EXPLORING SCIENCE

2nd edition

For the Junior Cycle

Michael O'Callaghan • Pat Doyle • Orla Molamphy • Ger Reilly

Edco

Unit 4 Physical World
Chapter 25 What is density and why do some things float?

Michael O'Callaghan • Pat Doyle • Orla Molamphy • Ger Reilly

Edco

Density

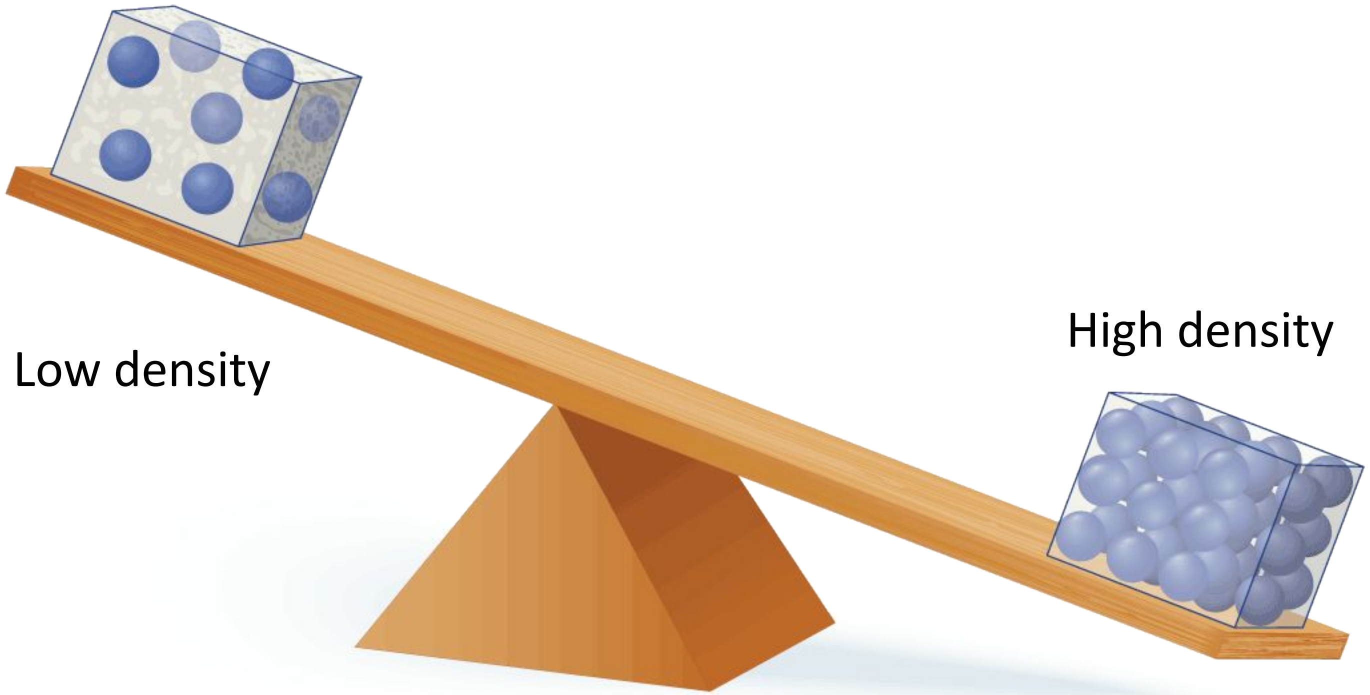
When you go shopping for a new school bag you will often see several bags on display. To give the customer an idea of the size of the bag the shopkeeper might stuff the bag full of crumpled-up tissue paper. This helps you to visualise the size of the bag. The bag looks full but feels very light when stuffed with the tissue paper. But when this bag is full of books, it is much heavier.

Density

The paper used in books is more tightly packed than the paper in crumpled-up pieces of tissue paper. In a bag full of books there is more paper in the same size or volume of bag. The mass of the books is greater than the mass of the tissue paper, even though the volumes are the same. We would say that the **density** of the books is greater than the density of the tissue paper.

Density

Density of a substance tells you how much mass is packed into a particular volume. Experience will tell you that a bag full of books will be heavier than a bag of crumpled tissue paper. A mathematical formula explains it, and can be used in other situations:



Units for density

There are two sets of units that can be used for density:
First,

$$\text{Since density} = \frac{mass}{volume}, \text{ units of density} = \frac{units\ of\ mass}{units\ of\ volume}$$

$$= \frac{gram}{cm^3}$$

In science we write this as **gram $\mathbf{cm^{-3}}$** or simply **g $\mathbf{cm^{-3}}$**.

The minus sign in front of the number 3 is to remind you that the cm^3 are below the line in the formula.

