4 DENSITY

Videos & questions on the CD ROM

Gold is one of the densest metals. A block the size of a 1 L carton of milk would have a mass of almost 20 kg and would be very hard to pick up.

We must have all noticed that the weight of objects can vary greatly. A plastic teaspoon weighs less than a metal one, and a gold ring weighs twice as much as a silver one, even if the objects are exactly the same size.

The density of a material is a measure of how 'squashed up' it is, and a dense object contains more mass than a light object of the same size.

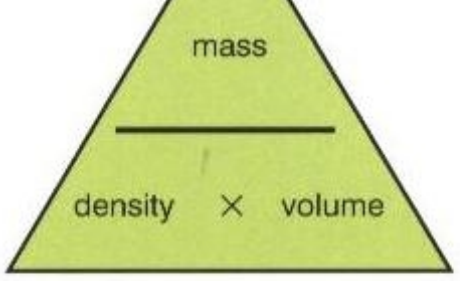
Density is calculated using this formula:

$$d = \frac{m}{V}$$

m = mass in g or kg

V = volume in cm^3 or m^3

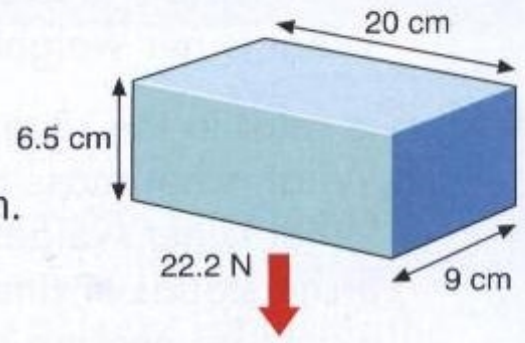
d = density in g/cm^3 or kg/m^3



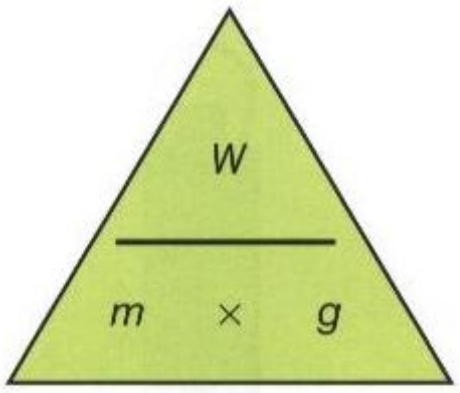
Note that in this equation you must use g and cm throughout or you must use kg and m. And note that if you measure the weight in N you must convert it into g or kg.

THE DENSITY OF A REGULARLY SHAPED OBJECT

WORKED EXAMPLE



The brick has dimensions 20 cm x 9 cm x 6.5 cm.
Weight of brick = 22.2 N
What is the density of the brick?



Mass of brick, m $= \frac{W}{g}$

$= \frac{22.2}{10}$ kg

$= 2.22$ kg

$= 2220$ g

(Remember that 1 kg = 1000 g)

Volume of brick, V $= 20 \times 9 \times 6.5$ cm^3

$= 1170$ cm^3

Density of brick, d $= \frac{\text{mass}}{\text{volume}}$

$= \frac{2220}{1170}$ g/cm^3

$= 1.90$ g/cm^3

Note that the density of water is 1.0 g/cm^3, and the rule is that an object of greater density will sink in a liquid of lower density. So, perhaps not surprisingly, the brick will sink in water. But will it sink in mercury? See the table right.

