## NUMERICAL QUESTIONS

1. Determine the work done in each of the following cases:
   a) Kicking a soccer ball forward with a force of 40 N over a distance of 15 cm
   b) Lifting a 50-kg barbell straight up 1.95 m
2. Calculate the velocity of a 1.2 kg falling star (meteorite) with $5.5 \times 10^8$ J of energy.
3. Calculate the gravitational potential energy of a 2000 kg piano
   a) resting on the floor b) with respect to the basement floor, 1.9 m below.
4. An elevator weighing 5000N is raised to a height of 15.0 m in 10.0 s, how much power is developed?
5. What power is required for a ski-hill chair lift that transports 500 people (average mass 65 kg) per hour to an increased elevation of 1200 m?
6. How long will it take a 2750-W motor to lift a 385-kg sofa set to a sixth-story window 16.0 m above?
7. How much work can a 2.0-hp motor do in 1.0 h?

## WEB LINKS

www.mowp.gov.pk/

http://www.aedb.org/




Unit 7

# PROPERTIES OF MATTER

CHECK LIST

**After studying this unit you should 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., ($p=\rho gh$) and solve problems using this equation.
- ✓ 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.

Look around, everything, from our body to the air we breath is matter. The features of a substance and how it behave are called its properties. Therefore it is important to know about the properties of matter. Knowing about properties of matter helps us to understand what ice cube rain and steam have in common? What is the impact of amount of substance in a body? How matter behaves when forces are applied? Questions like these can be answered after reading this chapter.

We will see how solids respond to external forces, and how fluids liquids and gases develop pressure that is responsible for such phenomena as buoyancy and fluid flow.

## 7.1 KINETIC MOLECULAR MODEL OF MATTER

It is a well established by chemical and physical evidence that matter is composed of molecules. Matter has three states solids, liquids and gases. These three states of matter are explained on the basis of Kinetic Molecular Theory. In kinetic molecular model, it is assumed that:

### Solids:

1. Solids are made up of molecules which are arranged closely in a fixed pattern.
2. Molecules in solids vibrate about their mean positions.
3. The attractive forces between the molecules are strong.

### Liquids:

1. Liquids are also made up of molecules which are close together.
2. The pattern of molecules is not fixed and does not extend far. The molecules in a pattern keep changing their position.
3. Molecules are able to move about, which means that a liquid is able to change its shape and can adopt the shape of the container.
4. The attractive forces between the molecules of liquid is less than the solid..

### Gases:

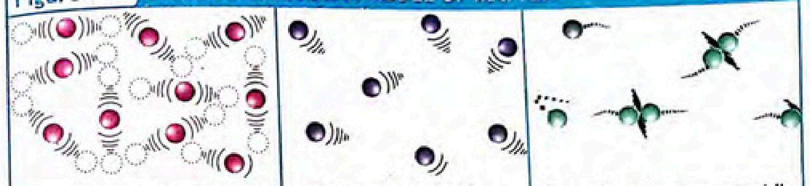
1. A gas is made up of molecules which are in constant random motion.
2. The distance between molecules is larger as compared to the size of the molecules.
3. The molecules are constantly colliding elastically with each other and with the walls of the container.
4. Forces between molecules are negligible, except during collisions.





Because liquids and gases do not maintain a fixed shape, they both have the ability to flow. They are thus also referred collectively as fluids.

Figure 7.1 KINETIC MOLECULAR MODEL OF MATTER



Solid molecules vibrate in fixed positions. | Liquid molecules flow over each other. | Gas molecules move rapidly in all directions and collide.

### PLASMA:

There is another state of matter, the fourth state, called Plasma. It consists of free electrons and atoms from which the electrons have been removed. Plasma exists in the sun, where thermonuclear reactions take place at very high temperatures.

## 7.2 DENSITY

**Density of a substance is defined as the mass of substance per unit volume.** For example iron is denser than air, because iron has more mass in the same volume as compared to air. Conversely for same mass of iron and air, volume of iron will be less than air. Symbolically density is denoted by 'ρ' (called Rho). For an object of mass 'm' and volume 'V', density is given as

$$\rho = \frac{m}{V} \qquad (7.1)$$

**TABLE 7.1 DENSITIES**

| Material | Density ($kg/m^3$) |
|---|---|
| iron | 7900 |
| gold | 19300 |
| ice | 920 |
| polythene | 900 |
| petrol | 800 |
| pure water | 1000 |
| mercury | 13600 |
| air | 1.3 |
| carbon dioxide | 2.0 |

Hence the S.I. unit of density is kg $m^{-3}$. Some common density values, are given in table 7.1.

## Example 7.1 DENSITY OF METAL

A rectangular metal piece has length 0.3 m, width 0.2 m and height 0.1 m. If its mass is 47.4 kg. Calculate its density.

**SOLUTION**

**GIVEN:**

Mass of metal piece m = 47.4 kg

Volume V = length × width × height

0.3 m × 0.2 m × 0.1 m = 0.006 m

**REQUIRED:**

density ρ = ?

By definition of density $\rho = \frac{m}{V}$

putting values $\rho = \frac{47.4\,kg}{0.006\,m^3}$

therefore $\rho = 7900\,kg\,m^{-3}$ —— Answer

From the table 7.1 we can see that it is density of iron, therefore the metal piece under study is that of iron.

## Assignment 7.1 DENSITY OF DIAMOND

A diamond has a volume of 0.00002 m³, its mass is measured as 0.072 kg. Calculate its density.

## 7.3 PRESSURE

**Pressure is defined as force per unit area.** Pressure is represented by letter 'P', if force 'F' is applied on area 'A', the pressure is

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

The SI unit of pressure is the newton per square meter (N/m²), which is given a special name, the pascal (Pa).

$$1Pa = \frac{1N}{1m^2}$$

**QUIZ ? SMAE VOLUME OBJECTS**

Which is a heavier, a cubic metre of steel or a cubic metre of wood? Why?

