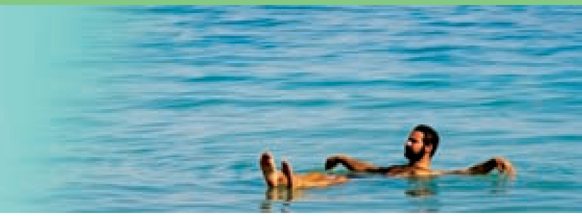
11 Density

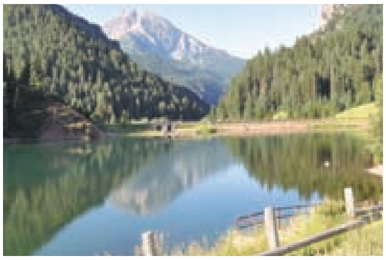


11.1 Introduction to density

In a glass of drinking water, contains a small volume of water and the mass of it is also small. In a well, there is a large volume of water and the mass of it is also large. But, when a reservoir is considered, the volume of water it contains is massive and the mass of it is also massive (figure 11.1).

(a) Glass of water

(b) Well



(c) Reservoir

Figure 11.1

Though the volume of a substance and its mass differs, there is a common relationship between those two. Let us do the activity 11.1 to reveal this.

Activity 11. 1

You will need :- Measuring cylinders of varied capacities 100 ml, 250 ml and 500 ml, a 500 ml beaker, a triple beam balance, water

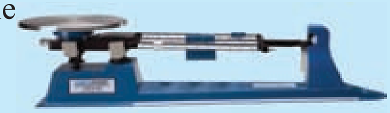


Figure 11.2 (a) - A triple beam balance

Figure 11.2 (b) - Measuring mass by a triple beam balance

Method :-

- Adjust the triple beam balance to its zero mark.
- Measure the mass of cleaned and dried 500 ml empty beaker using this balance.
- Measure 100 ml of water into the beaker using 100 ml measuring cylinder.
- Measure the mass of beaker with water.
- Measure the mass of 250 ml and 500 ml of water separately using the same beaker.
- Divide the mass of water by its volume and find the ratio in each instance above.
- Fill table 11.1 using the readings and calculations you obtained.

- What can be concluded according to the results obtained?
    * Consider that **1 ml = 1 cm^3**

The mass of empty beaker =..............

Table 11.1

Volume of water (cm^3)	Mass of beaker with water (g)	Mass of water (g)	$\frac{\text{Mass of water}}{\text{Volume}}$ (g cm^{-3})

According to the above activity, it is clear that the ratio of mass of water to its volume is constant, though the volume taken differs. This constant value is specific for water. And this value is known as the **density**.

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

Density can be explained as the ratio between mass and volume.

The density can be defined as follows.

The mass per unit volume of a substance is known as the density of that substance.

Density, mass and volume are symbolized by ρ, m and v respectively.

The formula for density is $\rho = \frac{m}{v}$

11.2 Units of density

The measurements taken in activity 11.1 above, units of density can be deduced as follows.

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

$$= \frac{\text{g}}{\text{cm}^3}$$

$$= \text{g cm}^{-3}$$

But, according to the Standard International (SI) units, mass is measured in kg and volume in m^3. Thus;

$$\text{Standard units (SI) of density} = \frac{\text{SI unit of mass}}{\text{SI unit of volume}}$$

$$= \frac{kg}{m^3}$$

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

The Standard Units (SI) of density is kg m^{-3} (kilogram per cubic meter).

Now let us do the activity 11.2 to compare the densities of several substances.

