Density

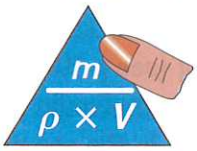
Time for some maths I'm afraid. But at least it comes with a fun experiment, so it's not all bad...

Density is Mass per Unit Volume

Density is a measure of the 'compactness' (for want of a better word) of a substance. It relates the mass of a substance to how much space it takes up.

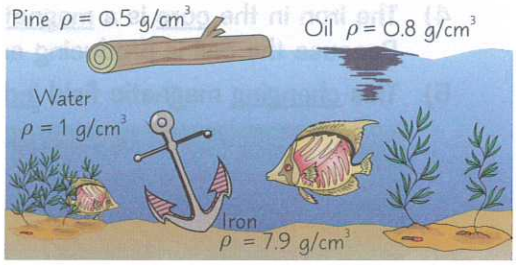
The symbol for density is a Greek letter rho (ρ) — it looks like a p but it isn't.

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$



The units of density are g/cm³ or kg/m³.

1) The density of an object depends on what it's made of. Density doesn't vary with size or shape.
2) The average density of an object determines whether it floats or sinks — a solid object will float on a fluid if it has a lower average density than the fluid.

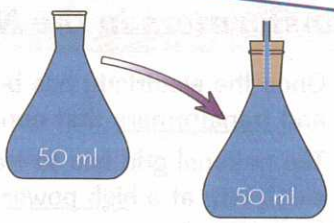


You Can Find the Density of Solids and Liquids

1) To find the density of a substance, measure its mass and volume and use the formula above.
2) The easiest way to find the density of a liquid is to use a measuring cylinder.
3) Use a mass balance (p.208) to measure the mass of the empty measuring cylinder.
4) Pour in the liquid you're investigating. Measure the mass of the cylinder again — the difference in mass is equal to the mass of the liquid.
5) Finding the volume of the liquid is easy — just read it from the cylinder's scale. 1 ml = 1 cm³.
6) If you want to measure the volume of a prism, find the area of its base and then multiply it by its height. For a cube this is dead easy — it's just length × width × height.
7) If your object isn't a regular shape, you can find its volume using the fact that an object submerged in water will displace a volume of water equal to its own volume. One way of doing this is to use a density bottle:

PRACTICAL

1) Measure the mass (m_1) of the object using a mass balance.
2) Fill the bottle with a liquid of a known density (e.g. water).
3) Place the stopper into the bottle and dry the outside.
4) Measure the mass of the bottle (m_2).
5) Empty the bottle and place the object into the density bottle. Repeat steps 2 and 3. Measure the mass of the bottle (m_3).
6) Calculate the volume of displaced water:
   - The mass of the displaced water = $m_2 - (m_3 - m_1)$
   - You know the density of water, so you can use $V = m \div \rho$ to find the volume displaced. This equals the volume of the object.
7) Calculate the density of the object using $\rho = m \div V$ with the mass you measured in step 1 (m_1) and the volume you calculated in step 6.



Liquid is pushed up the tube in the stopper, so the volume inside the bottle is constant.

You can also use a eureka can and a measuring cylinder if you don't have access to density bottles.

I'm feeling a bit dense after that lot...

Remember — density is all about how tightly packed the particles in a substance are. Nice and simple really.

Q1 An object has a mass of 0.45 kg and a volume of 75 cm³. Calculate its density in kg/m³. [3 marks]

Q2 A cube has edges of length 1.5 cm and an average density of 3500 kg/m³. What is its mass? [3 marks]

Density

1 A 0.5 m^3 block of tungsten has a mass of 10 000 kg. Grade 4-6

a) i) Write down the equation that links density, mass and volume.

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[1]

ii) Calculate the density of tungsten.

Density = ... kg/m^3

[2]

b) Calculate the mass of a 0.02 m^3 sample cut from the tungsten block.

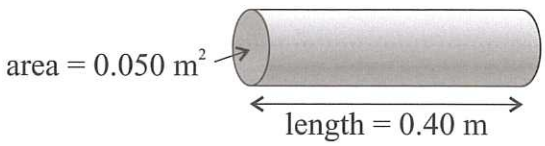
Mass = ... kg

[2]

[Total 5 marks]

2 The titanium bar shown in **Figure 1** has a mass of 90.0 kg. Grade 6-7

Figure 1



Calculate the density of titanium.

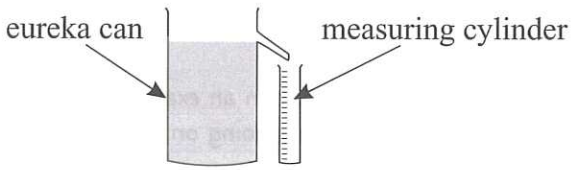
Density = ... kg/m^3

[Total 3 marks]

PRACTICAL

3 A student uses the apparatus in **Figure 2** to calculate the volumes of different rings to determine what materials they are made from. Grade 6-7

Figure 2



The can is filled up to the spout so that when a ring is placed in the can, the displaced water flows into the measuring cylinder. **Figure 3** shows an incomplete table of the student's results.

Figure 3

Ring	Mass (g)	Water displaced (ml)	Material
A	5.7	0.30	.....
B	2.7	0.60	.....
C	3.0	0.30	.....

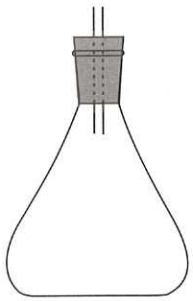
One ring is made from gold, one is made from silver and the other is made from titanium.
Complete **Figure 3** using the following information:
Density of gold = 19 g/cm^3 Density of silver = 10 g/cm^3 Density of titanium = 4.5 g/cm^3

[Total 5 marks]

PRACTICAL

4 **Figure 4** shows a density bottle. When full, the density bottle holds a set volume of liquid that is accurately known. Grade 6–7

Figure 4



Describe how the student could use a density bottle and a mass balance to calculate the density of a small, irregularly-shaped object.

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[Total 6 marks]

Exam Practice Tip

You may be asked about experiments you've never seen before in an exam, but don't panic. To get full marks, take your time to read all the information carefully and work out what's going on before attempting any questions.