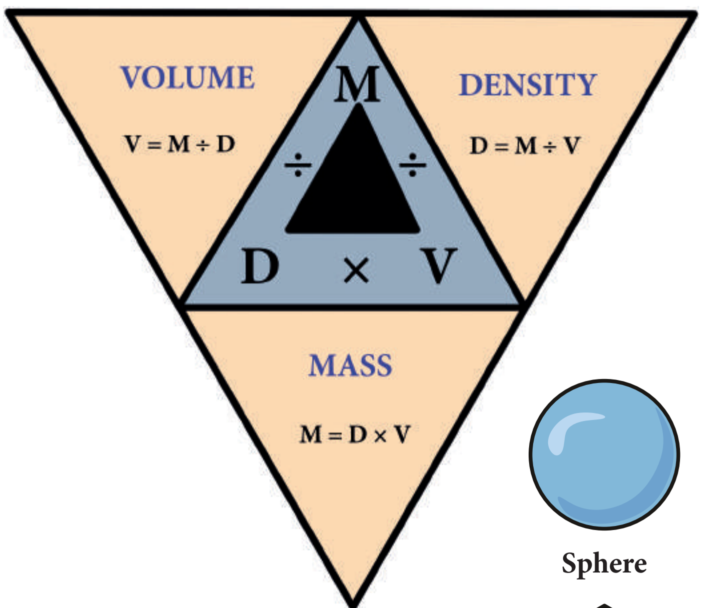
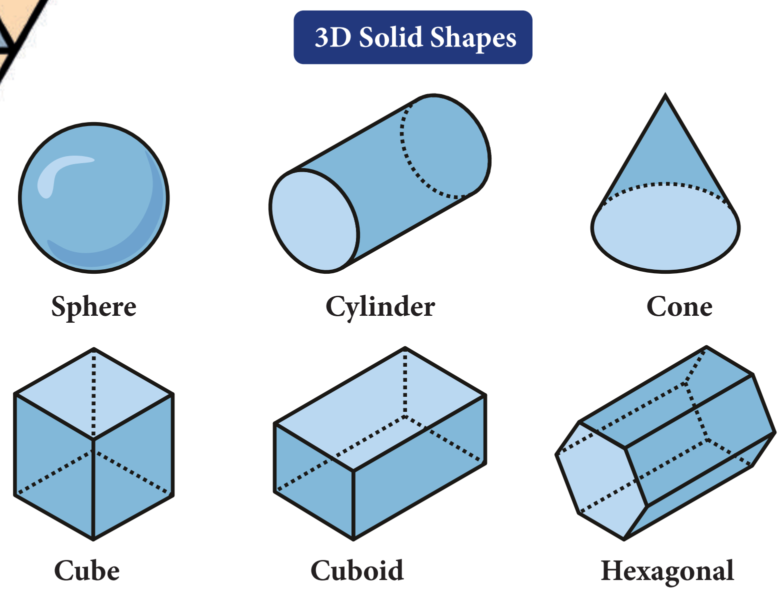
Unit 1

Measurement





Learning Objectives

After studying this unit, students will be able to:

- ❖ identify fundamental and derived physical quantities.
- ❖ identify fundamental and derived units.
- ❖ obtain units for certain derived quantities.
- ❖ measure the area and volume of some regular shaped and irregular shaped objects.
- ❖ convert the volume of objects from cubic metre to litre and vice versa.
- ❖ calculate the density of solids and liquids.
- ❖ define astronomical unit and light year.

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Introduction

In day to day life, we measure many things such as weight of fruits, vegetables and food grains, volume of liquids, temperature of the body, speed of the vehicles etc., Quantities such as mass, weight, distance, temperature, volume are called physical quantities. A value and a unit are used to express the magnitude of a physical quantity. For example, let us assume that you walk 2 kilometre everyday. In this example '2' is the value and 'kilometre' is the unit used to express the magnitude of distance which is a physical quantity. In this lesson, we are going to study about fundamental quantities, derived quantities such as area, volume and density, and measurement of larger quantities.

1.1 Fundamental Quantities and Derived Quantities

Generally, physical quantities are classified into two types. They are: fundamental quantities and derived quantities.

1.1.1 Fundamental Quantities

A set of physical quantities which cannot be expressed in terms of any other quantities are known as fundamental quantities. Eg. Length, Mass, Time. Their corresponding units are called fundamental units. There are seven fundamental physical quantities in SI Units (System of International Units). They are given in Table 1.1.

Table 1.1 Fundamental quantities and their units

Fundamental quantity	Fundamental unit
Length	metre (m)
Mass	kilogram (kg)
Time	second (s)
Temperature	Kelvin (K)
Electric current	Ampere (A)
Amount of substance	mole (Mol)
Luminous intensity	Candela (cd)

1.1.2 Derived quantities

All other physical quantities which can be obtained by multiplying, dividing or by mathematically combining the fundamental quantities are known as derived quantities. Eg. Area and volume. Their corresponding units are called derived units. Some of the derived quantities and their units are given in Table 1.2.