Activity 11.2

You will need :- A measuring cylinder of 250 ml, a beaker of 250 ml, enough water, coconut oil, kerosene, concentrated salt solution, a triple beam balance

Method :-

- Clean and dry the beaker of 250 ml and measure the mass of it using the triple beam balance
- Measure 250 ml of water by using the measuring cylinder of 250 ml. Then put into the beaker. Measure the mass of beaker with water.
- Remove water and measure 250 ml of concentrated salt solution. Then, put into the beaker. Measure the mass of beaker with salt solution.
- Same way, measure 250 ml of coconut oil and kerosene separately into the same beaker and measure their masses.
- Note that the beaker and the measuring cylinder should be well cleaned and dried before measuring coconut oil and kerosene.
- Tabulate your readings and work out the calculation as shown in the following table 11.2.

Mass of the empty beaker = ...

Table 11.2

Liquid/ Solution	Volume of the liquid/ Solution - V (cm^3)	Mass of the beaker with liquid/Solution (g)	Mass of liquid - m (g)	$\frac{\text{Volume (m)}}{\text{Scale (v)}}$ (g cm^{-3})

- What can be concluded according to the results obtained?

According to this activity, it can be seen that the ratio of mass to its volume is different for different substances, though their volumes are equal.

Density of various substances differ from each other. It is a specific property of the respective substance. Substances can be identified by the value of their density. This is common for solids as well as for liquids. Therefore, density is a vital physical quantity of a substance.

Let us study how to solve the problems regarding density.

Solved example 01:- Mass of $2m^3$ of water is 2000 kg. Calculate the density of water.

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

$$= \frac{2000\ \text{kg}}{2\ \text{m}^3}$$

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

Solved example 02:- The mass of a solution, which has the density of 800 kg m^{-3}, is 200 kg. What is the volume of it?

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

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

$$\text{Volume} = \frac{200\ \text{kg}}{800\ \text{kg m}^{-3}}$$

$$= \frac{1}{4}\ \text{m}^3$$

$$= \underline{\underline{0.25\ \text{m}^3}}$$

11.3 Hydrometers

If you want to find the density of a liquid, you can measure the volume and mass of it and calculate the density, as you have done in activity 11.2. But it is a time-consuming difficult process. Therefore, to measure the density of a liquid easily, an equipment known as **hydrometer** is used.

Figure 11.3 shows several types of hydrometers. Hydrometer is made of a thin glass tube, the lower part of which is blow to form a bulb. This bulb is filled with lead shots, so that a part of the tube is submerged and float vertically in the liquid.

When a hydrometer is partially immersed and floating in a liquid, the length of the immersed part depends on the density of the liquid. It sinks less in high-density liquids and more in low-density liquids. The upper tubular part of the hydrometer is calibrated in such a way that density can directly read by the depth it immerse.

Figure 11.3 - Different types of hydrometers

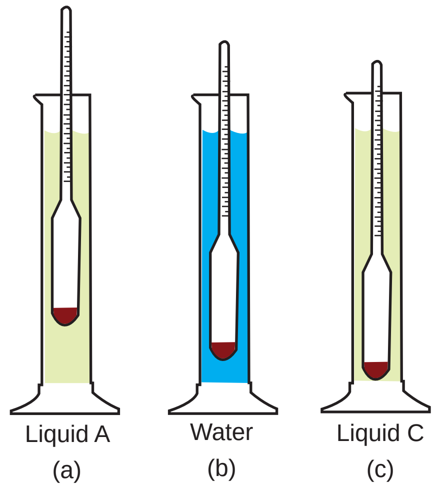
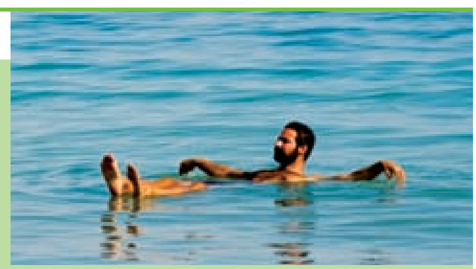


Figure 11.4

It is shown that the same hydrometer is made to float in three different liquids in figure 11.4. Figure 11.4 (b) shows how it floats in water. Immersed height of the hydrometer is less in liquid A, than in water (figure 11.4 (b)). It indicates that density of liquid A is higher than that of water. Immersed length of the hydrometer is more in liquid C than in water (figure 11.4 (c)). So, the density of liquid C is lower than that of water.

