SLO 7: Pressure

7.1 Density

7.1.1 Define The Term 'Density'

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

$$density = \frac{mass}{volume}$$

Its S.I units are kg/m^3 or g/cm^3

7.1.2 Compare The Densities Of Three States Of Matter (Solids, Liquids And Gases)

STATE	PARTICLE ARRANGEMENT	DENSITY	WHY
Solids	Tightly packed	Highest	Particles are closely packed, so more mass in less space
Liquids	Loosely packed (slide freely)	Moderate	Particles are less tightly packed than solids
Gases	Very loosely packed	Lowest	Particles are far apart, so very low mass in a given volume

7.1.3 Solve Word Problems Using The Relation Of Density

Practice questions available on worksheet.

7.2 Pressure

7.2.1 Define The Term 'Pressure'

Pressure is defined as the force exerted normally on unit area of an object.

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

Its S.I unit is Pascal (Pa). If a force of 1 Newton acts on a surface of area 1 square metre, the pressure on surface will be 1 Pascal. $1Pa = Nm^{-2}$

7.2.2 Pressure Varies With Force And Area With The Help Of Real-Life Examples

- The edge of the blade of a chopper is made very sharp. When we apply force on the handle of the chopper to cut an object, the pressure on the object, at the contact surface, due to its small area becomes very high and the object is easily cut.
- The top of a thumb pin is flat but the end of the pin is very sharp. So, the contact area is very small. When we apply force at the top, the pressure at the end of pin is so high that it pierces into the wooden board.
- When we walk on ground, we exert a force on it due to which we experience a reaction force. When the ground is flat, this reaction force is spread over the whole area of the foot and the pressure due to reaction force is not painful. But when we walk on pebbles, the contact area is reduced. Then the pressure due to reaction force becomes so high that it becomes painful.
- Heavy animals like elephant have thick legs and large flat feet so that due to large contact area, pressure becomes less otherwise, their bones would not tolerate the pressure.

7.3 Atmospheric Pressure

7.3.1 Explain Atmospheric Pressure

The Earth is surrounded by a layer of air which we call atmosphere. Air is a mixture of gases. Their molecules are always in motion. They collide with one another and with all other objects coming in their way. Thus, they exert force on the objects. Thin, force per unit area is the atmospheric pressure. Since the molecules of air have random motion, therefore, atmospheric pressure acts equally in all directions.

The atmosphere exerts pressure on the surface of the Earth and on everything on the Earth. This pressure is called atmospheric pressure.

Atmospheric pressure extends up to a height of about 100 kilometres. The density of air is not the same in the atmosphere. It decreases continuously with altitude.

The pressure of 1 atmosphere is equivalent to placing a 1.0 kg mass (10 N weight) on an area of 1 cm^2.

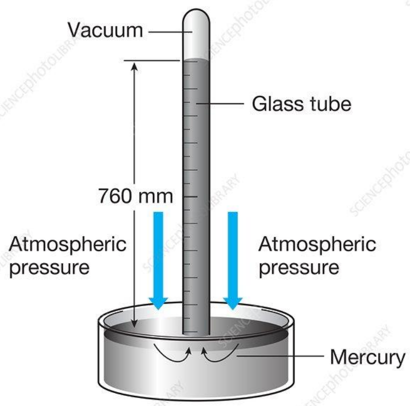
We live at the bottom of the Earth's atmosphere which is a fluid that exerts pressure on our bodies.

At sea level, the value of atmospheric pressure is about 1.013×10^5 Pa. This value is referred to as standard atmospheric pressure.

It is an enormous pressure which can crush anything. We do not feel it because practically all the bodies have air inside them. As atmospheric pressure acts in all directions, so it balances the pressure inside.

7.3.2 Describe The Use Of The Height Of A Liquid Column To Measure The Atmospheric Pressure (Barometer)

Atmospheric pressure is usually measured by the height of mercury column which it can support. Instruments which measure the atmospheric pressure are called barometers. A simple mercury barometer consists of a glass tube about one metre long that is closed at one end. It is completely filled with mercury, then it is inverted vertically in a dish of mercury. A metre scale is placed by the side of the tube to measure the height of mercury column. The space in glass tube over the top of the mercury is completely empty. The pressure is almost zero.



The pressure P, at point A in the mercury column is the same as at point B at the surface of mercury in the dish because both the points are at the same level. This is equal to the atmospheric pressure $P = \rho g h$ acting at the surface of mercury in the dish.