Table 1.2 Derived quantities and their units

Derived quantity	Unit
Area = Length × Breadth	m^2
Volume = Length × Breadth × Height	m^3
Speed = Distance / Time	ms^{-1}
Electric Charge = Electric Current × Time	C
Density = Mass / Volume	$kg\ m^{-3}$

*C - Coulumb

1.2 Area

Area is a measure of how much space is there on a flat surface. The area of a plot of land is derived by multiplying its length and breadth.

Area = length × breadth

The unit of the area is m^2 (Read as square metre). Area is a derived quantity as we obtain it by multiplying the fundamental physical quantity length (length x breadth).

Problem 1.1

What is the area of 10 squares each having side of 1 m?

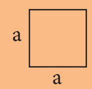
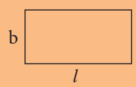
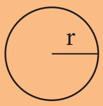
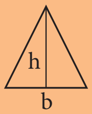
Area of a square = side × side
= 1 m × 1 m
= 1 m^2 or 1 square metre

Area of 10 squares = 1 square metre × 10
= 10 square metre

1.2.1 Area of regularly shaped objects

The area of regularly shaped objects can be calculated using the relevant formulae. In Table 1.3, the formulae used to calculate the area of certain regularly shaped figures are given.

Table 1.3 Area of some regularly shaped objects

S.No.	Plane figure	Diagram	Area
1	Square		side × side $a \times a = a^2$
2	Rectangle		length × breadth $l \times b = lb$
3	Circle		$\pi \times (\text{radius})^2$ $\pi \times r^2 = \pi r^2$
4	Triangle		(1/2) × base × height 1/2 × b × h

Problem 1.2

Find the area of the following regular shaped figures (Take $\pi = 22/7$).

a. A rectangle whose length is 12 m and breadth is 4 m.

b. A circle whose radius is 7 m.

c. A triangle whose base is 6 m and height is 8 m.

Solution

a. Area of rectangle = length × breadth
= 12 × 4 = 48 m^2

b. Area of circle = $\pi \times r^2 = (22/7) \times 7 \times 7$
= 154 m^2

c. Area of triangle = 1/2 × base × height
= 1/2 × 6 × 8 = 24 m^2

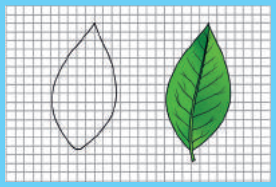
1.2.2 Area of irregularly shaped objects

In our daily life, we encounter many irregularly shaped objects like leaves, maps, stickers of stars or flowers, peacock feather etc. The area of such irregularly shaped objects cannot be calculated using any formula.

How can we find the area of these irregularly shaped objects? We can find the area of these figures with the help of a graph sheet. The following activity shows how to find the area of irregularly shaped plane figures.

ACTIVITY 1

Take a leaf from any one of the trees. Place it on a graph sheet and draw the outline of the leaf with a pencil. Remove the leaf. You can see the outline of the leaf on the graph sheet.



i. Now, count the number of whole squares enclosed within the outline of the leaf. Take it as M.

ii. Then, count the number of squares that are more than half. Take it as N.

iii. Next, count the number of squares which are half of a whole square. Note it as P.

iv. Finally, count the number of squares that are less than half. Let it be Q.

Now, the approximate area of the leaf can be calculated using the following formula.

Approximate area of the leaf
= M + (3/4) N + (1/2) P + (1/4) Q square cm.

Area of the leaf = _______________ cm^2.

This method can be used to find the area of regularly shaped figures also. In the case of square and rectangle, this method gives the measure area accurately. This method can be used to calculate the area of any irregularly shaped plane figures.

ACTIVITY 2

Draw the following regularly shaped figures on a graph sheet and find their area by the graphical method. Also, find their area using appropriate formula. Compare the results obtained in two methods by tabulating them.

a. A rectangle whose length is 12 cm and breadth is 4 cm.

b. A square whose side is 6 cm.

c. A circle whose radius is 7 cm.

d. A triangle whose base is 6 cm and height is 8 cm.

S. No.	Shape	Area using formula	Area using graphical method

DO YOU KNOW?

One square metre is the area enclosed inside a square of side 1 metre. Even though area is given in square metre, the surface need not to be square in shape

1.3 Volume

The amount of space occupied by a three dimensional object is known as its volume.