For extra knowledge

The density of the salty water of the dead sea located in between Israel and Jordan is very high. It has the ability of floating a man without sinking.



Let us do activity 11.3 by using a hydrometer to know the density of some common liquids.

Activity 11.3

You will need :- Three tall vessels, (measuring cylinders or lower part of plastic bottles), water, kerosene, coconut oil, hydrometer

Method :-

- Put water, kerosene and coconut oil in to three vessels.
- Dip hydrometer in each liquid and take down the reading of density (clean the hydrometer before you put it into each liquid).
- Compare your valves with the table 11.3.

Table 11.3

Liquid	Density ($kg\ m^{-3}$)
Mercury	13600
Glycerin	1262
Milk	1030
Sea water	1025
Water	1000
Olive oil	920
Coconut oil	900
Turpentine	870
Petrol	800
Liquor	791
Kerosene	790

A simple hydrometer can easily be made by you using a drinking straw. Engage in the activity 11.4.

Activity 11.4

You will need :- A drinking straw, a candle, several iron balls of the diameter of 3 mm, a measuring cylinder, 250 ml of coconut oil, 250 ml of concentrated salt solution and water.

Method :-

- Heat one end of the drinking straw in the candle flame to seal it.
- Add enough water into the density jar or the measuring cylinder.
- Put iron balls into the straw so that it floats vertically while 2/3 of its length is immersed in water.
- Mark the floating level on the straw, while it is in water. Now you have finished making the hydrometer.
- Add salt water into the measuring cylinder and float the hydrometer in it. Mark the level of floating on the hydrometer.
- Repeat the above step using coconut oil as the liquid.
- Decide whether the density of the liquids used is higher or lower than that of water, according to the levels of floating.

Use of hydrometers

Cow's milk contains approximately 90% of water. Other than water, it contains lipids, protein etc. Because of the contribution of the density of other constituents, density of milk is slightly higher than that of water. Amount of water in milk can be determined by measuring the density of it, using a hydrometer. This measurement can be used to decide whether water is added to milk. Hydrometers which are specially made to measure the density of milk are known as lactometers.

Hydrometers are also used to measure the percentage of alcohol in alcoholic drinks, like wine and beer. Those are known as alcoholmeters. These alcoholic drinks also contain high percentage of water. Therefore, the density of alcoholic drinks are slightly different from density of water.

The density of the acid, changes according to the changes in lead-acid batteries used in vehicles. Therefore, the condition of batteries can be examined by measuring the density with a hydrometer.

Soil hydrometer is used in determining composition of a soil sample. It can be concluded by dissolving a constant mass of soil, in a constant volume of water to calculate the density of soil solution.

Sea water contain high amount of salt dissolved in it. There is a special hydrometer called seawater hydrometer, used to measure the density of sea water. Due to high concentration of salts, the density of sea water is higher than normal fresh water.

Composition of Rubber is also measured by special hydrometer known as metrolac.

Summary

- Density of a substance is the mass per unit volume of that substance.
- $\text{Density} = \dfrac{\text{Mass}}{\text{Volume}}$
- The standard unit of density is kilogram per cubic-meters ($kg\ m^{-3}$).
- Density is a vital, physical property of a substance. It differs from substance to substance.
- Hydrometer is used to measure the density of liquid.
- Density is a criteria to determine quality of liquids and solutions.

Exercises

(01) Select the correct or most suitable answer.