Second,

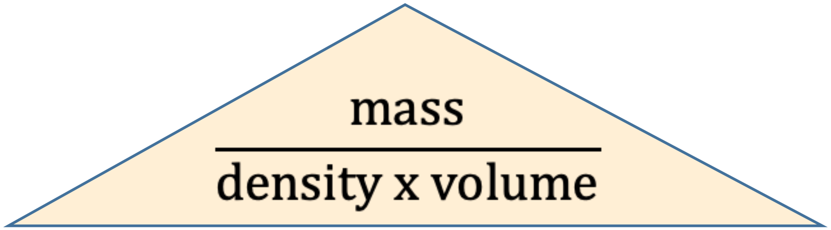
$$\text{density} = \frac{mass}{volume}, \text{ units of density} = \frac{units\ of\ mass}{units\ of\ volume}$$

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

Units for density

In science we write this as **kilogram m^{-3}** or simply **kg m^{-3}**.

Helpful hint: Look at the following triangle:



or

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

Units for density

In a calculation you may be asked to find:

- The value of density
- The value of mass
- The value of volume.

Place your finger over the quantity you are measuring in the triangle above and the instruction for your calculation is right in front of you. This is what you get:

- To calculate the value of density: $\text{density} = \dfrac{\text{mass}}{\text{volume}}$
- To calculate the value of mass: mass = density × volume
- To calculate the value of volume: $\text{volume} = \dfrac{\text{mass}}{\text{density}}$

Sample calculation 1

Brian noted that 100 cm3 of a liquid had a mass of 80 g. Calculate the density of this liquid.

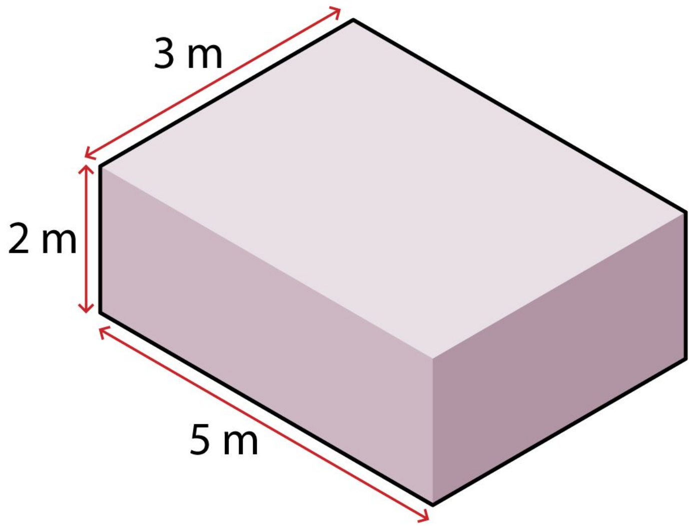
Answer:

$$\text{density} = \frac{\text{mass}}{\text{volume}} = \frac{80}{100}$$
$$= 0.8 \text{ g cm}^{-3}$$

Sample calculation 2

The rectangular block in Figure 25.4 has a length of 5 m, a width of 3 m and a height of 2 m. The mass of the block is 21 000 kg. Calculate the density of the block.

Answer:



First you have to calculate the volume of the block:
Volume = length × width × height
Volume = 5 × 3 × 2
Volume = 30 m^3
Then use your answer in the formula:

$$\text{density} = \frac{\text{mass}}{\text{volume}} = \frac{21\,000}{30} = 700 \text{ kg m}^{-3}$$

Sample calculation 3

A substance has a density of 19 g cm^{-3}. Calculate the mass of 8 cm^3 of this substance.

Answer:

Mass = density × volume
Mass = 19 × 8
Mass = 152 g

Sample calculation 4

The density of a stone is 5 g cm^{-3}. Calculate the volume of this stone if it has a mass of 17 g.

Answer:

$$\text{volume} = \frac{\text{mass}}{\text{density}} = \frac{17}{5} = 3.4\ \text{cm}^3$$

Sample calculation 5

A student measured the values of the volume for five different pieces of cork. Each piece of cork had its mass value written on it. She presented the data as shown in the table below.

Mass (g)	2	4	6	8	10
Volume (cm^3)	10	20	30	40	50

Draw a graph with values of mass on the y-axis and values of volume on the x-axis.
(a) What do you notice about the shape of the graph?
(b) Divide any mass value by its corresponding volume value. Do you notice any pattern?
(c) What unit would you get when a mass value is divided by a volume value?