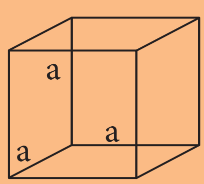
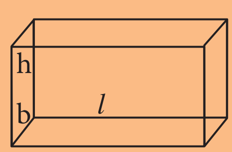
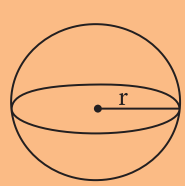
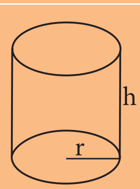
Volume = Surface area × Height

The SI unit of volume is cubic metre or m^3.

1.3.1 Volume of regularly shaped objects

As in the case of area, the volume of a regularly shaped objects can also be determined using an appropriate formula. Table 1.4 gives the formulae used to calculate the volume of the regularly shaped objects.

Table 1.4 Volume of regularly shaped objects

S.No.	Objects	Figure	Volume
1	Cube		side × side × side $a \times a \times a = a^3$
2	Cuboid		length × breadth × height $l \times b \times h = lbh$
3	Sphere		$4/3 \times \pi \times (\text{radius})^3$ $4/3 \times \pi \times r^3 = 4/3\ \pi\ r^3$
4	Cylinder		$\pi \times (\text{radius})^2 \times \text{height}$ $\pi \times r^2 \times h = \pi r^2 h$

Problem 1.3

Find the volume of the following (Take π = 22/7).

a. A cube whose side is 3 cm.

b. A cylinder whose radius is 3 m and height is 7 m.

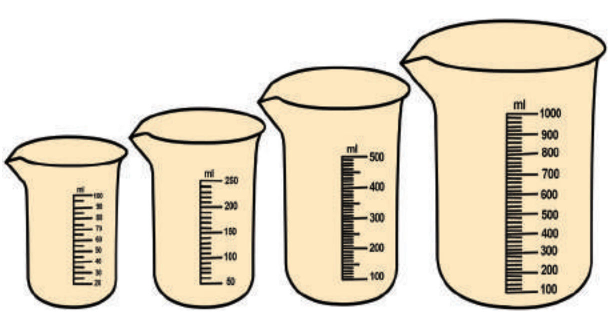
Solution

a. Volume of a cube = side × side × side
   = 3 cm × 3 cm × 3 cm = 27 cubic cm or cm^3.

b. Volume of a cylinder = $\pi \times (radius)^2 \times height$
   = 22/7 × 3 × 3 × 7 = 198 m^3.

1.3.2 Volume of Liquids

Liquids also occupy some space and hence they also have volume. But, liquids do not possess any definite shape. So, the volume of a liquid cannot be determined as in the case of solids. When a liquid is poured into a container, it takes the shape and volume of the container. The volume of any liquid is equal to the space that it fills and it can be measured using a measuring cylinder or measuring beaker. The maximum volume of liquid that a container can hold is known as the capacity of the container. A measuring container is graduated as shown in figure.



Measuring containers

The volume of a liquid is equal to the volume of space it fills in the container. This can be directly observed from the readings marked in the measuring containers. If we notice the measuring cups given in figure carefully, we can observe that the readings are marked in the unit of 'ml'. This actually represents millilitre. To understand this unit of volume, let us first understand how much a litre means. Litre is the commonly used unit to measure the volume of liquids. We know that the unit of volume is cubic cm if the dimensions of the object are given in cm. This cubic cm is commonly known as 'cc'. A volume of 1000 cc is termed as one litre (*l*).

1 litre = 1000 cc or cm^3

1000 ml = 1 litre

1.3.3 Volume of irregularly shaped objects

There is no formula to determine the volume of irregularly shaped objects as in the case of area. For such objects, volume can be determined using a measuring cylinder and water.

