Physical Quantities & Measurement

Measurement of Volume

Volume of an object is the amount of space occupied by it.

- **Volume of regular solid**

The volume of a regular solid is determined by multiplying its length, width, and height.

Therefore,

Volume of a regular solid = Length × Width × Height

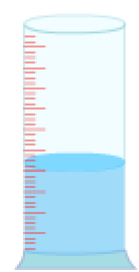
Therefore, measuring the volume of a regular solid is very easy. You just have to measure the length of the sides of the solid.

The SI unit of volume of an object is cubic metre i.e. m^3.

> **If the length of one side of cube is *l*, then what is the volume of the cube?**

- **Volume of liquid**

Unlike solids, liquids do not have any specific shape. Therefore, we cannot measure the volume of liquid by using simple scale. For that, we require a special measuring device known as measuring cylinder. It is nothing but a glass cylinder of uniform diameter. The cylinder has a marking scale on its side wall. To measure the volume of a certain amount of liquid, you have to pour the liquid into the cylinder. After the liquid comes to rest, take the reading of the upper surface of the liquid. This reading is the volume of the liquid.



Measuring cylinder

Measurement of Density

Take an iron ball and a wooden ball of the same radius. Now can you say which one is heavy?

The answer is very simple—the iron ball. Why is it so despite the equal volumes of the balls?

This is because of the difference of the masses present in a unit volume of iron and wood. Both the balls have the same volume, but their masses are different. Therefore, we can say that the mass per unit volume of iron is more than that of wood. This is called **density**.

Hence we define **density** of a matter as the **mass per unit volume** present in it.

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

Density is the primary property of a matter. Every substance has different density. Densities of different substances vary on how closely the molecules are packed. In a substance having high density such as iron, the molecules are densely packed.

Units of Density

As density is defined as the mass per unit volume, the unit of density is also defined as

$$\text{Unit of density} = \frac{\text{Unit of mass}}{\text{Unit of volume}}$$

In **CGS System,** mass is measured in grams and volume in cubic centimetres. Therefore, the unit of density is CGS system is **g/cm^3** or **g cm^{-3}**.

In **SI System,** mass is measured in kilograms and volume in cubic metres. Therefore, the unit of density is SI system is **kg/m^3** or **kg m^{-3}**.

Relation Between S.I. and C.G.S units

1 kg m^{-3} = 10^{-3} g cm^{-3}

or, 1 g cm^{-3} = 1000 kg m−3

Measurement of Density

(i) Density of a Regular Solid

For measuring the density of a regular solid, we require the measurements of its mass and volume.

- Mass of the regular solid can be measured using a physical balance.

- For measuring the volume *V* of the given regular solid, we can use the formula given below

- Volume of cube, V = (side)^2
- Volume of cuboid, V = length × breadth × height
- Volume of sphere, $V = 4/3\pi r^3$; where r is the radius of the spherical solid
- Volume of cylinder, $V = \pi r^2 h$; where r and h are the radius and height of cylindrical solid

Dimensions of the regular solids can be measured using a metre rule.

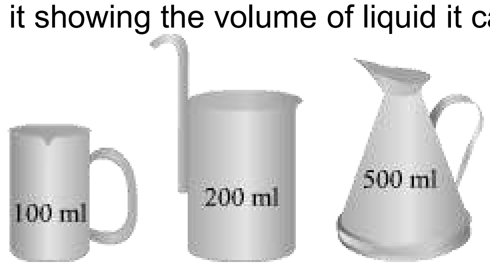
(ii) Density of an Irregular Solid

- Mass of the irregular solid can be measured in the similar way by a physical balance.

