7.1: Density

As an example of a quantity involving mixed units, consider the important quantity called density. Density is defined to be mass per unit volume:

$$\rho = \frac{M}{V} \tag{7.1.1}$$

Here ρ is the density of a body, M is its mass, and V is its volume. The SI units of density are $\mathrm{kg/m^3}$; mass has SI units of kg, and volume has SI units of $\mathrm{m^3}$.

Density is a measure of how heavy something is for a fixed volume. For example, lead has a high density; styrofoam has a low density.

It is common to find densities of materials listed in handbooks in units of $\mathrm{g/cm^3}$. Since the density of water is $1\ \mathrm{g/cm^3}$, this makes it easy to compare a material's density with water. But in doing calculations involving density, you'll need to use SI units, $\mathrm{kg/m^3}$. A useful conversion factor to remember to convert between these units is the density of water: it's $1\ \mathrm{g/cm^3} = 1000\ \mathrm{kg/m^3}$.

Occasionally we'll run into other definitions of density. For two-dimensional bodies, for example, we define an area density σ (mass per unit area) by $\sigma = M/A$. For one-dimensional bodies, we define a linear density λ (mass per unit length) by $\lambda = M/L$. And sometimes we may need to define something like a charge density (electric charge per unit volume) or a number density (number of particles per unit volume). Unless otherwise indicated, though, the word "density" usually refers to mass density.

Often the density of a material is a useful clue to determining its composition. For example, suppose you're handed a gold-colored brick. Is the brick solid gold, or is it just a block of lead covered with gold paint? Of course, you could just scratch the brick to see if the gold is just painted on, but suppose you don't want to damage the brick? One test you might do is determine the brick's density. First, determine the volume of the block (either by measuring the brick or by immersing it in a calibrated beaker of water). Then place the brick on a scale to find its mass. Now divide the mass by the volume to find the density, and compare with the densities of gold $\left(19.3\ \mathrm{g/cm^3}\right)$ and lead $\left(11.3\ \mathrm{g/cm^3}\right)$ [1]

Densities of some common materials are shown in Table $7.1.1$

Table $7.1.1$. Densities of some materials.

Material	Density $\frac{g}{cm^3}$
Air (STP)	0.001275
Ice	0.9169
Water	1.000
Aluminum	2.6989
Iron	7.874
Silver	10.50
Lead	11.35
Mercury	13.55
Gold	19.3
Osmium	22.59

1. It happens that tungsten also has a density of $19.3\ \mathrm{g/cm^3}$, so the density test alone would not be sufficient to distinguish a solid gold brick from a gold-painted tungsten brick. In that case, some other test would be required, such as measuring the brick's hardness or electrical resistivity.