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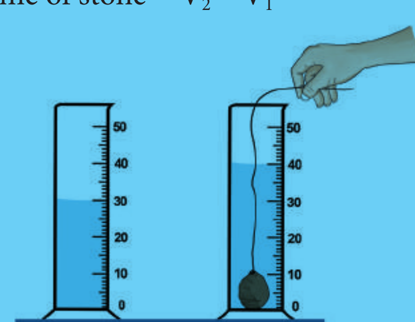
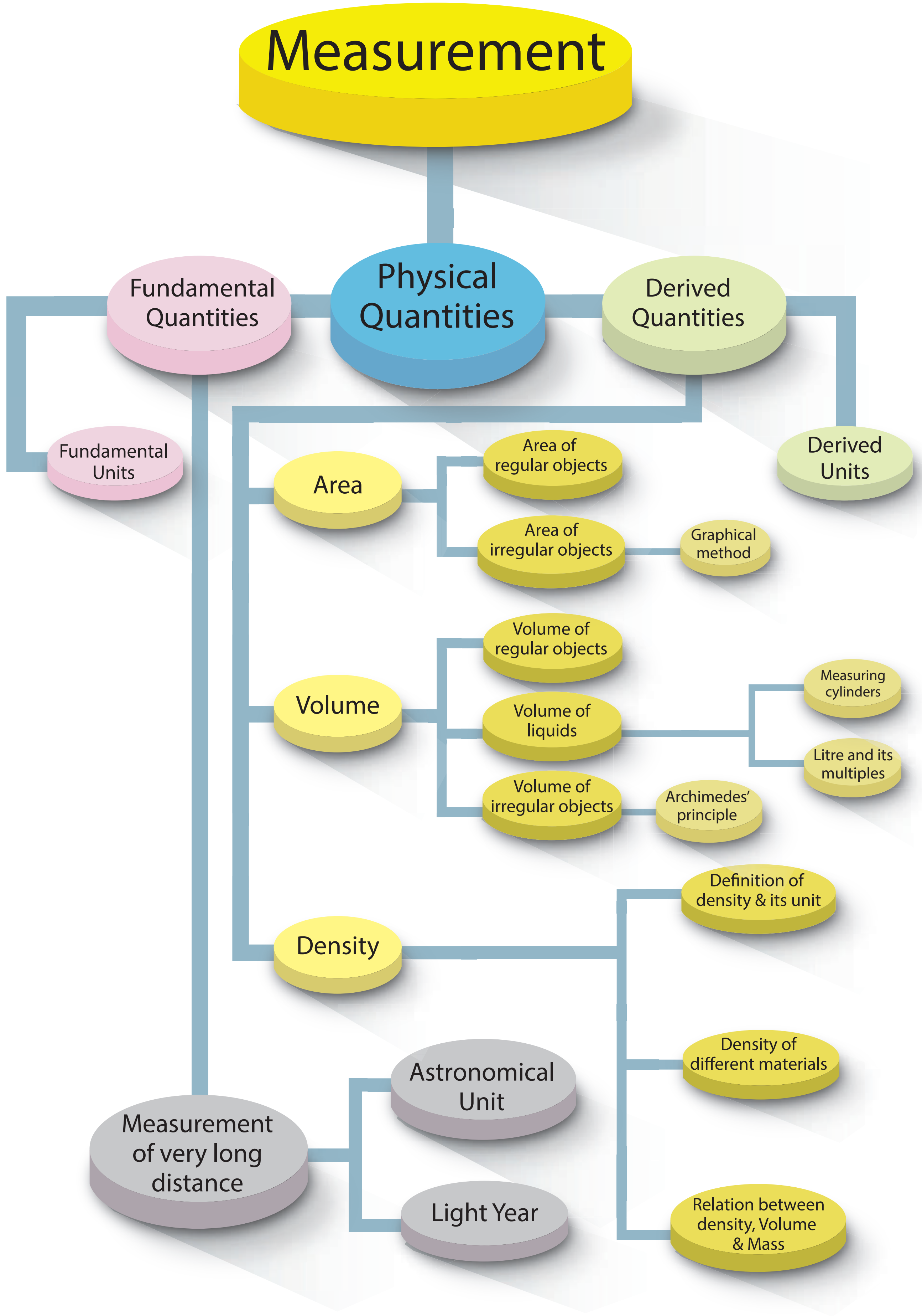
ACTIVITY 3

Take a measuring cylinder and pour some water into it (Do not fill the cylinder completely). Note down the volume of water from the readings of the measuring cylinder. Take it as V_1. Now take a small stone and tie it with a thread. Immerse the stone inside the water by holding the thread. This has to be done such that the stone does not touch the walls of the measuring cylinder. Now, the level of water will raise. Note down the volume of water and take it as V_2. The volume of the stone is equal to the raise in the volume of water.

Volume of stone = $V_2 - V_1$





Measurement
Fundamental Quantities
Physical Quantities
Derived Quantities
Fundamental Units
Derived Units
Area
Area of regular objects
Area of irregular objects
Graphical method
Volume
Volume of regular objects
Volume of liquids
Measuring cylinders
Litre and its multiples
Volume of irregular objects
Archimedes' principle
Density
Definition of density & its unit
Density of different materials
Relation between density, Volume & Mass
Measurement of very long distance
Astronomical Unit
Light Year

DO YOU KNOW?

To measure the volume of liquids, some other units are also used. Some of them are gallon, ounce, and quart.