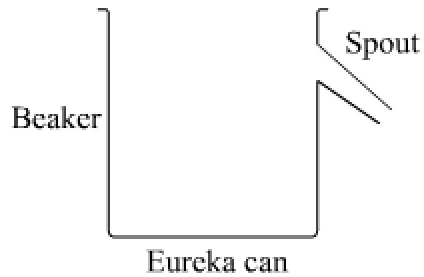
- To find the volume of the solid, the displacement method is used. In this method, when a solid is immersed in a liquid, it displaces volume of liquid equal to its own volume. Now for measuring the volume of a liquid, various types of vessels are used. Some of them are:

(a) Measuring cylinder: Glass or plastic is used for its making. It has graduations in millilitre (ml) with zero mark at the bottom. The graduations increase upwards as shown in the figure below.

(b) Measuring beaker: Glass, plastic or metal is used for its making. Also, the capacity of the beaker is marked on it showing the volume of liquid it can hold.



(c) Eureka can: Eureka can, made up of glass, plastic or metal, is used to hold a volume of liquid upto its spout.

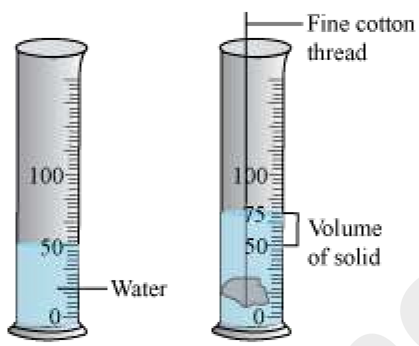


Let us see how to find the volume an irregular solid using a measuring cylinder. Take a measuring cylinder and pour some water in it. Note the level of water. Let the level be V_1. Now, tie the solid to a thin thread and dip it into the water. When the solid is completely submerged in the water, note the water level from the measuring cylinder. Let it now be say V_2. Then the difference $V_2 - V_1$ i.e. the rise in the water level will give you the volume of the solid. Thus, the volume of the solid is

$V = (V_2 - V_1)$

If mass of the solid measured using beam balance is *M,* then the density of the solid is

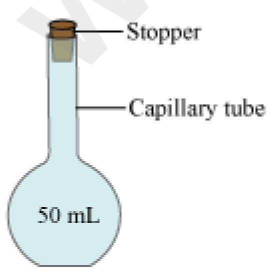
D = M/V



- Now you can easily calculate the density of the solid by using the formula:

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{\text{Mass of the solid}}{\text{Volume of the displaced water}}$$

Density of Liquid



For measuring the density of a liquid, a specially designed bottle is used. This bottle is called **density bottle**. It is a small glass bottle having capacity of 50 mL and a closefitting round stopper at its neck. The stopper has a small capillary glass tube attached to it. When the bottle is completely filled with some liquid and the stopper is inserted, the excess liquid rises up through the capillary tube. This ensures that the bottle is always filled with exactly 50 mL of liquid.

- First, the bottle is washed with distilled water and then dried with hot air. Then the stopper is inserted and the mass of the bottle is measured.
- The bottle is then completely filled with distilled water. After attaching the stopper, the bottle is wiped properly from the outside. Now, the mass of the bottle is measured.
- Distilled water is poured off the density bottle and then the bottle is again dried with hot air. The liquid (density of which has to be measured) is then filled into the bottle. After attaching the stopper, the mass of the density bottle is measured.

Calculations

Let the mass of the empty bottle be m_0 g.

Mass of the empty bottle + Water = m_1 g

Therefore, mass of water = $(m_1 - m_0)$ g

Now, density of water = 1 g cm^{-3}

Hence, the volume of 1 g of water is 1 cm^3.

Therefore, volume of $(m_1 - m_0)$ g of water = $(m_1 - m_0)$ cm^3

As the bottle is completely filled with water,

Volume of water = Volume of the bottle

Hence, volume of the bottle = $(m_1 - m_0)$ cm^3

Let the mass of empty bottle + liquid be m_3 g.

