DENSITY AND BUOYANT FORCE

Have you ever felt confined in a crowded elevator? You probably felt that way because there were too many people in the elevator for the amount of space available. In other words, the *density* of people was too high. In general, density is a measure of a quantity in a given space. The quantity can be anything from people or trees to mass or energy.

Mass density is mass per unit volume of a substance

When the word *density* is used to describe a fluid, what is really being measured is the fluid's **mass density.** Mass density is the mass per unit volume of a substance. It is often represented by the Greek letter ρ (*rho*).

mass density

the concentration of matter of an object, measured as the mass per unit volume of a substance

MASS DENSITY

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

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

The SI unit of mass density is kilograms per cubic meter (kg/m^3). In this book we will follow the convention of using the word *density* to refer to *mass density.* **Table 1** lists the densities of some fluids and a few important solids.

Solids and liquids tend to be almost incompressible, meaning that their density changes very little with changes in pressure. Thus, the densities listed in **Table 1** for solids and liquids are approximately independent of pressure. Gases, on the other hand, are compressible and can have densities over a wide range of values. Thus, there is not a standard density for a gas, as there is for solids and liquids. The densities listed for gases in **Table 1** are the values of the density at a stated temperature and pressure. For deviations of temperature and pressure from these values, the density of the gas will vary significantly.

Table 1
Densities of Some Common Substances*

Substance	ρ (kg/m^3)
Hydrogen	0.0899
Helium	0.179
Steam (100°C)	0.598
Air	1.29
Oxygen	1.43
Carbon dioxide	1.98
Ethanol	0.806×10^3
Ice	0.917×10^3
Fresh water (4°C)	1.00×10^3
Sea water (15°C)	1.025×10^3
Iron	7.86×10^3
Mercury	13.6×10^3
Gold	19.3×10^3

*All densities are measured at 0°C and 1 atm unless otherwise noted.

Buoyant forces can keep objects afloat

Have you ever wondered why things feel lighter underwater than they do in air? The reason is that a fluid exerts an upward force on objects that are partially or completely submerged in it. This upward force is called a **buoyant force.** If you have ever rested on an air mattress in a swimming pool, you have experienced a buoyant force. The buoyant force kept you and the mattress afloat.

Because the buoyant force acts in a direction opposite the force of gravity, the net force acting on an object submerged in a fluid, such as water, is smaller than the object's weight. Thus, the object appears to weigh less in water than it does in air. The weight of an object immersed in a fluid is the object's *apparent weight.* In the case of a heavy object, such as a brick, its apparent weight is less in water than its actual weight is in air, but it may still sink in water because the buoyant force is not enough to keep it afloat.

buoyant force

the upward force exerted by a liquid on an object immersed in or floating on the liquid