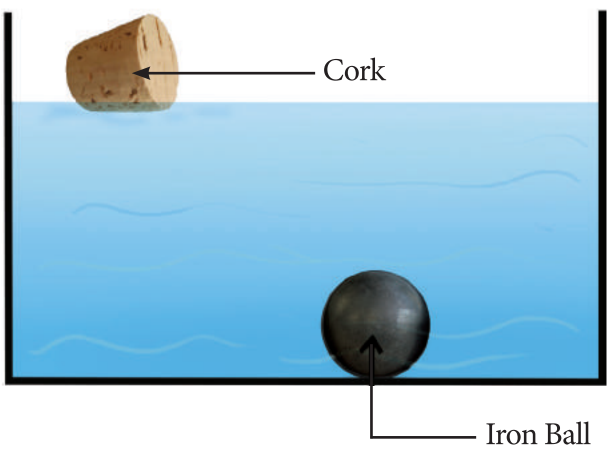
1 gallon = 3785 ml

1 ounce = 30 ml

1 quart = 1 litre

1.4 Density

Take water in a beaker and drop an iron ball and a cork into the water. What do you observe? The iron ball sinks and the cork floats as shown in figure. Can you explain why?



Iron ball sinks while cork floats in water

If your answer is heavy objects sink in water and lighter objects float in water, then, why does a metal coin sinks in water whereas a much heavier wooden log floats? These questions can be answered if we understand the concept of density.

Lighter coin sinks while heavier wooden log floats

ACTIVITY 4

a. Take an iron block and a wooden block of same mass (say 1kg each). Measure their volume. Which one has more volume and occupies more volume?
Ans: ________________

b. Take an iron block and a wooden block of same size. Weigh them and measure their mass. Which one of them has more mass?
Ans: ________________

From activity 4, we observe that wooden block occupies more volume than the iron ball of same mass. Also, we observe that wooden block is lighter than the iron block of same size.

The lightness or heaviness of a body is due to density. If more mass is packed into some volume, it has greater density. So, the iron block will have more mass than the wooden block of the same size. Therefore, iron has more density.

Density of a substance is defined as the mass of the substance contained in unit volume (1 m^3). If the mass of a substance is M and volume is V, then, its density is given as

$$Density\ (D) = \frac{Mass\ (M)}{Volume\ (V)}$$

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

SI unit of density is kg/m^3. The CGS unit of density is g/cm^3.

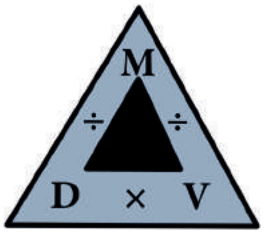
1.4.1 Density of different materials

Different materials have different densities. The materials with more density are called denser and the materials with less density are called rarer. The density of some widely used materials are listed in Table 1.4.

Table 1.4 Density of some common substances, at room temperature

S.No.	Nature	Materials	Density (kg/m³)
1	Gas	Air	1.2
2	Liquid	Kerosene	800
3		Water	1,000
4		Mercury	13,600
5	Solid	Wood	770
6		Aluminium	2,700
7		Iron	7,800
8		Copper	8,900
9		Silver	10,500
10		Gold	19,300

The relationship between mass, density and volume are represented in the following density triangle.



- Density = Mass/ Volume
- Mass = Density × Volume
- Volume = Mass / Density

Problem 1.4

A solid cylinder of mass 280 kg has a volume of 4 m^3. Find the density of cylinder.

Solution

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

$$= \frac{280}{4} = 70\ kg/m^3$$

Problem 1.5

A box is made up of iron and it has a volume of 125 cm^3. Find its mass if the density of iron is 7.8 g / cm^3.

Solution

Density = Mass / Volume

Hence, Mass = Volume × Density

= 125 × 7.8 = 975 g.

DO YOU KNOW?

Water has more density than oils like cooking oil and castor oil, although these oils appear to be denser than water. Density of castor oil is 961 kg/m3. If we put one drop of water in oil, water drop sinks. But, if we put one drop of oil in water, oil floats and forms a layer on water surface. However, some oils are denser than water.

Problem 1.6

A sphere is made from copper whose mass is 3000 kg. If the density of copper is 8900 kg/m, find the volume of the sphere.