1. International unit (SI) of density is,

   (1) g ml^{-1} (2) g cm^{-3} (3) kg m^{-3} (4) kg m^{-2}

2. Four different liquids have equal masses of 8000 kg each. The volumes of them are given below.

   A. Liquid - 12 m^3 B. Liquid - 10 m^3
   C. Liquid - 8 m^3 D. Liquid - 6 m^3

   The liquid that has the highest density is;

   (1) A   (2) B   (3) C   (4) D

3. Consider the following statements on the density of a liquid.

   a. Density of a liquid depends on its mass.
   b. Density of a liquid depends on its volume.
   c. Density of a liquid depends on the kind of liquid.

   The true statement/s out of those is/are,

   (1) a and b only   (2) b and c only
   (3) c only   (4) All a, b and c

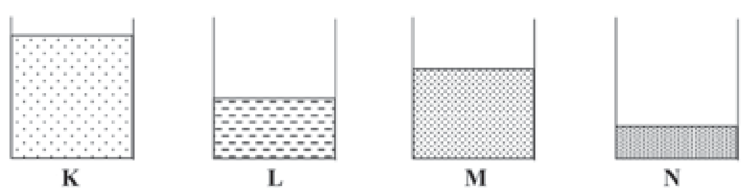
4. Four different liquids have equal volumes of 0.5 m^3 each. The masses of these liquids are given below.

   Liquid P - 400 kg   Liquid Q - 500 kg
   Liquid R - 550 kg   Liquid S - 600 kg

   The liquid that has the lowest density is,

   (1) P   (2) Q   (3) R   (4) S

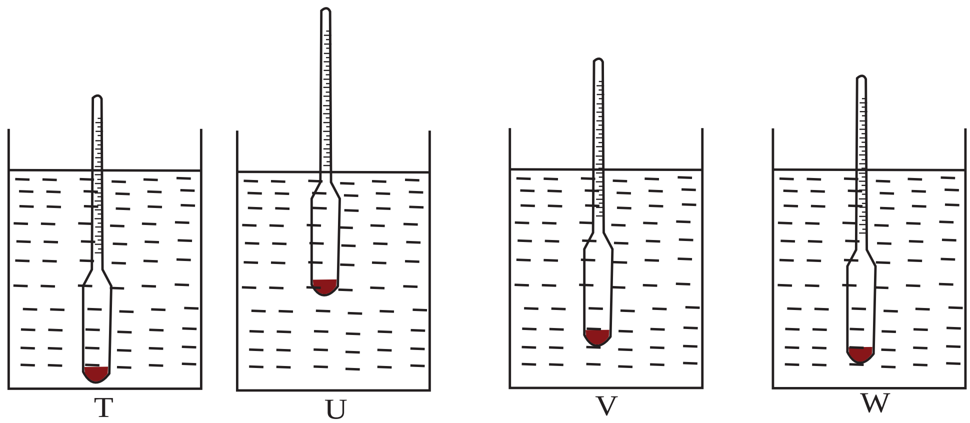
5. Figure given below shows four liquids, that have equal masses, kept in equal containers.



   Select the correct answer, which illustrate the ascending order of densities of four liquids.

   (1) K < L < M < N   (2) K < M < L < N
   (3) N < L < M < K   (4) N < M < L < K

6. Figure below shows four equal hydrometers floating in four types of liquids.



Out of those, the liquid that has the highest density is,

(1) T (2) U (3) V (4) W

(02) Observation received, while preparing an orange solution is given below.

Orange seeds which were at the bottom of glass, started floating when adding sugar.

Give reasons for this observation.

(03) Calculate the density of 4 m^3 volume of liquid with 3600 kg mass.

(04) Density of a solution is 2000 kg m^{-3}. Calculate the mass of 0.25 m^3 volume, of this solution.

Technical Terms

Density	- ඝනත්වය	- அடர்த்தி
Hydrometer	- ද්‍රවමානය	- நீரமானி
Lactometer	- ක්ෂීරමානය	- பால்மானி
Alcoholmeter	- මද්‍යසාරමානය	- மதுசாரநீரமானி
Liquid	- ද්‍රවය	- திரவம்
Solution	- ද්‍රාවණය	- கரைசல்