UNIT 3 FLUIDS

Warm greetings:

Dear students,

Welcome all. In this section of Science I class you get to learn about laws of floatation. In this class we are going to discuss the following topics.

- Hydraulic pressure
- Pascal's law
- Archimedes principle
- Laws of floatation

Gauge pressure and absolute pressure:

Our daily activities are happening in the atmospheric pressure. We are so used to it that we do not even realise. When tyre pressure and blood pressure are measured using instruments (gauges) they show the pressure over the atmospheric pressure.

Hence, absolute pressure is zero-referenced against a perfect vacuum and gauge pressure is zero referenced against atmospheric pressure.

For pressures higher than atmospheric pressure,

absolute pressure = atmospheric pressure +gauge pressure

For pressures lower than atmospheric pressure,

absolute pressure = atmospheric pressure – gauge pressure

We have seen that liquid column exerts pressure. So the pressure inside the sea will be more. This is more than twice the atmospheric pressure. Parts of our body, especially blood vessels and soft tissues cannot withstand such high pressure. Hence, scuba divers always wear special suits and equipment to protect them (Fig. 3.7).

Figure 3.7 Scuba divers with special protecting equipment

Pascal's Law:

- ❖ Pascal's principle is named after Blaise Pascal (1623-1662), a French mathematician and physicist.
- ❖ The law states that the external pressure applied on an incompressible liquid is transmitted uniformly throughout the liquid.
- ❖ Pascal's law can be demonstrated with the help of a glass vessel having holes all over its surface. 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 (Fig. 3.8).
- ❖ This principle is applied in various machines used in our daily life.

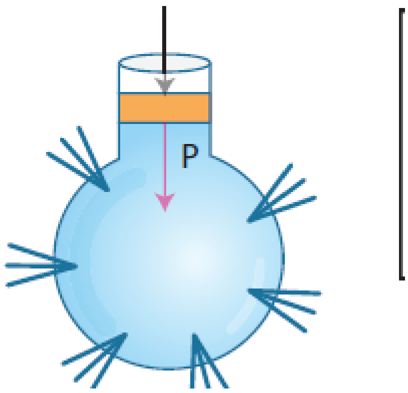

Figure 3.8 Demonstration

Hydraulic press:

Pascal's law became the basis for one of the important machines ever developed, the hydraulic press. It consists of two cylinders of different cross-sectional areas as shown in Figure 3.9. They are fitted with pistons of cross-sectional areas “a” and 'A'. The object to be lifted 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 large piston and a force F_2 acts on A which is much larger than F_1. Pressure on piston of small area 'a' is given by,

$P = F_1 / A_1$ ------------------------(1)

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

Therefore, $P = F_2 / A_2$ -----------------------(2)

Comparing equations (1) and (2),we get

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

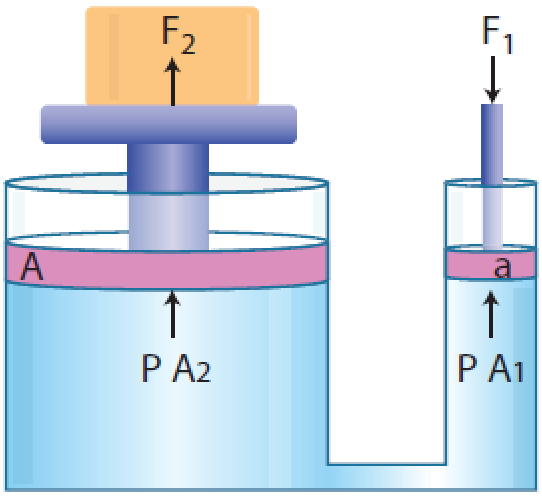

Figure 3.9 Hydraulic press

Since, the ratio A_2 / A_1 is greater than 1, the force F_2 that acts on the larger piston is greater than the force F1 acting on the smaller piston. Hydraulic systems working in this way are known as *force multipliers*.

Density:

- To understand density better, let us assume that the mass of the flask be 80 g. So, the mass of the flask filled with water is 330 g and the mass of flask filled with kerosene is 280 g.
- Mass of water only is 250 g and kerosene only is 200 g. Mass per unit volume of water is 250/250 cm^3. This is 1g/cm^3.
- Mass per unit volume of kerosene is 200 g/250 cm^3. This is 0.8 g/cm^3. The result 1 g/cm^3 and 0.8 gcm^3 are the densities of water and kerosene respectively.
- *Therefore, the density of a substance is the mass per unit volume of a given substance.*

- The SI unit of density is kilogram per meter cubic (kg/m^3) also gram per centimeter cubic (g/cm^3).
- The symbol for density is rho (ρ).