**TID-BIT THUMB PIN**

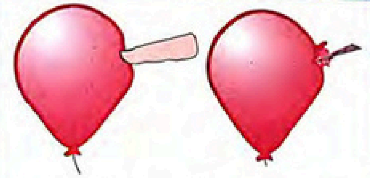
Assuming same force is applied at both ends of this thumb-pin, On which side pressure is greater?







**ACTIVITY PRESSURE AND PRICKING**



Pressure is increased if the force applied to a given area is increased, or if a given force is applied to a smaller area. For example, if you press your finger against a balloon, not much happens—your finger causes a small indentation. On the other hand, if you push a needle against the balloon with the same force, you get an explosive pop. The difference is that the same force applied to the small area of a needle tip causes a large enough pressure to rupture the balloon.

**POINT TO PONDER HEELES**

Have you ever wonderd why getting steped on by heeled shoe hurts more than getting stepped by flat one?

Since the pressure depends upon the amount of force acting on the surface and size of the surface. Therefore for same force smaller surface exerts greater pressure. For the same reason the spiked shoes are painful to wear, as it concentrate your body weight (force) on the ball of foot.

## Example 7.2 WEIGHT AS PRESSURE ON GROUND

A 40-kg girl's two feet cover an area of 500 cm² (a) Determine the pressure exerted by the two feet on the ground. (b) If the girl stands on one foot, what will be the pressure under that foot?.

**SOLUTION**

**GIVEN:**

Force F = Weight W = mg = 40 kg × 9.8 ms⁻² = 392 N

Area A = 500 cm² = 500 × (10⁻²)² m² = 500 × 10⁻⁴ m² = 0.05 m²

**REQUIRED:**

Pressure P = ?

**(a)** Assume the girl is at rest. Then she exerts a force equal to her weight mg on the ground where her feet contact it. Therefore by definition of pressure

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

putting values $P = \frac{392\,N}{0.05\,m^2}$

**EXTENSION EXERCISE 7.1**

What will be pressure if she is wearing heeled shoe with an area of tip 0.0001 m², and stand with all her weight on that tip?

or $P = 7840\,Nm^{-2}$

or $P = 7.8 \times 10^3\,Nm^{-2}$

or $P = 7.8\,kPa$ — Answer

**(b)** If the person stands on one foot, the force is still equal to the person's weight, but the area will be half as much, so the pressure will be twice as much

$P = 15.6\,kPa$ — Answer

**Assignment 7.2 CONCRETE BLOCK**

A block of concrete weighs 900 N and its base is a square of side 3 m. What pressure does the block exert on the ground?

## 7.4 ATMOSPHERIC PRESSURE

Pressure is particularly useful for dealing with fluids. It is an experimental observation that a fluid exerts pressure in every direction. This is well known to swimmers and divers who feel the water pressure on all parts of their bodies. A person need not be under water to experience the effects of pressure. Walking about on land, we are at the bottom of the earth's atmosphere, which is a fluid and pushes inward on our bodies just like the water in a swimming pool.

**The pressure that atmosphere exerts is called atmospheric pressure.** The pressure of the air at a given place varies slightly according to the weather. At sea level, the pressure of the atmosphere on average is $1.013 \times 10^5\,Nm^2$ (or $1.013 \times 10^5$ Pa).This value lets us to define a commonly used unit of pressure, the atmosphere (abbreviated atm), such that 1 atm = $1.013 \times 10^5$ Pa.

Another unit of pressure sometimes used (in meteorology and on weather maps) is the bar, which is defined as 1 bar = $1.000 \times 10^5$ Pa

Thus standard atmospheric pressure is slightly more than 1 bar. The air around us exerts a force in all directions and is opposed by an equal pressure inside our body, thus we are generally unaware of it. However, when the air is pumped out of a sealed can, atmospheric pressure produces an inward force that is unopposed. The resulting collapse of the can illustrates the pressure that is all around us.

The climbers at high altitudes encounter lower atmospheric pressure due to the thinner air. The thinner air causes breathing difficulties due to the lower level of oxygen.







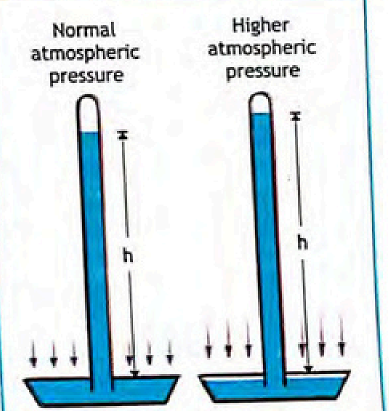
**ACTIVITY USING ATMOSPHERIC PRESSURE TO CRUSH CAN**

Figure shows a thin-walled metal can, attached to a vacuum pump. Before the air was pumped out, the pressure inside the can is equal to that outside (atmospheric) pressure. As the air is pumped out, a partial vacuum of very low pressure forms inside the can and immediately the external atmospheric pressure crushes the can. It will only happen if the material of the can is thin or flexible.

### 7.4.1 MEASUREMENT OF ATMOSPHERIC PRESSURE

An instrument that is commonly used to measure atmospheric pressure is the **mercury barometer**. Italian mathematician Evangelista Torricelli (1608-1647) invented it in 1643. Figure 7.2 shows a Torricellian barometer. A long tube that is open at one end and closed at the other is filled with mercury and then inverted into a dish of mercury. Once the tube is inverted, the mercury does not empty into the bowl. Instead, the atmosphere exerts a pressure on the mercury in the bowl. This atmospheric pressure pushes the mercury in the tube to some height 'h' above the bowl. In this way, the force exerted on the bowl of mercury by the atmosphere is equal to the weight of the column of mercury in the tube. Any change in the height 'h' of the column of mercury means that the atmosphere's pressure has changed. At sea level, the atmosphere will push down on a pool of mercury and make it rise up in a tube to a height of approximately 760mm.