If we put P = 1.013×10^5 Pa at sea level, $\rho = 13.6 \times 10^3\ kgm^{-3}$ for mercury, the height of mercury column comes out to be 760 mm. By using this instrument, atmospheric pressure at any altitude in the air can be measured in terms of height of mercury column.

7.3.3 Describe That Atmospheric Pressure Decreases With The Increase In Height Above The Earth's Surface

Pressure in a liquid increases with depth. At depth h, the pressure of liquid is given by $P = \rho g h$

This formula is applicable to all the fluids. As the gases of the atmosphere are also fluid, therefore, the atmospheric pressure should be maximum on the ground at sea level. As we go up in the air, atmospheric pressure decreases. At a height of about 5 km, it falls to 55 kPa and at a height of 30 km, it falls to 1 kPa. By measuring the atmospheric pressure at a point in air, altitude of that point can be determined. The lower the atmospheric pressure, the greater is the altitude.

7.3.4 Explain That Changes In Atmospheric Pressure In A Region May Indicate A Change In The Weather

The atmospheric pressure does not always remain uniform but fluctuates. By observing the variation, the meteorologists can forecast the weather conditions.

Atmospheric pressure depends upon the density of air. At high altitudes, where the air is less dense, the atmospheric pressure falls down. Similarly, increase in the quantity of water vapours also decreases the density. Thus, atmospheric pressure becomes low in cloudy regions. Weather casters use this knowledge to predict rains. A fall in pressure often means that rain clouds are on the way and the rain is to follow.

7.4 Pressure in Liquids

7.4.1 State Pascal's Law

When pressure is applied at one point in an enclosed fluid, it is transmitted equally to all parts of the fluid without loss.

7.4.2 Discuss The Use Of Pascal's Law

Hydraulic Press

Consider a specially designed container as shown in figure. In this container there are two cylinders joined by means of a pipe. The cross-sectional area of the smaller cylinder is A_1 and that of the larger one is A_2. The cylinders are filled with some incompressible liquid.

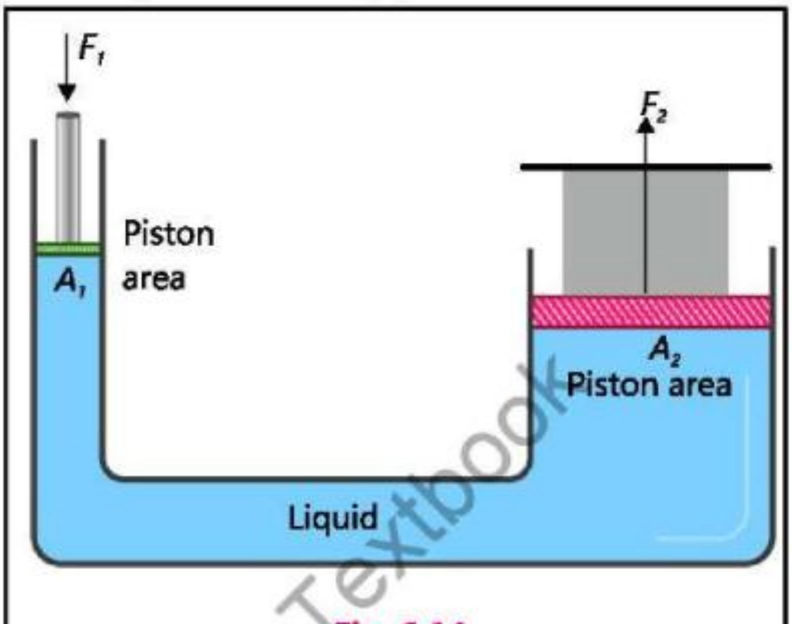


Fig. 6.14

Suppose that the small piston is pressed down by applying a force F_1. The pressure

$$P_1 = \frac{F_1}{A_1}$$

produced by small piston is transmitted equally to the large piston. Due to this pressure P_1, a force F_2 will act on A_2 which is given by $F_2 = P_1 A_1$

Putting the values $F_2 = \frac{F_1}{A_1} A_2$

Since $A_2 > A_1$ therefore, $F_2 > F_1$. The result indicates that a small force applied on the smaller piston, results into a large force on the larger piston. Such a system is known as force multiplier.