Relative Density

We can compare the densities of two substances by finding their masses. But, generally density of a substance is compared with the density of water at 4 °C because density of water at that temperature is $1g/cm^3$. Density of any other substance with respect to the density of water at 4 °C is called the relative density. Thus relative density of a substance is defined as ratio of density of the substance to density of water at 4 °C.

Mathematically, relative density (R.D),

$$= \frac{\text{Density of the substance}}{\text{Density of water at 4 °C}}$$

$$\text{We know that, Density} = \frac{\text{Mass}}{\text{Volume}}$$

$\therefore$ Relative density

$$= \frac{\text{Mass of the substance/Volume of the substance}}{\text{Mass of water/Volume of water}}$$

Since the volume of the substance is equal to the volume of water,

Relative density

$$= \frac{\text{Mass of certain volume of substance}}{\text{Mass of equal volume of water (at 4°C)}}$$

Thus, the ratio of the mass of a given volume of a substance to the mass of an equal volume of water at 4°C also denotes relative density.

Measurement of relative density:

Relative density can be measured using Pycnometer also called density bottle. It consists of ground glass stopper with a fine hole through it. The function of the hole in a stopper is that, when the bottle is filled and the stopper is inserted, the excess liquid rises through the hole and runs down outside the bottle. By this way the bottle will always contain the same volume of whatever the liquid is filled in, provided the temperature remains constant. Thus, the density of a given volume of a substance to the density of equal volume of referenced substance is called relative density or specific gravity of the given substance. If the referenced substance is water then the term specific gravity is used.

Floating and sinking:

Whether an object will sink or float in a liquid is determined by the density of the object compared to the density of the liquid. If the density of a substance is less than the density of the liquid it will float. For example a piece of wood which is less dense than water will float on it. Any substance having more density than water (for example, a stone), will sink into it.

Application of principle of flotation:

Hydrometer:

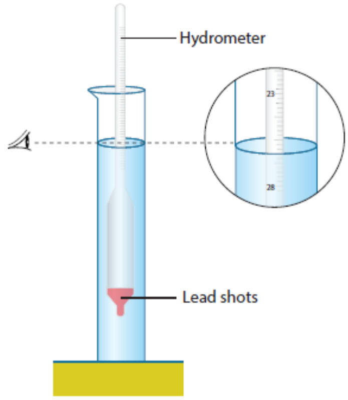

Figure 3.10 Hydrometer

- A direct-reading instrument used for measuring the density or relative density of the liquid is called hydrometer.
- Hydrometer is based on the principle of flotation, i.e., the weight of the liquid displaced by the immersed portion of the hydrometer is equal to the weight of the hydrometer.
- Hydrometer consists of a cylindrical stem having a spherical bulb at its lower end and a narrow tube at its upper end.
- The lower spherical bulb is partially filled with lead shots or mercury. This helps hydrometer to float or stand vertically in liquids.
- The narrow tube has markings so that relative density of a liquid can be read directly. The liquid to be tested is poured into the glass jar.
- The hydrometer is gently lowered in to the liquid until it floats freely.
- The reading against the level of liquid touching the tube gives the relative density of the liquid.
- Hydrometers may be calibrated for different uses such as lactometers for measuring the density (creaminess) of milk, saccharometer for measuring the density of sugar in a liquid and alcoholometer for measuring higher levels of alcohol in spirits.

Lactometer:

- ✓ One form of hydrometer is a lactometer, an instrument used to check the purity of milk.
- ✓ The lactometer works on the principle of gravity of milk.
- ✓ The lactometer consists of a long graduated test tube with a cylindrical bulb with the graduation ranging from 15 at the top to 45 at the bottom.
- ✓ The test tube is filled with air. This air chamber causes the instrument to float.
- ✓ The spherical bulb is filled with mercury to cause the lactometer to sink up to the proper level and to float in an upright position in the milk. Inside the lactometer there may be a thermometer extending from the bulb up into the upper part of the test tube where the scale is located.
- ✓ The correct lactometer reading is obtained only at the temperature of 60 °F. A lactometer measures the cream content of milk. More the cream, lower the lactometer floats in the milk.
- ✓ The average reading of normal milk is 32.
- ✓ Lactometers are used at milk processing units and dairies.

Buoyancy:

- ❖ We already saw that a body experiences an upward force due to the fluid surrounding, when it is partially or fully immersed in to it.
- ❖ We also know that pressure is more at the bottom and less at the top of the liquid. This pressure difference causes a force on the object and pushes it upward. This force is called buoyant force and the phenomenon is called buoyancy (Fig.3.11).
- ❖ Most buoyant objects are those with a relatively high volume and low density. If the object weighs less than the amount of water it has displaced (density is less), buoyant force will be more and it will float (such object is known as positively buoyant).
- ❖ But, if the object weighs more than the amount of water it has displaced (density is more), buoyant force is less and the object will sink (such object is known as negatively buoyant).