Some useful densities

	Density in g/cm^3	Density in kg/m^3
Vacuum	0	0
Helium gas	0.00017	0.17
Air	0.00124	1.24
Oil (Petroleum)	0.88	880
Water	1.0	1000
Seawater	1.03	1030
Plastic	0.9 – 1.6	900 – 1600
Wood	0.5 – 1.3	500 – 1300
Magnesium	1.74	1740
Aluminium	2.7	2700
Titanium	4.5	4500
Steel	7.8	7800
Mercury (liquid)	13.6	13600
Silver	10.5	10500
Gold	19.3	19300

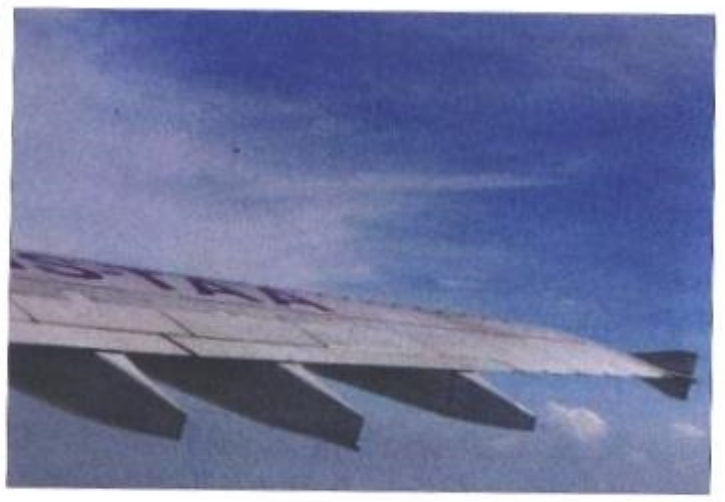
WHY DO MATERIALS HAVE DIFFERENT DENSITIES?

If you look inside a block of gold and inside a block of aluminium with a modern electron microscope, you will see that the atoms are almost exactly the same size (the gold atoms are just a little bit bigger). As we will see later, most of an atom is actually empty space, and the mass of an atom is concentrated in the nucleus, which is far smaller than the atom. So the extra density of the gold is due to the fact that the nuclei of the gold atoms are far more massive than the nuclei of the aluminium ones.

Many materials have a lower density because they contain large air bubbles or other voids inside them. Bread has a lower density than most cakes; and expanded polystyrene cups have a lower density than other cups.

A bag of popcorn has a far lower density than the same bag filled with corn that has not been popped.

The choice of materials used to make an aircraft is critical in making it as light as possible and thus reducing fuel consumption.



An aeroplane is another example of a lower density. Although aeroplanes are made of aluminium and other metals of lower density, there is no way that an aeroplane could fly if it was made of solid aluminium. In fact, because most of the inside of an aeroplane consists of air, the average densities of all aeroplanes are sufficiently low that, in the event of a forced landing on water, they can easily float for long enough for everyone to escape.

WORKED EXAMPLE

What is the mass of a block of expanded polystyrene that is 1 m long, 0.5 m wide and 0.3 m high? The density of this sample of expanded polystyrene is 8 kg/m^3.

Volume of block, V $= 1.0 \times 0.5 \times 0.3$ m^3
$= 0.15$ m^3

Write down the formula: $m = d \times V$

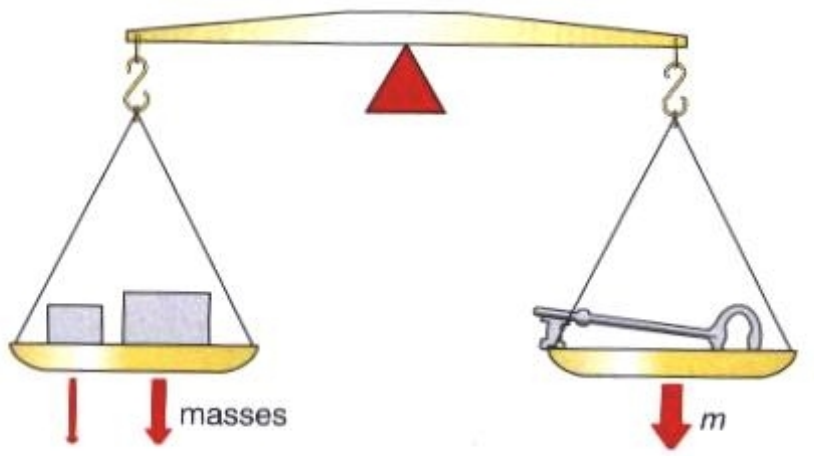
Substitute the values for d and V: $m = 8 \times 0.15$ kg