**Figure 7.2 BAROMETER**



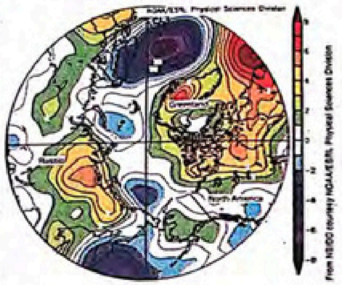

A mercury barometer. If there is no air in the tube, the air pressure on the mercury in the bowl forces the mercury to rise up the tube. The pressure at the bottom of the tube equals the air pressure. The higher the air pressure, the higher the column of mercury.

**Is it possible to build a barometer with water rather than mercury?**

Water is less dense (less heavy, in effect) than mercury so air pressure will lift a certain volume of water much higher up a tube than the same volume of mercury. In other words, if we use water, we would need a really tall tube and our barometer will be so enormous as to be impractical.

## 7.4.2 ATMOSPHERIC PRESSURE AND WEATHER

Sea level Pressure Anomaly (mb)
May 2011



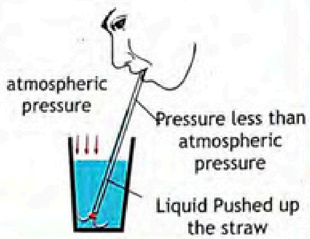
Barometers kept in the same place at the same height above sea level shows some variation in atmospheric pressure from day to day. These pressure variations are shown on weather maps. The lines in the map joining all those places with the same atmospheric pressure are called isobars. The unit for pressure used in weather maps is the millibar (mbar).

*1000 mbar = 1 bar*

*1 bar = 100 kPa, nearly equal to normal atmospheric pressure.* Usually the range of atmospheric pressure varies from the very high pressure of 1040 mbar to as low as 950 mbar. Winds move from high pressure regions to low pressure regions. In the northern hemisphere, the wind moves anticlockwise around areas of low pressure and clockwise around areas of high pressure. The strength of the wind is determined by the pressure gradient. From the weather map, when the isobars are packed closely together, it indicates a high pressure gradient. This means that strong winds may result.

### APPLICATION DRINKING THROUGH STRAW

The action of sucking increases the volume of lungs, thereby reducing the air pressure in the lungs and the mouth. The atmospheric pressure acting on the surface of the liquid will then be greater than the pressure in the mouth, thus forcing the liquid to rise up the straw into the mouth.

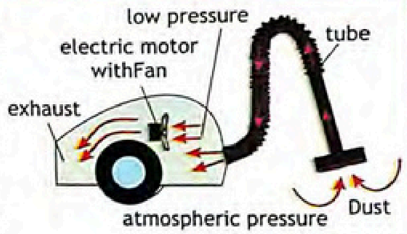







### APPLICATION WORKING OF VACUUM CLEANER

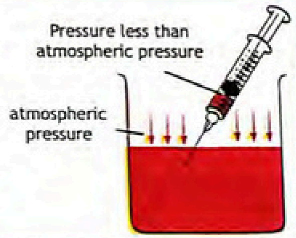
Vacuum cleaner consists of an electric motor with fan, filter bag (dirt bag) and a tube. When the electric motor is switched on the fan rotates in such a way it sucks the air inside container and sends it out through exhaust, creating a partial vacuum inside the container. By doing so, a low pressure region is created inside the container.




As we already know materials move from high pressure region to low pressure region, here, surrounding air moves from outside the container via the tube to inside the container. While surrounding air moves inside with more force, it gathers all the dirt and dust that comes across its way, thus pulling them inside the container. These dust and dirt particles are filtered and stored in the filter bag, which will be disposed later.

### APPLICATION PULLING LIQUID UP THE SYRINGE

To draw liquid into the syringe, as shown in Figure, the piston of the syringe is drawn back upwards. This decreases the pressure within the cylinder. Atmospheric pressure acting on the surface of the liquid drives the liquid into the cylinder through the nozzle of the syringe. Thus atomospheric pressure helps the fluid to lift up the cylinder.



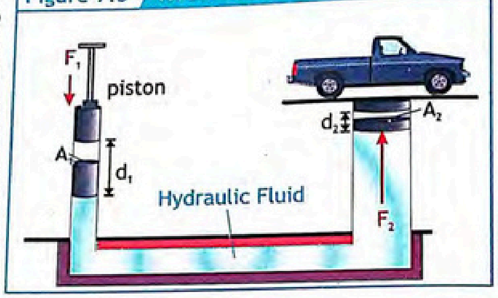

## 7.5 PASCAL'S PRINCIPLE

When you pump a bicycle tyre, you apply a force on the pump that in turn exerts a force on the air inside the tyre. The air responds by pushing not only against the pump but also against the walls of the tyre. As a result, the pressure increases by an equal amount throughout the tyre. In general, if the pressure in a fluid is increased at any point in a container (such as at the valve of the tyre), the pressure increases at all points inside the container by exactly the same amount. Blaise Pascal (1623-1662) noticed this fact in what is now called Pascal's principle (or Pascal's law):

An external pressure applied to an enclosed fluid is transmitted unchanged to every point within the fluid.