Sample calculation 5

Answer:

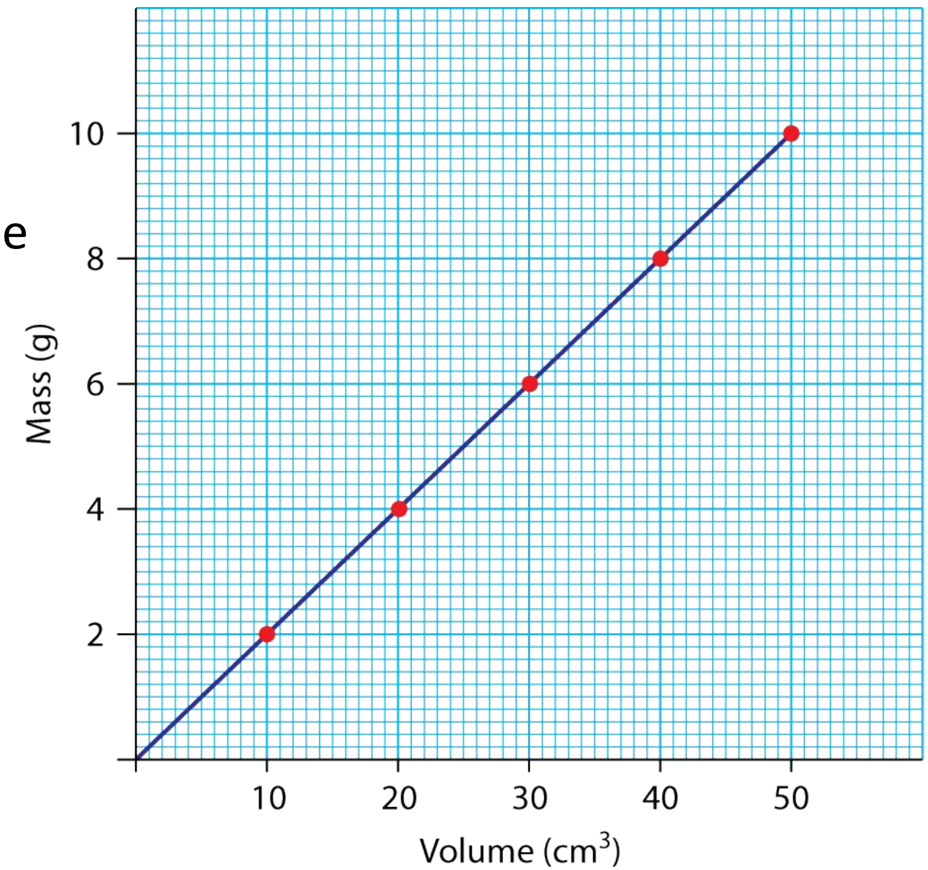
(a) The graph is a straight line passing through the origin.

(b) Every time you divide the mass value by the volume value you get the same answer of 0.2:

$$\frac{2}{10} = 0.2 \quad \frac{4}{20} = 0.2 \quad \frac{6}{30} = 0.2$$

(c) The unit would be

$$\frac{\text{unit of mass}}{\text{unit of volume}} = \frac{\text{g}}{\text{cm}^3} = \text{g cm}^{-3}$$



By now you have noticed that there is a relationship between the mass and the volume of objects made of the same material: for example, the brass weights. This relationship leads to the idea of density. You have also seen some maths calculations based on the density formula.

Michael O'Callaghan • Pat Doyle • Orla Molamphy • Ger Reilly

Values of density

Material	Density (kg m^{-3})	Density (g cm^{-3})
Polystyrene	20	0.02
Cork	200	0.2
Paraffin oil	800	0.8
Ice	900	0.9
Water	1 000	1
Aluminium	2 700	2.7
Mercury	13 600	13.6
Gold	19 300	19.3
Osmium	22 600	22.6

Values of density

Be careful with the units for density. Table 25.1 shows how the numerical value of density depends on the units you choose. For water, the density is 1 if you use g cm^{-3} and the density is 1000 if you use kg m^{-3}.

The density of water is exactly 1 g cm^{-3}. This is not a coincidence. This value was used many years ago when scientists were deciding on an exact meaning for the kilogram.

Flotation

We observe many examples of **flotation** in our everyday lives. Boats float in the sea, twigs float in rivers, and we know that icebergs are huge floating blocks of ice. Why do some objects float and other objects sink? The answer to this question lies in knowing about the density of the objects.

Flotation

This figure shows three different liquids, each with different densities. The liquid on the top has the smallest value of density while the liquid on the bottom has the greatest value of density.

How can seemingly heavy objects float?

Have you ever wondered why a ship that is made of a metal is able to float in water?

If the metal is more dense than the water you might expect the ship to sink. However, the ship is hollow and the inside of the ship is filled with air.

The average density of the ship and the air in it is less than the density of the water. The ship is therefore able to float.

Photo credits

- Shutterstock
- Science Photo Library
- Michael Philips
- Compuscript