A hydraulic press works on this principle. Cotton bale or any other object to be compressed is placed over the larger piston. A force F_1 is applied on the smaller piston. The pressure P_1 produced by smaller piston is transmitted equally to the larger piston, A much greater force F_2 acts on it. This force lifts the larger piston and compresses the cotton bale. This principle is also used at service stations to lift cars for washing.

Hydraulic Brakes

The brakes of some vehicles work on Pascal's law. In such type of brakes, cylinders with pistons are attached to the wheels. The brake pedal is attached to a master cylinder having smaller area of cross-section. Master cylinder is connected to all the larger cylinders attached to the wheel through pipes as shown in figure.

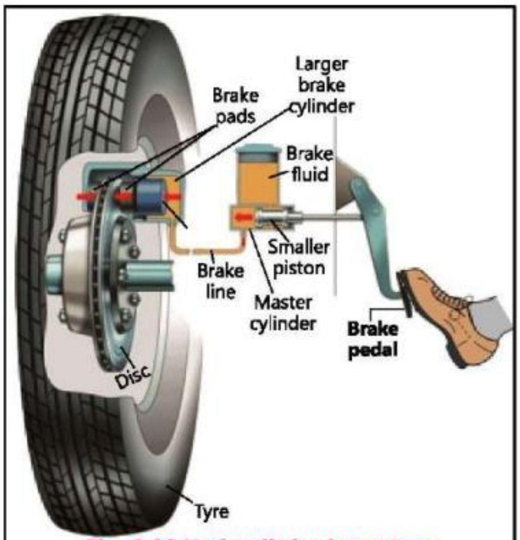


Fig. 6.16 Hydraulic brake system

Oil is filled in this system. When pedal is pushed down, the piston applies pressure on the liquid in the master cylinder. The liquid pressure is transmitted equally to all the larger pistons of other cylinders. This pressure causes these pistons to move outward pressing the brake pads towards brake discs or brake drums. Force of friction between the pads and discs or drums slows down the vehicle. When pressure is released from the pedal, the springs pull back the brake pads and wheels again turn freely.

7.4.3 Pressure Beneath A Liquid Surface Increase With Depth And Depends On The Density Of The Liquid

Liquids exert pressure in all directions. Moreover, liquid pressure increases with depth. Let us consider a container of some liquid. Consider an area A in the liquid at depth h. The force acting on this area is equal to the weight of the liquid column over surface A.

The volume of this liquid is $V = Ah$

If ρ is the density of liquid, then $\rho = \frac{m}{V}$

mass m of the liquid column will be:

$$m = \rho V = \rho A h$$

Therefore, force acting on area A will be

$$F = mg = (\rho A h)g$$

The pressure P at area A will be

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

$$P = \frac{\rho Ahg}{A}$$

$$P = pgh$$

This equation shows that pressure in a liquid increases with depth. The value of pressure depends on the depth and density of the liquid.

Pressure produces force at right angle to the surface. A force or its component that is parallel to the surface, does not contribute to pressure. The pressure, by definition, is only contributed by the normal component of the force. That is, the forces in a liquid that push directly against the surface and add up to a net force is perpendicular to the surface. If there is a hole in the surface of the liquid container, the liquid spurts at right angle to the surface before curving downward due to gravity

7.4.4 Solve Word Problems Related To The Relationship Between Pressure, Depth And Liquid Density

Practice questions available on worksheet.

7.4.5 Discuss The Working And Applications Of Liquid Manometer

A simple manometer consists of a U-shaped glass tube which contains mercury. In the beginning, the atmospheric pressure at the two open ends of the tube is the same and hence, mercury level in the two arms remains same. If on connecting a gas cylinder with short arm keeping the longer arm of the tube open, the mercury level in short arm is lower than that in the long arm, then the unknown pressure is more than the atmospheric pressure. If the mercury level in the short arm is more than the long arm, then the unknown pressure is less than the atmospheric pressure.

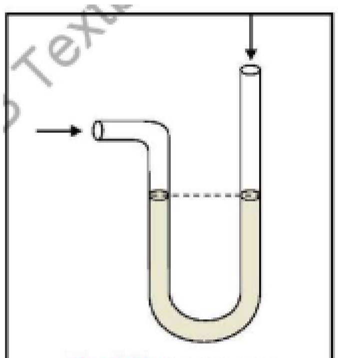


Fig. 6.10 manometer