 weighing 20 000 N on its piston if the diameter of the piston of the pump is 3 cm? (200 N)

7.12 A steel wire of cross-sectional area $2x10^{-5}$ 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 2 m. ($2x10^{11}$ Nm^{-2})

Unit 8

Thermal Properties of Matter

STUDENT'S LEARNING OUTCOMES

After studying this unit, the students will be able to:

- define temperature (as quantity which determines the direction of flow of thermal energy).
- define heat (as the energy transferred resulting from the temperature difference between two objects).
- list basic thermometric properties for a material to construct a thermometer.