Now,

Volume of water = Volume of the liquid = Volume of the bottle

As density = $\frac{\text{Mass}}{\text{Volume}}$, Density of the liquid = $\left(\frac{m_3 - m_0}{m_1 - m_0}\right) \text{ g cm}^{-3}$

Variation of Density with Temperature

- **Solids:** All forms of matter expand on heating; but in solids, heating has very little effect on the volume of the solid. Solids do not expand significantly to bring any considerable change in their volumes. As a result, the density of a solid does not change much with temperature variation.

- **Liquids and Gases:** When liquids and gases are heated, their volume increases. As the volume is inversely proportional to density, an increase in volume decreases density. Hence, **with the increase in temperature, densities of liquids and gases decrease and with the decrease in temperature, densities increase.**

Consequence of Density Variation with Change in Temperature

Let us take the example of water. When we heat a beaker filled with water, the density of the water near the bottom of the beaker decreases and rises up. To take its place, cold water from the top goes down. Thus, a current is set in the water. This current is called convection current. This process is the same for any liquid when it is heated.

As in liquids, convection current also sets up in gases because of variation in density with temperature change. In atmosphere, when air is heated up, hot air rises up. Denser and cooler air from the upper level of the atmosphere starts settling down at the bottom. As a result of this, convection current sets up in the atmosphere.

Measurement of Area

The amount of flat surface or region occupied by a closed figure is known as the area of the closed figure. The SI unit of area is square metre (m^2).

Conversion of Units of Area

1 km^2	= 1 km × 1 km	= 1000 m × 1000 m = 10,00,000 m^2
1 hectare	= 1 hm × 1 hm	= 100 m × 100 m = 10,000 m^2
1 are	= 1 dcm × 1 dcm	= 10 m × 10 m = 100 m^2
1 m^2	= 1 m × 1 m	= 100 cm × 100 cm =10,000 cm^2

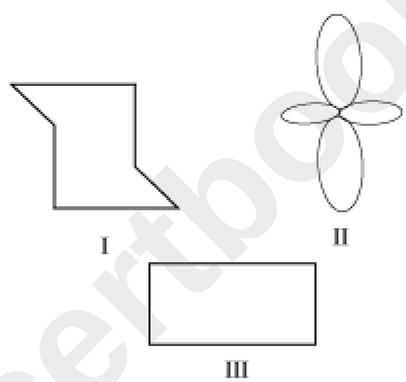
1 m^2	= 1 m × 1 m	= 1000 mm × 1000 mm =10,00,000 mm^2
1 cm^2	= 1 cm × 1 cm	= 10 mm × 10 mm = 100 mm^2

Area is represented in square millimetres or mm^2 for small surfaces and the area of slightly bigger surfaces is represented in cm^2.

Areas of bigger and bigger surfaces are represented in m^2, ares, hectares and km^2.

Measurement of area using graph paper

Look at the following closed figures.



All of the above figures occupy some region or flat surface**.**

Can we tell which one of the above three figures occupy a greater area?

We can answer this question, if we calculate the area of each figure. Now, **how can we do so?**

To calculate the area of each closed figure, we follow the below given steps.

Step 1: Firstly, we place the closed figure on a squared paper or a graph paper where every square measures 1 cm × 1 cm.

Step 2: Then we make an outline of the figure.

Step 3: Now we look at the squares enclosed by the figure. Some of them are completely enclosed, some half, some less than half and some more than half. Note down the number of squares of each category.

Step 4: Calculate the area of the closed figure by considering the following points.

(a) Take the area of 1 full square as 1 square unit.

(b) Ignore portions of the area that are less than half a square.

(c) If some portion enclosed by the figure is more than half a square, then

count its area as one square unit.

(d) If exactly half of the square is counted, take its area as 1/2 square unit.

Such a convention gives a fair estimate of the desired area.

Let us calculate the area of each figure using the above method and try to find out the figure whose area is more than the other two figures. So go through the given videos to understand the method.

