Gravitation - Lesson 22
Density

The previous experiment leads us to an important fact, density. We can compare the density of different objects using a fluid. Density is, basically, a parameter that tells the object's mass per unit volume, which has units of kg/m^2.

$$D = \frac{M}{V}$$

For example, the same amount of sugar and salt weighs differently. Why? Because their density is different. If we mix two immiscible fluids, we can tell which fluid has less density, the one with the less density will always be on top. Take the case of water and oil. Whenever we try to mix water and oil, the oil always remains on top, no matter what, as its density is less than that of water, hence the buoyant force experienced by oil is greater than its weight, and therefore it floats on water. Here, we can introduce a new comparative parameter called relative density, which will tell you if the substance is denser than water or not.

$$\text{Relative density} = \frac{\text{Density of the Substance}}{\text{Density of water}}$$

It has no units, as it is a comparative parameter. $\frac{Density}{Density}$ will have no units.

Let us look at a few examples:

1. **Example 1:** Density of mercury is 13.6 $g\ mL^{-1}$. Calculate the relative density of mercury?

   Answer
   Density of mercury = 13.6 $g\ mL^{-1}$ = 13.6 $kg\ L^{-1}$
   Density of water = 1 $kg\ L^{-1}$

$$\begin{aligned}\text{Relative Density} &= \frac{\text{Density of mercury}}{\text{Density of water}} \\ &= \frac{13.6\ kg\ L^{-1}}{1\ kg\ L^{-1}} \\ &= 13.6\end{aligned}$$

2. **NCERT Example:** Relative density of silver is 10.8. The density of water is $10^3\ kg\ m^{-3}$. What is the density of silver in SI unit?

   Answer
   Relative density of silver = 10.8

   We know that,

$$\begin{aligned}\text{Relative Density} &= \frac{\text{Density of silver}}{\text{Density of water}} \\ \text{Density of silver} &= \text{Relative Density} \times \text{Density of water} \\ &= 10.8 \times 10^3\ kg\ m^{-3}\end{aligned}$$

You should, now, be able to answer the following questions:

1. What is the SI unit of density?
2. Define relative density?
3. What should be the value of the relative density such that the object floats on water?

Conclusion

The density of an object is its mass per unit volume, and the relative density of an object is its original density with respect to the density of water.

Note to Teacher

The aim of the text is to contniue the Archimedes' principle to density. The text intents to state that a single parameter called density is enough to determine if an object will float or sink. The text also introduces relative density which is useful to tell if an object will float on water.

Student Worksheet

1. Buoyant force depends on the:
    (a) Density of the object
    (b) Density of the fluid
    (c) Density of both
    (d) None of the above
2. An iron nail sinks in water because _____.
3. A hollow plastic ball floats on water because _____.
4. What can be done to the water so that the iron nail does not sink (Altering the nail is not allowed)?
5. A 10 *kg* object when immersed in water displaces 7 *L* of water. How much upward force is experienced by the object? (1 *L* = 1 *kg*)
6. Calculate the relative density of mercury? (Density of mercury = 13.6 $g\ mL^{-1}$)

Answers

1. $kg\ m^{-3}$
2. $$\text{Relative density} = \frac{\text{Density of the Substance}}{\text{Density of water}}$$
3. ≤ 1

Student Worksheet Answers

1. (b) Density of the fluid
2. Density of iron $\geq$ Density of water
3. Density of the hollow plastic ball $\leq$ Density of water
4. Increase the density of water by mixing sugar or salt of any kind
5. Upward force experinced is equal to the weight f the water displaced, which is given by,

$$\begin{aligned} Volume \times Density &= 7 \times 1 = 1\ kg \\ Weight &= 7 \times 9.8 = 68.6\ N \end{aligned}$$

6. $$\begin{aligned} 1\ mL &= 1\ cm^{-3} \\ \implies 13.6\ g\ mL^{-1} &= 13.6\ g\ cm^{-3} \\ \text{Density of water} &= 1\ g\ cm^{-3} \\ \text{Relative Density} &= \frac{\text{Density of the substance}}{\text{Density of water}} \\ &= \frac{13.6\ g\ cm^{-3}}{1\ g\ cm^{-3}} = 13.6 \end{aligned}$$