Classic example of Pascal's principle at work is the hydraulic lift, which is shown schematically in figure 7.3. Here we see two cylinders, one of cross-sectional area $A_1$ the other of cross-sectional area $A_2 > A_1$. The cylinders, each of which is fitted with a piston, are connected by a tube and filled with a suitable fluid usually oil called Hydraulic fluid. Initially the pistons are at the same level and exposed to the atmosphere.

Figure 7.3 HYDRAULIC LIFT




Now, suppose we push down on piston with the force $F_1$. The pressure $P_1$ exerted by this piston is

$$P_1 = \frac{F_1}{A_1} \quad \text{—— (1)}$$

Similarly, the pressure on the piston lifting vehicle is $P_2$, which can be written as

$$P_2 = \frac{F_2}{A_2} \quad \text{—— (2)}$$

By pascal's principle

$$P_2 = P_1 \quad \text{—— (3)}$$

putting values from equation 1 and equation 2 in equation 3, we get

$$\frac{F_2}{A_2} = \frac{F_1}{A_1}$$

or $$F_2 = \frac{A_2 \times F_1}{A_1}$$

or $$F_2 = \frac{A_2}{A_1} F_1 \quad \text{—— (7.3)}$$

Depending on the ratio $A_2/A_1$ the force $F_2$ can be as large as required. To be



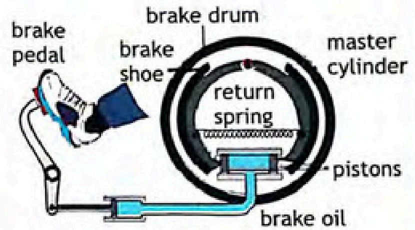


specific, let's assume that $A_2$ is 100 times greater than $A_1$. Then, by pushing down on piston 1 with a force $F_1$ we push upward on piston 2 with a force of $F_2 = 100\,F_1$. Our force has been magnified 100 times! Hence a relatively small effort can be used to overcome a much larger load.

**APPLICATION HYDRAULIC BRAKES OPERATION**

Hydraulic car brakes are shown in Figure . When the brake pedal is pushed, the piston in the master cylinder exerts a force on the brake fluid and the resulting pressure is transmitted equally to eight other pistons.

These force the brake shoes or pads against the wheels and stop the car.




## 7.6 LIQUID PRESSURE

The liquid is incompressible therefore the pressure increases directly below the surface of the liquid. In figure 7.4 a disc is placed at the bottom of a tank in fluid. The force F acting on the disc is the weight W of the cylindrical column of liquid of mass m.

$$F = W = mg \quad \text{—— (1)}$$

For the fluid of density ρ, the mass m of the fluid above the disk, with volume V is

$$\rho = \frac{m}{V}$$

or $$m = \rho V \quad \text{—— (2)}$$

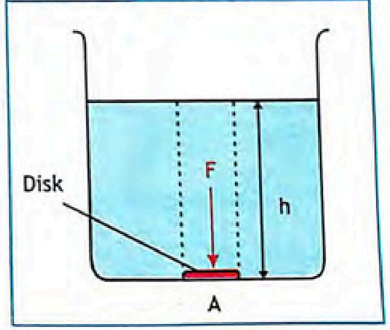
Since the fluid forms a cylindrical volume V shown by dotted lines in the figure which has height h and area of cross section A. Therefore

$$V = Ah \quad \text{—— (3)}$$

putting equation 3 in equation 2, we get

$$m = \rho Ah \quad \text{—— (4)}$$

Figure 7.4 LIQUID PRESSURE



putting equation 4 in equation 1, we get

$$F = \rho A h g \quad \text{—— (5)}$$

Since pressure is defined as

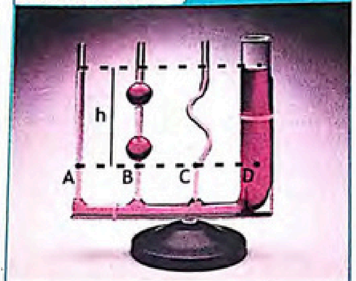
$$P = \frac{F}{A} \quad \text{—— (6)}$$

putting value of force from equation 5 in equation 6 we get

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

therefore $P = \rho h g$ —— 7.4

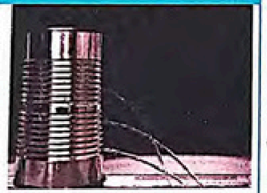
**INFORMATION**

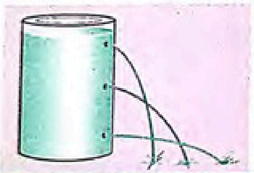



Since points A, B, C, and D are at the same distance h beneath the liquid surface, the pressure at each of them is the same.

## PROPERTIES OF LIQUIDS AND PRESSURE

**1) Pressure in a liquid increases with depth** because the further down you go, the greater the weight of liquid above. As can be seen in Figure . A water spurts out fastest and furthest from the lowest hole.





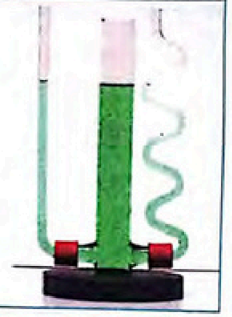
**2) Pressure at one depth acts equally in all directions.**

The can of water in Figure has similar holes all round it at the same level. Water comes out equally fast and spurts equally far from each hole. Hence the pressure exerted by the water at this depth is the same in all directions.





**3) A liquid finds its own level.** In figure the liquid is at the same level in each tube and confirms that the pressure at the bottom of a liquid depends only on the vertical depth of the liquid and not on the tube width or shape.



### Example 7.3 LIMITS ON SUBMARINE DEPTH

A submarine is constructed so that it can safely withstand a pressure of $1.6 \times 10^7$ Pa. How deep may this submarine descend in the ocean if the average density of seawater is $1025\ kg/m^3$?