Solution

Density = Mass / Volume

Hence, Volume = Mass / Density

= 3000 / 8900 = 30 / 89

= 0.34 m^3

1.5 Measuring larger distances

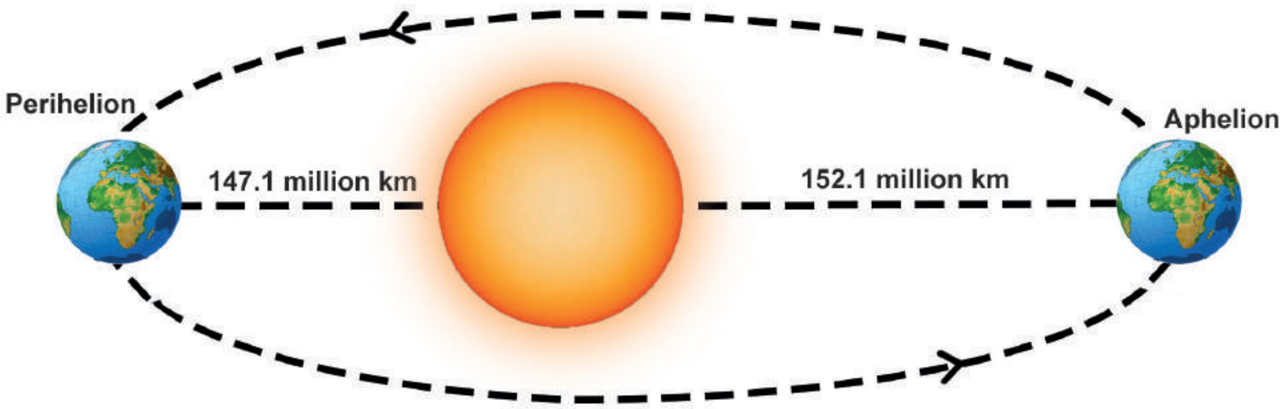
Normally, we use centimetre, metre and kilometre to express the distances that we measure in our day to day life. But, for space research, astronomers need to measure very long distances such as the distance between the earth and a star or the distance between two stars. To express these distances, we shall learn about two such units, namely,

i. Astronomical unit

ii. Light year

1.5.1 Astronomical Unit

We all know that the earth revolves around the sun in an elliptical orbit. Hence, the distance between the sun and the earth varies every day. When the earth is in its perihelion position (the position when the distance between the Earth and the Sun is short), the distance between



Perihelion and Aphelion position of Earth

the earth and the sun is about 147.1 million kilometre. When the earth is in its aphelion position, (the position when the distance between Earth and the Sun is the largest) the distance is 152.1 million kilometre. The average distance between the earth and the sun is about 149.6 million kilometre. This average distance is taken as one astronomical unit. Neptune is 30 AU away from the Sun. It means it is thirty times farther than the Earth.

One astronomical unit is defined as the average distance between the earth and the sun.

1 AU = 149.6 million km

$= 149.6 \times 10^6$ km $= 1.496 \times 10^{11}$ m.

1.5.2 Light year

The nearest star to our solar system is Proxima Centauri. It is at a distance of 2,68,770 AU. We can note here that using AU for measuring distances of stars would be unwieldy. Therefore, astronomers use a special unit, called 'light year', for measuring the distance in deep space. We have learnt that the speed of light in vacuum is 3×10^8 m/s. This means that light travels a distance of 3×10^8 m in one second. In a year (non-leap), there are 365 days. Each day has 24 hours, each hour has 60 minutes and each minute has 60 seconds.

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Thus, the total number of seconds in one year

$= 365 \times 24 \times 60 \times 60$

$= 3.153 \times 10^7$ second

If light travels at a distance of 3×10^8 m in one second, then the distance travelled by light in one year $= 3 \times 10^8 \times 3.153 \times 10^7 = 9.46 \times 10^{15}$ m. This distance is known as one light year.

One light year is defined as the distance travelled by light in vacuum during the period of one year.

1 Light year $= 9.46 \times 10^{15}$ m.

In terms of light year, Proxima Centauri is at 4.22 light-years from Earth and the Solar System. The Earth is located about 25,000 light-years away from the galactic centre.

Points to Remember

❖ A set of physical quantities which cannot be expressed in terms of any other quantities are known as fundamental quantities. Their corresponding units are called fundamental units.

❖ The physical quantities which can be obtained by mathematically combining (i.e., multiplying and dividing) the fundamental quantities are known as derived quantities. Their corresponding units are called derived units.

- The area of a figure is the region covered by the boundary of the figure. Its SI unit is square metre or m^2.
- The area of irregularly shaped figures can be calculated with the help of a graph sheet.
- The amount of space occupied by a three dimensional object is known as its volume. The SI unit of volume is cubic metre or m^3.
- The volume of liquids are expressed in terms of litre. One litre = 1000 cc.
- The maximum volume of a liquid that a container can is known as the capacity of the container.
- Density of a substance is defined as the mass of the substance contained in unit volume (1 m^3).
- SI unit of density is kg/m^3. The CGS unit of density is g/cm^3. $1 g/cm^3 = 10^3 kg/m^3$.
- The materials with higher density are called denser materials and the materials with lower density are called rarer materials.
- If the density of a solid is higher than that of a liquid, it sinks in that liquid. If the density of a solid is lower than that of a liquid, it floats in that liquid.
- Density = Mass / Volume

  Mass = Density × Volume

  Volume = Mass / Density
- One astronomical unit is defined as the average distance between the Earth and the Sun. $1\ AU = 149.6 \times 10^6\ km = 1.496 \times 10^{11}\ m$.
- One light year is defined as the distance travelled by light in vacuum during the period of one year. 1 Light year $= 9.46 \times 10^{15}$ m.