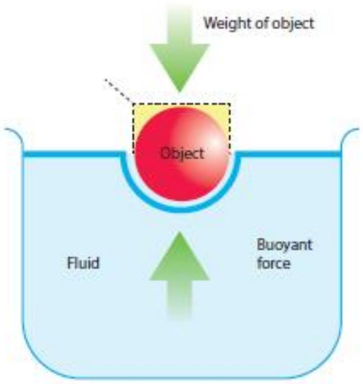

Figure 3.11 Buoyant force

Cartesian diver:

Cartesian diver is an experiment that demonstrates the principle of buoyancy. It is a pen cap with clay. The Cartesian diver contains just enough liquid that it barely floats in a bath of the liquid; its remaining volume is filled with air. When pressing the bath, the additional water enters the diver, thus increasing the average density of the diver, and thus it sinks.

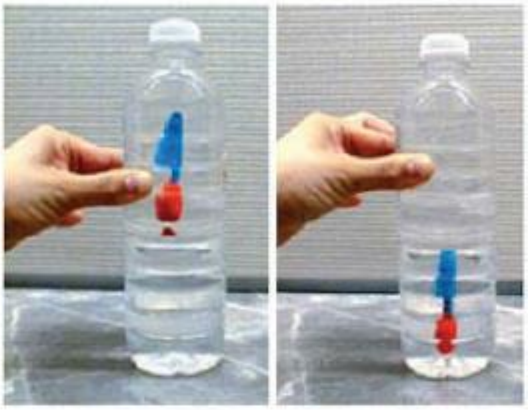
Figure 3.12 Cartesian diver

Archimedes' Principle

- Archimedes principle is the consequence of Pascal's law.
- According to legend, Archimedes devised the principle of the 'hydrostatic balance' after he noticed his own apparent loss in weight while sitting in his bath.
- The story goes that he was so enthused with his discovery that he jumped out of his bath and ran through the town, shouting 'eureka'.
- Archimedes principle states that 'a body immersed in a fluid experiences a vertical upward buoyant force equal to the weight of the fluid it displaces'.
- When a body is partially or completely immersed in a fluid at rest, it experiences an upthrust which is equal to the weight of the fluid displaced by it.

➢ Due to the upthrust acting on the body, it apparently loses a part of its weight and the apparent loss of weight is equal to the upthrust.

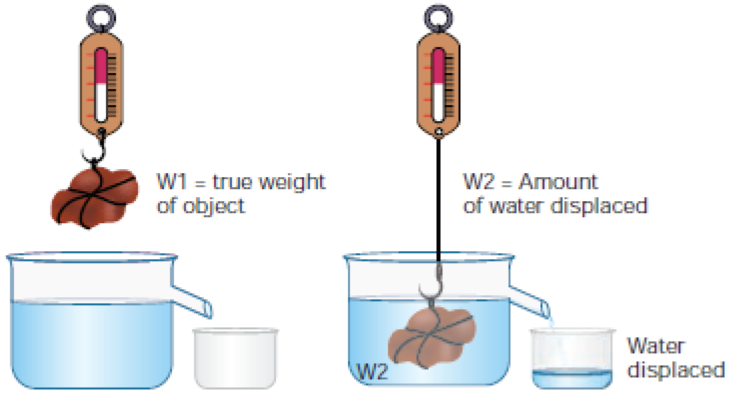

Figure 3.13 Upthrust is equal to the weight of the fluid displaced

Thus, for a body either partially or completely immersed in a fluid,

Upthrust = Weight of the fluid displaced = Apparent loss of weight of the body.

Apparent weight of an object = True weight of an object in air – Upthrust (weight of water displaced)

Laws of flotation:

Laws of flotation are:

1. The weight of a floating body in a fluid is equal to the weight of the fluid displaced by the body.

2. The centre of gravity of the floating body and the centre of buoyancy are in the same vertical line.

The point through which the force of buoyancy is supposed to act is known as centre of buoyancy. It is shown in Figure 3.14.

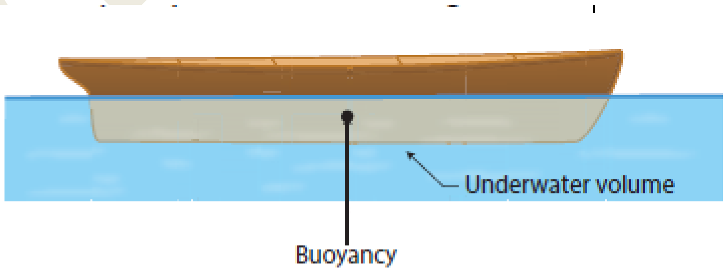

Figure 3.14 Centre of buoyancy

@@@@@@@@@