**SOLUTION**

**GIVEN:**

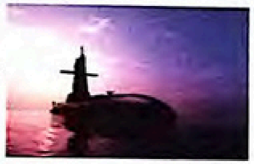
Pressure $P = 1.6 \times 10^7\ Pa = 1.6 \times 10^7\ kgm^{-1}s^{-2}$

Density $= 1025\ kg/m^3$

Acceleration due to gravity $= 9.8\ ms^{-2}$

**REQUIRED:**

depth = height h = ?



(a) The maximum depth a submarine can go down can be measured by equation

$$P = \rho h g$$

or

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

putting values

$$h = \frac{1.6 \times 10^7\ \cancel{kg}m^{-1}\cancel{s^{-2}}}{1025\ \cancel{kg}m^{-3} \times 9.8\ m\cancel{s^{-2}}}$$

therefore $h = 1.6 \times 10^3 m = 1.6\ km$ —— Answer

### Assignment 7.3 PRESSURE AT 100m DEPTH OF WATER

What is the pressure at a depth of 100 m below the surface of water?

## 7.7 UPTHRUST AND BUOYANCY

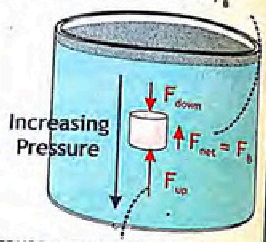
When an object is immersed in a fluid, the pressure on the lower surface of the object is higher than the pressure on the upper surface. The difference in pressures leads to an upward net force acting on the object due to the fluid pressure called up-thurst or buoyant force and phenomena is called buoyancy.

If you try to push a piece of cork underwater, you feel the buoyant force pushing the cork back up.

**Figure 7.5 UPTHRUST**

Net force $F_{net}$ of the fluid on the cork is the buoyant force $F_B$

The buoyant force arises because the fluid pressure at the bottom of the cylinder is larger than at the top.




$F_{up} > F_{down}$ because pressure is greater at bottom of beaker, hence the fluid exerts a net upward force

## 7.8 ARCHIMEDES PRINCIPLE

Why do some things float while others do not? Is floating determined by the weight of the object? A large ship floats, but a small pebble quickly sinks. Clearly, it is not a matter of the total weight of the object. The density of the object may be the key. Objects that are denser than the fluid they are immersed in, will sink—those less dense will float. The complete answer to the question of why things sink or float is found in Archimedes' principle, which is stated as

**The buoyant force acting on an object fully or partially submerged in a fluid is equal to the weight of the fluid displaced by the object.**

Everyone has experienced Archimedes' principle. For example, it is relatively easy to lift someone in a swimming pool.

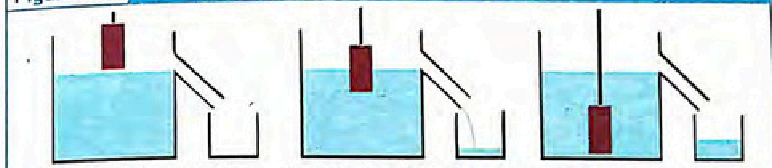
Imagine that you submerge a brick in a container of water, as shown in Figure 7.6. A spout on the side of the container at the water's surface allows water to flow out of the container. As the brick sinks, the water level rises and water flows through the spout into a smaller container. The total volume of water that collects in the smaller container is the displaced volume of water from the large container. The displaced volume of water is equal to the volume of the portion of





the brick that is underwater.

**Figure 7.6 ARCHIMEDES' PRINCIPLE**



a. A brick is being lowered into a container of water.

b. The brick displaces water, causing the water to flow into a smaller container.

c. When the brick is completely submerged, the volume of the displaced water is equal to the volume of the brick.

The magnitude of the buoyant force $F_B$ acting on the brick at any given time can be calculated by using Archimedes' principle. Any object completely or partially submerged in a fluid experiences an upward buoyant force equal in magnitude to the weight of the fluid displaced by the object.

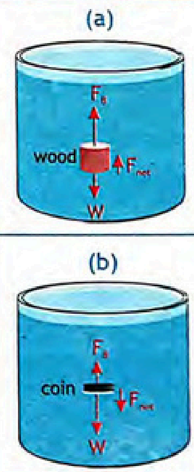
$F_B = W$ (displaced fluid) $= m_f g$

magnitude of buoyant force = weight of fluid displaced

According to Archimedes principle, every object experiences a buoyant force. The buoyant force will decrease the weight of the object which is termed as apparent lose of weight. Whether it floats or sinks depends on the object's density relative to the fluid. When we push a wood block underwater and you will feel the upward buoyant force as in figure 7.7(a). By Archimedes principle, the buoyant force equals the weight of water displaced; since water is denser than wood, the buoyant force is greater than the wood's weight, and that is why wood

**Figure 7.7 FLOAT OR SINK**

(a)




(a) $F_B$ = weight of fluid displaced by wood. Water is denser than wood $\rho_{water} > \rho_{wood}$ so block's weight W is less than $F_B$, and the net force is upward.

(b) $F_B$ = weight of fluid displaced by coin. Coin is denser than water $\rho_{water} < \rho_{coin}$ so coin's weight W is greater than $F_B$, and the net force is downward.

floats. Now when we submerge a coin figure 7.7(b). It's denser than water, so the coin's weight is greater than the weight of the displaced water. Hence the coin's weight is greater than the upward buoyant force, and it sinks.