Evaluation

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I. Choose the best answer.

1. Which of the following is a derived quantity?
   a) mass b) time
   c) area d) length
2. Which of the following is correct?
   a) 1L = 1cc b) 1L = 10 cc
   c) 1L = 100 cc d) 1L = 1000 cc
3. SI unit of density is
   a) kg/m^2 b) kg/m^3 c) kg/m d) g/m^3
4. Two spheres have mass and volume in the ratio 2:1. The ratio of their density is
   a) 1:2 b) 2:1 c) 4:1 d) 1:4
5. Light year is the unit of
   a) distance b) time
   c) density d) Both length and time

II. Fill in the blanks.

1. Volume of irregularly shaped objects are measured using the law of ______________.
2. One cubic metre is equal to ______________ cubic centimetre.
3. Density of mercury is ________________.
4. One astronomical unit is equal to ________.
5. The area of a leaf can be measured using a _________________________.

III. State true or false. If false, correct the statement.

1. The region covered by the boundary of a plane figure is called its volume.

2. Volume of liquids can be found using measuring containers.
3. Water is denser than kerosene.
4. A ball of iron floats in mercury.
5. A substance which contains less number of molecules per unit volume is said to be denser.

IV. Match the following items.

a.

1. Area	a. light year
2. Distance	b. m^3
3. Density	c. m^2
4. Volume	d. kg
5. Mass	e. kg / m^3

b.

1. Area	a. g / cm^3
2. Length	b. measuring jar
3. Density	c. amount of a substance
4. Volume	d. rope
5. Mass	e. plane figures

V. Arrange the following in correct sequence.

1. 1L, 100 cc, 10 L, 10 cc
2. Copper, Aluminium, Gold, Iron

VI. Use the analogy to fill in the blank

1. Area : m^2 :: Volume : __________
2. Liquid : Litre :: Solid : __________
3. Water : Kerosene :: ________ : Aluminium

VII. Consider the following statements and choose the correct option.

1. Assertion: Volume of a stone is found using a measuring cylinder.

Reason: Stone is an irregularly shaped object.

2. Assertion: Wood floats in water.

Reason: Water is a transparent liquid.

3. Assertion: Iron ball sinks in water.

Reason: Water is denser than iron.

a. Both assertion and reason are true and reason is the correct explanation of assertion.
b. Both assertion and reason are true, but reason is not the correct explanation of assertion.
c. Assertion is true but reason is false.
d. Assertion is false but reason is true.

VIII. Answer very briefly.

1. Name some of the derived quantities.
2. Give the value of one light year.
3. Write down the formula used to find the volume of a cylinder.
4. Give the formula to find the density of objects.
5. Name the liquid in which iron ball sinks.
6. Name the units used to measure the distance between celestial objects.
7. What is the density of gold?

IX. Answer briefly.

1. What are derived quantities?
2. Distinguish between the volume of liquid and capacity of a container.
3. Define the density of objects.
4. What is one light year?
5. Define - Astronomical unit.

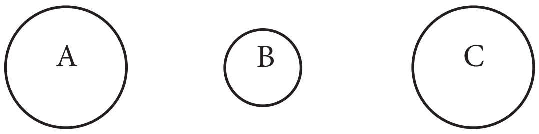
X. Answer in detail.

1. Describe the graphical method to find the area of an irregularly shaped plane figure.
2. How will you determine the density of a stone using a measuring jar?

XI. Questions based on Higher Order Thinking Skills:

There are three spheres A, B, C as shown below.

Sphere A and B are made of same material. Sphere C is made of a different material. Spheres A and C have equal radii. The radius of sphere B is half that of A. Density of A is double that of C.



Now answer the following questions.

i. Find the ratio of masses of spheres A and B.

