Density

Comparison of Materials

We are often interested in having a final product that is light in weight. Rarely, however, do we select a material solely for its density. Most often, we combine density with a strength property. We will look at an example of this for yield strength in subunit 3.4.

The values in the table below are for specific gravity (SG), which is defined as the ratio of the density of a material to the density of water. Under common conditions of temperature and pressure, water has a density of approximately 1000 kg/m^3.

Specific Gravity (dimensionless)

2.0 – 20.0	METALS		CERAMICS (glasses)	COMPOSITES
0.2 – 2.0		PLASTICS (elastomers)	(porous)	(woods)
0.02 – 0.2		(foams)		

Key:	CERAMICS	Engineering Ceramics
	PLASTICS	Engineering Polymers
	COMPOSITES	Engineering Composites
	(porous)	Porous Ceramics
	(foams)	Foamed Polymers

Commentary

Of the major materials classes, only plastics are significantly less dense than the others. Some plastics float (SG < 1.0), and some sink (SG > 1.0). Within the classes, there are smaller spreads in specific gravity.

Commentary – Metals

Steels	SG = 7.9
Titanium alloys	SG = 4.5
Aluminum alloys	SG = 2.7
Magnesium alloys	SG = 1.7

Copper (SG = 8.9) is heavier than any of the above, but the very heavy metals are the noble metals: silver (SG = 10.5), gold (SG = 19.3), and platinum (SG = 21.4). These numbers are representative of their alloy systems, as alloying elements generally have a small effect on density.

Commentary – Polymers – Thermoplastics

PVC	SG =	1.3 – 1.6	vinyl chloride
PC	SG =	1.2 – 1.3	carbonate
PMMA	SG =	1.2 – 1.3	methyl methacrylate
PS	SG =	1.0 – 1.1	styrene
PE	SG =	0.91 – 0.97	ethylene
PP	SG =	0.88 – 0.91	propylene

Thermosetting plastics (SG = 1.1 – 1.4) are in the middle of the above list of thermoplastics; elastomers are about (SG = 0.8 – 0.9); and foamed polymers, which are mostly air, have densities in the range (SG = 0.01 – 0.6).

As suggested by the ranges of values, these numbers are more approximate than those for metals. In addition to differing chemistry, molecular weight and degree of crystallinity are also important variables with polymers.

Commentary – Ceramics – Engineering Ceramics

WC	SG =	15.6
ZrO_2	SG =	5.7
Al_2O_3	SG =	3.9
C	SG =	3.5
SiC	SG =	3.2

Carbon and oxygen are relatively light atoms, so these engineering ceramics tend to order according to the atomic weight of their metallic elements.

Commentary – Ceramics – Porous Ceramics

These lighter ceramics have specific gravities in the range of 2.0 to 2.5. Concrete is typically less dense than aluminum, which can lead to some creative applications. Civil engineering students like to hold concrete canoe races.

Commentary – Ceramics – Glasses

The open random structure of glasses results in densities that are comparable to the porous ceramics.

Commentary – Composites

Glass fibers are heavier than carbon fibers. This makes GFRP composites (SG = 1.4 – 2.2) slightly more dense than CFRPs (SG = 1.5 – 1.6). These densities are comparable to the lightest metals. Woods float and are lighter still with (SG = 0.4 – 0.8).