Whether an object will float or sink depends on the net force acting on it. This net force can be calculated as follows:

$$F_{net} = F_B - W \text{ (object)}$$

Now we can apply Archimedes' principle, using '$m_o$' to represent the mass of the submerged object and '$m_f$' as mass of fluid 'g' is acceleration due to gravity.

$$F_{net} = m_f g - m_o g$$

Remember that '$m = \rho V$', so the expression can be rewritten as follows:

$$F_{net} = \rho_f V_f\, g - \rho_o V_o g \quad \text{or} \quad F_{net} = (\rho_f V_f - \rho_o V_o)g$$

A simple relationship between the weight 'W' of a submerged object of mass $m_o$ and density $\rho_o$ and the buoyant force '$F_B$' on the object by fluid displaced of mass $m_B$ and density $\rho_B$ can be found by considering their ratio as follows:

$$\frac{W}{F_B} = \frac{m_O \cancel{g}}{m_B \cancel{g}}$$

$$\text{or} \quad \frac{W}{F_B} = \frac{m_O}{m_B} \quad \text{—— (1)}$$

for submerged object equal volume is displaced therefore

$$V_o = V_B = V$$

therefore $m_O = \rho_O V$ and $m_B = \rho_B V$

putting these values in equation 1, we get

$$\frac{W}{F_B} = \frac{\rho_O \cancel{V}}{\rho_B \cancel{V}}$$

$$\text{or} \quad \frac{W}{F_B} = \frac{\rho_O}{\rho_B} \quad \text{—— 7.5}$$

**LAB WORK**

To find the density of a body heavier than water by Archimedes Principle.

**Example 7.4 IS CROWN MADE OF PURE GOLD?**

A girl purchases a "gold" crown at a flea market. After she gets home, she hangs the crown from a scale and finds its weight to be 7.84 N. She then weighs the crown while it is immersed in water, and the scale reads 6.86 N. Is the crown made of pure gold?





**SOLUTION**

**GIVEN:**

Weight in air $W_A = 7.84$ N

Weight in water $W_B = 6.86$ N

Density of water $\rho_B = 1.00 \times 10^3$ kg/m$^3$

**REQUIRED:**

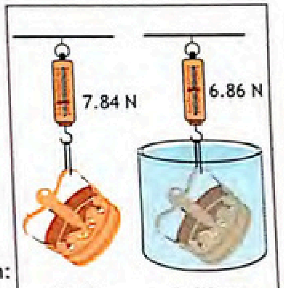
Density of crown $\rho_o$ = ?

The apparent weight of the crown in water $W_B$ is equal to the weight in air $W_A$ minus the buoyant force $F_B$ exerted by water i.e. $W_B = W_A - F_B$ which means that

$$F_B = W_A - W_B$$

$$F_B = 7.84N - 6.86N$$

$$F_B = 0.98N$$




The relationship between the weight 'W' and the buoyant force '$F_B$' is

$$\frac{W}{F_B} = \frac{\rho_O}{\rho_B}$$

Rearrange the equation to isolate the unknown:

$$\rho_O = \frac{W}{F_B} \times \rho_B$$

putting values $\rho_O = \dfrac{7.84\cancel{N}}{0.98\cancel{N}} \times 1 \times 10^3 \text{ kg/m}^3$

therefore $\rho_O = 8 \times 10^3 \text{ kg/m}^3$ —— **Answer**

From Table 7.1, the density of gold is $19.3 \times 10^3$ kg/m$^3$. Because $8.0 \times 10^3$ kg/m$^3$ is quite less than $19.3 \times 10^3$ kg/m$^3$, the crown cannot be pure gold.

**Assignment 7.4 DENSITY OF ROCK**

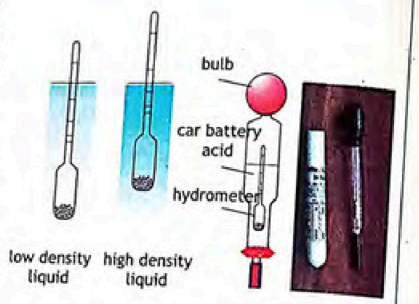
A geologist finds that a Moon rock whose weight is 90.9 N has an apparent weight of 60.6 N when submerged in water. What is the density of the rock?

**ACTIVITY WATER AND OIL**

Pour some water into a clear glass. Then pour in some cooking oil. Which liquid is less dense?

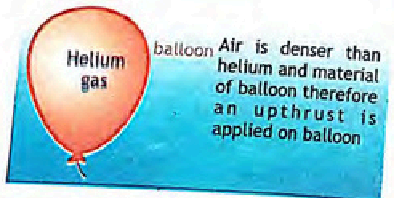
## APPLICATION HYDROMETER

A hydrometer is an instrument that measures the --the ratio of the density of the liquid to the density of water. This is a glass tube with a scale on the side weighted at the bottom with lead shot. The hydrometer floats in the liquid and if the liquid is dense the hydrometer does not need to sink very low to displace its own weight of liquid. If the liquid has a lower density it will sink much deeper.




Hydrometers are calibrated for different uses, such as a lactometer for measuring the density (creaminess) of milk, a saccharometer for measuring the density of sugar in a liquid, or an alcoholometer for measuring higher levels of alcohol in spirits.

A balloon, filled with helium (a gas lighter than air) will be pushed upwards by the denser air when it is released. This is because upthrust is greater than the total downward weight of the helium and the material of the balloon.




### POINT TO PONDER

Fluids of different densities float on top of each other.

A steel ball floats in mercury because the density of mercury is greater than that of steel.





## 7.9 ELASTICITY

In everyday conversation if someone speaks to you about an elastic body, you probably immediately think of a rubber band. A rubber band yields a great deal to a distorting force, and yet it returns to its original length after the distorting force is removed

The property of solid materials to return to their original shape and size after removal of deforming force is called elasticity.

When an archer shoots an arrow, he bends the bow which springs back to its original form after the arrow is released. When a tennis racket hits a tennis ball, the shape of the ball is distorted or deformed, but it regains its original shape when it bounces off the tennis racket.