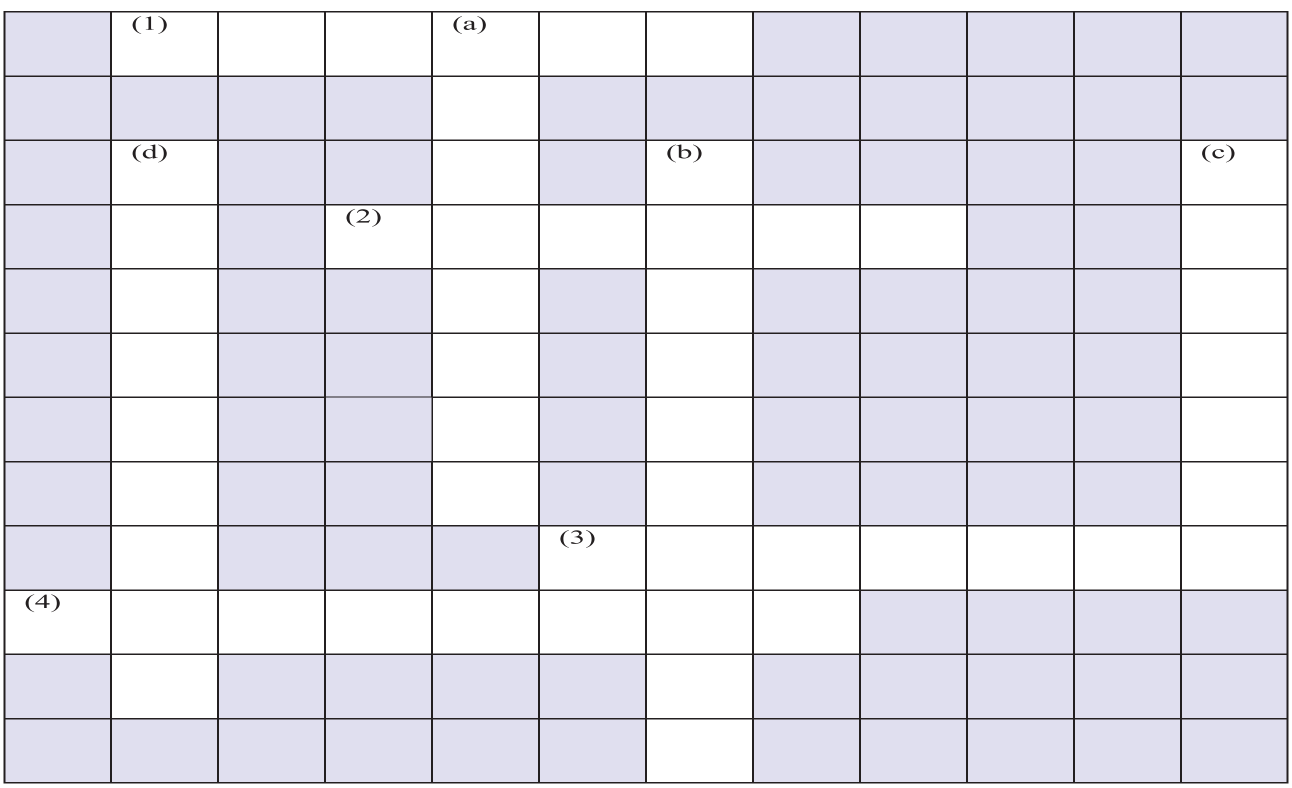
ii. Find the ratio of volumes of spheres A and B.

iii. Find the ratio of masses of spheres A and C.

XII. Numerical problems:

1. A circular disc has a radius 10 cm. Find the area of the disc in m^2 (Use $\pi = 3.14$).
2. The dimension of a school playground is 800 m × 500 m. Find the area of the ground.
3. Two spheres of same size are made from copper and iron respectively. Find the ratio between their masses (Density of copper is 8,900 kg/m^3 and iron is 7,800 kg/m^3).
4. A liquid having a mass of 250 g fills a space of 1000 cc. Find the density of the liquid.
5. A sphere of radius 1cm is made from silver. If the mass of the sphere is 33g, find the density of silver (Take $\pi = 3.14$).

XIII. Cross word puzzle.



Clues – Across

1. SI unit of temperature; 2. A derived quantity; 3. Mass per unit volume; 4. Maximum volume of liquid a container can hold

Clues – Down

a. A derived quantity b. SI unit of volume c. A liquid denser than iron d. A unit of length used to measure very long distances

Answer

1. Kelvin; 2. Volume; 3. Density; 4. Capacity a. Velocity; b. Cubic metre; c. Mercury; d. Lightyear

ICT CORNER

Measurement

Let's know about the effects of mass and volume on density.

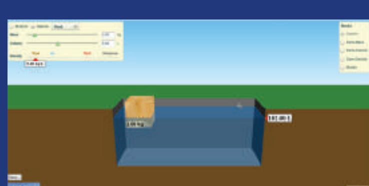
PROCEDURE :

Step 1: Use the URL or scan the QR code to open the activity page.

Step 2: Select the options at top right side window to customize

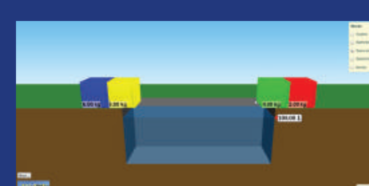
Step 3: Move the sliders on the top left-side window to change the Material and Mass, Volume. Now see the effects of mass and volume on density.

Step 4: Click 'Reset all' button to refresh



Step 1

Step 2



Step 3

Step 4

Measurement URL:

https://phet.colorado.edu/en/simulation/density (or) scan the QR Code

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*Pictures are indicative only

*If browser requires, allow Flash Player or Java Script to load the page.