Work out the answer and write down the units: $m = 1.2$ kg

MEASURING THE DENSITY OF AN IRREGULAR OBJECT

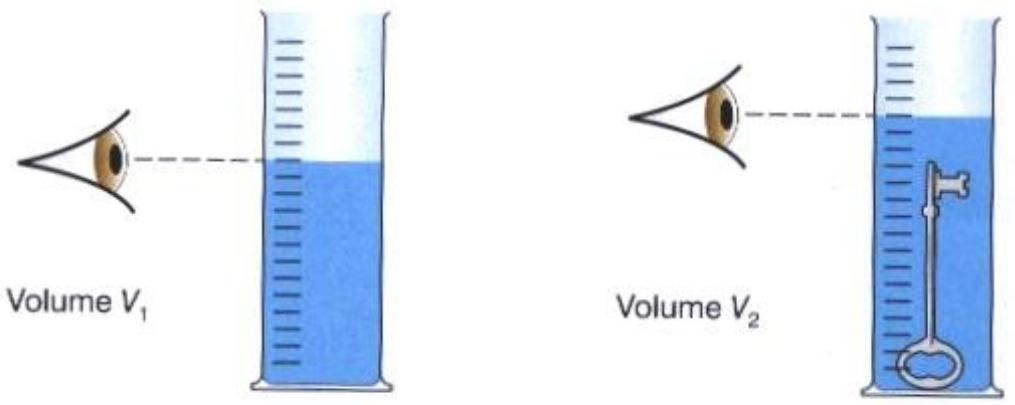
This method only works if the object is denser than the liquid used so that it sinks. It does not work if the object absorbs the liquid, nor if it is damaged by the liquid.

Step 1



Use a balance to weigh the object in question and so find its mass, m.

Step 2



Choose a measuring cylinder that will accept the object. A narrower cylinder will give a more accurate answer than a wider one. Add liquid to the cylinder to fill it to a deep enough level so that the object will be completely submerged, and then measure the volume of liquid V_1. The exact amount of liquid that you use is not at all critical. Water is often the liquid used.

Step 3

Lower the object into the liquid (without splashing) and measure the new reading V_2. This is the volume of the object and the liquid. The volume of the object is $V_2 - V_1$.

From the mass and the volume you can calculate the density of the object.

WORKED EXAMPLE

A small metal statue is measured to have a mass of 90 g.
A measuring cylinder is filled with water to the 82 cm^3 mark. The statue is lowered into the measuring cylinder and the water rises to the 91 cm^3 mark. What is the statue made of?

Volume of the statue $= 91 - 82\ cm^3$
$= 9\ cm^3$

Write down the formula: $d = \frac{m}{V}$

Substitute the values for m and V: $d = \frac{90}{9}$

Work out the answer and write down the units: $d = 10\ g/cm^3$

So from the table on page 21, the statue is made of, what?

Of course an experiment of this type is never perfectly accurate, so the density that you measure will never be exactly the same as the official values.

REVIEW QUESTIONS

Q1 For each of the following objects, state whether they will sink or float or whether the outcome depends on the sample of material chosen:

a wood in oil
b wood in mercury
c plastic in oil
d steel in mercury
e silver in air
f gold in mercury (this experiment must be done rapidly as the gold will dissolve very quickly)
g helium balloon in air.

Q2 Write out the worked example on page 20 for the case of the student who measures all the lengths of the brick in m, and calculates with the mass in kg. Give the answer in kg/m^3.

Q3 A king believes that his jeweller has given him a crown that is a mixture of gold and silver, and not the 1.93 kg of pure gold that he paid for. He weighs the crown in a balance and finds that it has the correct mass of 1.93 kg. He then immerses it in a measuring jug where the water level was 800 cm^3. If the crown is pure gold, what will the new water level be? What will happen to the water level if the jeweller has cheated?

Examination questions are on page 50.

More questions on the CD ROM