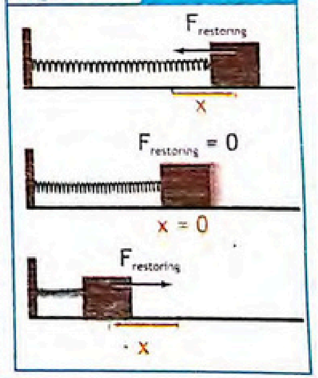
Not all materials return to their original shapes when a deforming force acting on it is removed. Materials that do not return to their original shapes after being distorted are said to be inelastic. Examples of inelastic materials are plasticine, clay and dough.

Most materials are elastic up to a certain limit known as the elastic limit. Beyond the elastic limit a material will not return to its original dimensions break or permanently deforms when the deforming force is removed.

Figure 7.8

A tennis ball is flattened by the contact force exerted on it by the strings of the tennis racket. Likewise, the strings of the racquet are deformed by the contact force exerted by the ball. The two forces are interaction partners.

Figure 7.9




### 7.9.1 HOOKE'S LAW

When a spring is stretched or compressed, the extension or compression is directly proportional to the applied force (Figure 7.9). This relationship is known as Hooke's law which states that **within elastic limits the extension (or** compression) x is directly proportional to the restoring force $F_{res}$, i.e.

$$F_{res} \propto -x$$

$$\text{or} \quad F_{res} = -kx \quad \text{—— 7.6}$$

where k is known as the force constant having units $N\,m^{-1}$. The negative sign shows that force is directed against displacement. This relationship is also true for a wire under tension.

## 7.10 STRESS, STRAIN AND YOUNG'S MODULUS

A wire under tension will extend. Its extension depends on a number of factors such as the tension, its diameter and length and the material of the wire.

Suppose that a wire of length l and cross-sectional area 'A' is stretched by a force F and the extension produced is x as shown in figure 7.10.

**Stress:**

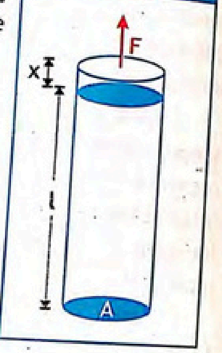
The stress applied to the wire is defined as the force applied per unit area of cross-section to produce deformation. Mathematically

$$\text{stress} = \frac{\text{Force}}{\text{Area of crossection}}$$

$$\text{or} \quad \text{stress} = \frac{F}{A} \quad \text{—— 7.7}$$

The unit for stress is $Nm^{-2}$ or pascal.

Figure 7.10




**Strain:**

As a result of the wire being stretched, it is under strain. The strain is defined as the extension per unit length. Mathematically

$$\text{strain} = \frac{\text{extension}}{\text{Original Length}}$$

$$\text{or} \quad \text{strain} = \frac{x}{l} \quad \text{—— 7.8}$$

Since strain is the ratio of two lengths, it does not have a unit.

**Young's Modulus:**

The strain produced in a stretched wire is proportional to the stress within

**LAB WORK**

To find the density of a liquid using 5 ml syringe (instead of dimity bottle).







the limit of proportionality. Within this limit, the ratio is a constant whose value depends on the material of the wire, and is known as the Young's modulus of the material. Mathematically

$$\text{Stress} \propto \text{Strain}$$

$$\text{or} \quad \text{Stress} = \text{Constant} \times \text{Strain}$$

Constant of proportionality is called Young's modulus is denoted by Y

$$\text{Stress} = \text{Young's Modulus} \times \text{Strain}$$

rearranging the above equation, we get

$$\text{Young's Modulus} = \frac{\text{Stress}}{\text{Strain}}$$

Young's modulus is denoted by Y, putting values of stress and strain, we get

$$Y = \frac{F/A}{x/l}$$

$$\text{rearranging} \quad Y = \frac{F \times l}{A \times x} \quad \text{—— 7.9}$$

Young Modulus for different materials are given in the table 7.2.

**Modulus for Selected Materials**

| Material | Young Modulus, Y, (Pa) |
|---|---|
| Aluminum | $7.0 \times 10^{10}$ |
| Brass | $9.0 \times 10^{10}$ |
| Copper | $11 \times 10^{10}$ |
| Crown glass | $6.0 \times 10^{10}$ |
| Iron | $21 \times 10^{10}$ |
| Lead | $1.6 \times 10^{10}$ |
| Nickel | $21 \times 10^{10}$ |
| Steel | $20 \times 10^{10}$ |

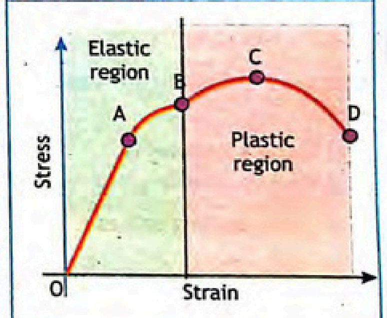
**Stress strain curves:**

Stress and strain curves are measured by stress tester.,

The applied stress is increased and the change in length is noted. The values are then printed on graph. A typical graph for metal is shown in the figure 7.11.

Here, Point, A, is the limit of proportionality, the limit up to which Hooke'

Figure 7.11 Stress strain curve




**LAB WORK**

To study the relation between load and extension (helical spring) by drawing graph.

law is obeyed called **proportional limit**. Point, B, is the **elastic limit**, the limit up to which material shows elastic behavior, point C is the maximum stress wire can with stand without breaking and point D, is the **breaking point**, where material breaks.

**Example 7.5 YOUNG'S MODULUS**

A wire of length 5.0 m and area of 0.03 $m^2$ is stretched 0.15 m within elastic limit, by hanging weight of 270 N. Calculate stress, strain and Young's modulus of material of wire.