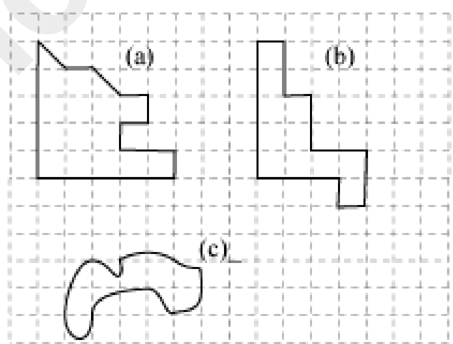
From the above calculations, we can say that figure III has more area than others.

Thus, figure III occupies more space than others.

Let us now discuss one more example based on the area of closed figures.

Example:

Find the areas of the following figures by counting the squares.



Solution:

(a) The number of completely-filled and half-filled squares for the given figure is 14 and 2 respectively.

Therefore, area covered by fully-filled squares = (14 × 1) square units = 14 square units

Area covered by half-filled squares = $\left(2 \times \frac{1}{2}\right)$ square units = 1 square unit

∴ Area of the given figure = (14 + 1) square units = 15 square units

(b) The number of completely-filled squares of the given figure is 11.

∴ Area of the given figure = 11 square units

(c) Observation of the number of completely-filled squares, half-filled squares etc. can be represented by the following table.

Covered Area	Number	Area estimate (square units)
Completely-filled squares	1	1
Half-filled squares	0	0
More than half-filled squares	7	7
Less than half-filled squares	4	0

∴ Estimated area of the given figure = (1 + 7) square units = 8 square units

Formulae for measuring area of regular bodies

- Area of square = $(\text{side})^2$
- Area of rectangle = length × breadth
- Area of circle = $\pi \times (\text{radius})^2$
- Surface area of cylinder = $2\pi \times (\text{radius}) \times$ length
- Surface area of sphere = $4\pi \times (\text{radius})^2$
- Area of triangle =1/2 × base × height

Speed

Sourabh and Apurva go to school on their bicycles. Sourabh covers 200 m in 4 minutes and Apurva covers the same distance in 5 minutes. **Who cycles faster?**

In this section, we will discuss the concept of speed and how it is used in solving various problems in our daily life.

Speed

The slowness or fastness of an object can be related with the help of their speeds. **The speed of a moving object is defined as the distance covered by it in unit time.** For example, if a car covers a distance of 25 km in one hour, then it is said that the car is moving with a speed of 25 km per hour. The speed of a vehicle can be measured by dividing the total distance covered by it by the total time it takes to cover that distance.

$$\text{Speed} = \frac{\text{Total distance covered } (d)}{\text{Total time taken } (t)}$$

You may have observed many times that the speed of your school bus keeps changing its motion along a straight path because of heavy traffic, traffic signals, etc. This is an example of **non-uniform motion**. In this type of motion, a vehicle's speed keeps changing with time. In this case, the speed can be determined in terms of its "**average**" speed. Average speed is determined by dividing the total distance covered by the total time taken.

In the case of **uniform motion**, a vehicle moves with constant speed along a straight path. Hence, its average speed is the same as its actual speed.

- An object that takes the minimum amount of time to cover a given distance is the one moving with the highest speed, whereas an object that takes the maximum amount of time to cover the same distance is the one moving with the slowest speed.

The times taken by each cyclist to complete one round of a racing circuit are given in the table. **Who is the fastest cyclist?**	
Participant	**Time taken (in seconds)**
Rajesh	12
Manish	22
Sujoy	12
Anuj	10
Pawan	8
Gaurav	9
Samik	17
Biswas	16

Do You Know:

Maglev trains are one of the fastest trains in the world. They can move at an average speed of 450 km/h i.e., they can cover a distance of 450 km in just an hour!

Modern vehicles use **speedometers** that measure speed in units of km/h. They also include **odometers** that record the total distance travelled by vehicles in units of kilometre (km). A simple speedometer with an odometer is shown in the given figure.