6.1 DENSITY AND INCOMPRESSIBLE FLUIDS

Density (ρ) of a material is defined as mass (M) divided by volume (V).

$$\rho = \frac{M}{V} \tag{6.1}$$

Density has the dimension of mass over length cubed, and has units of kg/m^3 in kg-m-sec system of the SI units. In the cgs system, the unit for density is g/cc, or gram per cubic cm, which is equal to one-thousand kg/m^3.

$$1 \text{ g/cc} = 1000 \text{ kg/m}^3.$$

The density of a homogeneous material is same everywhere, but for an inhomogeneous material, such as a mixture of two immiscible substances, the density will depend on the location. Therefore, we will introduce a concept, called the local density, $\rho(x, y, z)$, which is a function of the coordinates of the space point (Fig. 6.1).

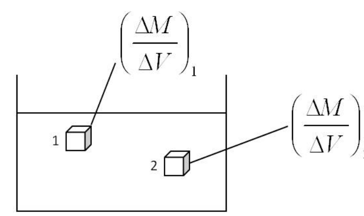

Figure 6.1: Density may be different at different places. Local density at a point is obtained from mass over volume in small volume around that point.

Local density can be obtained by a limiting process from the average density in a small volume around the space point. We write this process as a limit.

$$\rho(x, y, z) = \lim_{\Delta V \to 0} \left(\frac{\Delta M}{\Delta V}\right) \tag{6.2}$$

The densities of gases vary considerably with temperature, while the densities of liquids vary little with temperature. Therefore, we will treat the densities of liquids as constant. The variation of the density of gases with temperature will be studied in the chapter on heat and temperature.

The density is a dimensionful property. Therefore, you need to keep track of units to compare two densities. For comparison purposes a more convenient dimensionless quantity called the **specific gravity** is constructed. Specific gravity is defined as the ratio of the density of the material to the density of water at 0°C and one atmospheric pressure, which is 1 g/cc.

$$\text{Specific gravity} = \frac{\text{Density of material}}{\text{Density of water}}$$

Specific gravity, being dimensionless, provides a ready comparison among materials without having to worry about the unit of density. For instance density of aluminum is 2.7 in g/cc and 2700 in kg/m^3, but specific gravity is 2.7 regardless of the unit of density. The density of some common substances are listed in Table 6.1.

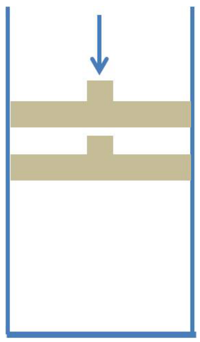

Figure 6.2: Gases are much more compressible than liquids or solids.

We will be dealing with fluids whose density does not change appreciably regardless of the physical conditions imposed them. We call these fluids incompressible. Liquids are to a large extent incompressible. Gases are quite compressible as you can easily demonstrate by filling a container with a gas. If the container is made up of a rigid material and the lid of the container can slide, you will find that the lid can be moved in and out to change the volume occupied by the same gas. This makes it easy to change the density of a gas.

Table 6.1: Density of some common substances at 0°C and 1 atm in g/cc. To obtain density in kg/m^3 multiply by 1000.

Material	Density (g/cc)	Material	Density (g/cc)
Solids		**Liquids**	
Aluminum	2.7	Alcohol, ethanol	0.81
Brass	8.6	Blood	1.05
Concrete	2	Gasoline	0.68
Copper	8.9	Glycerol	1.26
Glass	2.5	Mercury	13.6
Granite	2.7	Olive oil	0.92
Gold	19.3	Sea water	1.03
Ice	0.92	Water $(40°C)$	1.0
Iron	7.8	**Gases**	
Lead	11.3	Air	1.3×10^{-3}
Platinum	21.4	Carbon dioxide	2.0×10^{-3}
Silver	10.5	Helium	2.0×10^{-4}
Steel	7.8	Water $(steam, 100°C)$	6.0×10^{-4}
Wood	0.5		