**SOLUTION**

**GIVEN:**

length $l = 5.0\,m$

area $A = 0.03\,m^2$

extension $x = 0.15\,m$

weight = force $F = 270\,N$

**REQUIRED:**

stress = ?

strain = ?

Young's modulus Y = ?

a) By definition of stress $\quad stress = \frac{F}{A}$

putting values $\quad stress = \frac{270N}{0.03m^2}$

$stress = 9\times10^3\,Nm^{-2}$ — **Answer**

b) By definition of strain $\quad strain = \frac{x}{l}$

putting values $\quad strain = \frac{0.15m}{5.0m}$

$strain = 0.03$ — **Answer**

c) Young's Modulus is $\quad Young's\,Modulus = \frac{Stress}{Strain}$

putting values $\quad Y = \frac{9.0\times10^3 Nm^{-2}}{0.03}$

therefore $\quad Y = 3.0\times10^5 Nm^{-2}$ — **Answer**

**Assignment 7.5 WIRE STRETCHED**

An elastic wire of length 2 m and cross sectional area 0.02 $m^2$ is stretched 0.10 m by a 300 N weight. Calculate the Young modulus of the material.







**KEY POINTS**

**Density:** Mass per unit volume

**Pressure:** Force applied per unit area

**Barometer:** Device used to measure atmospheric pressure

**Pascal's Principle:** if the pressure at one point of a confined fluid is increased by an amount, the pressure increases by the same amount at all other parts throughout the fluid.

**Archimedes' principle:** A body when completely or partially immersed in a fluid will experience an upthrust equal to the weight of the fluid displaced by the body. This upthrust will bring about an apparent loss of weight of the body.

**Elasticity:** The property of a body which enables the body to regain its original dimension when the deforming force acting on the body is removed.

**Hooke's law:** Within elastic limits the extension (or compression) is directly proportional to the force applied.

**Stress:** The force applied per unit area of cross-section to produce deformation.

**Strain:** the extension per unit length.

**Young's Modulus:** The ratio of stress to strain.

**PROJECTS**

**GROUP - A**

**TYRE PRESSURE:** Research air pressures in different tyre types (bicycles, motor bikes, cars and trucks). Why are the pressures different for different automobile tyres? Prepare a presentation to be presented in physics class.

**GROUP - B**

**SUBMARINES:** Prepare a chart on submarine technology, what is the science of their sinking and raising up.

**GROUP - C**

**WEATHER IN PAKISTAN:** What is the organization that monitors and predicts weather in Pakistan, write a research article for the school library.

**GROUP - D**

**PRESSURIZED CABINS:** Write an article for school magazine on why submarine and aircraft cabins are pressurized at certain level. What would happen if the cabins are not maintained at constant pressure.

**GROUP - E**

**DENSITIES:** Find a spring balance and use Archimedes Principle to determine the densities of few objects. Compare the calculated density results with the table and comment on their composition. Deliver presentation to the class for your findings.

# EXERCISE

MULTIPLE CHOICE QUESTIONS

Choose the best possible answer:

1. A container having volume of 6 $m^3$ is full with a liquid, having density of 30 kg $m^{-3}$. The mass of the liquid is
   A. 180 kg B. 24 kg C. 5 kg D. 0.2 kg
2. Liquids and gases and collectively categorized as
   A. Liquids B. Pascals C. Fluids D. None
3. Which of the following cannot be used to measure pressure
   A. Atm B. Pa C. bar D. kg $m^{-3}$
4. Pressure at depth in fluid
   A. increases B. decreases C. none D. stays the same
5. The unit used for pressure in weather maps is
   A. Atm B. Pa C. bar D. N $m^{-2}$
6. A rock weighs 25.7 N in air and 21.8 N in water. What is the buoyant force of the water
   A. 4.1 N B. 3.9 N C. 1.18 N D. 0.84 N
7. Which of the following objects, submerged in water, experiences the largest magnitude of the buoyant force?
   A. 1-kg helium balloon; B. 1 kg of wood;
   C. 1 kg of iron; D all the same.
8. The unit of strain is
   A. kg $m^{-3}$ B. Pa C. N $m^{-2}$ D. none
9. Young modulus is measured in units of
   A. kg $m^{-3}$ B. Pa C. N D. none





## CONCEPTUAL QUESTIONS

Give a brief response to the following questions.

1. If you climbed a mountain carrying a mercury barometer, would the level of the mercury column in the glass tube of the barometer increase or decrease as you climb the mountain? Explain.
2. Walnuts can be broken in the hand by squeezing two together but not one. Why?
3. Why is the cutting edge of the knife made very thin?
4. Why water tanks are constructed at the highest level in our houses?
5. Why a small needle sinks in water and huge ships travel easily in water without sinking?
6. Explain how and why camels have adapted to allow them to walk more easily in desert conditions?
7. You would have probably experienced your ears 'popping' while driving in the mountains. Why ears 'pop'?
8. If you filled an airtight balloon at the top of a mountain, would the balloon expand or contract as you descend the mountain? Explain.
9. A rowboat is floating in a swimming pool when the anchor is dropped over the side. When the anchor is dropped, will the water level in the swimming pool increase, decrease, or remain the same? Explain.
10. Which material is more elastic, steel or rubber and why?

## COMPREHENSIVE QUESTIONS

Give an extended response to the following questions.

1. Using kinetic molecular model of matter, explain three states of matter.
2. Define and explain density and pressure.
3. What is atmospheric pressure? How is it measured by using a mercury barometer? Also describe how weather changes with atmospheric pressure?
4. State Pascal's principle and explain with example?
5. How pressure varies with depth in liquids? Explain.
6. What is meant by buoyant force or upthrust in fluids?