# Density

The density is defined at any point in the body of a fluid by choosing a very small volume around that point and assessing the mass within that volume divided by the volume. It is a fundamental thermodynamic quantity characterizing the state of the fluid at that location within the fluid and can be used with one other thermodynamic variable such as the **pressure**, **temperature**, **entropy** or **enthalpy** to completely define the state of the fluid at that location.

The density therefore has units of mass per unit volume ($M/L^3$) or $kg/m^3$. It is useful to remember that under normal atmospheric conditions the density of water is approximately $1000kg/m^3$ and the density of air is approximately $1kg/m^3$. More specific data is included in Figure 1 which shows how the densities of water and mercury vary with temperature at a pressure of one atmosphere and in Figure 2 which shows how the density of water varies with pressure at $0°C$.

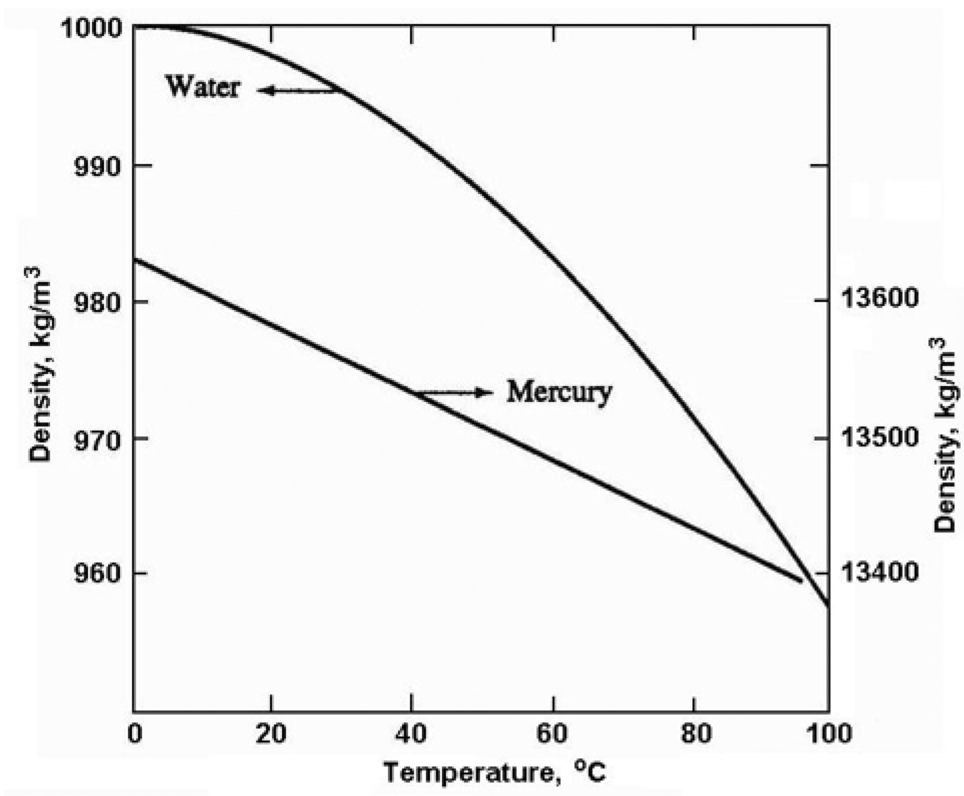


Figure 1: The density of water and mercury as a function of temperature at a pressure of one atmosphere.

In general, the variation of density with a pair of thermodynamic variables is given by the **equation of state** for that fluid. Simple equations of state for the commonly encountered fluids water and air are as follows. Though the **compressibility** of water is sometimes important, it is frequently sufficient to assume that water is **incompressible**, that is to say that its density is independent of the pressure and a function only of temperature. Commonly the temperature is the same throughout the flow and then the density is constant everywhere. It is more commonly the case that the variations in the density within a air or gas flow need to be taken into account. Usually, it is sufficient to assume that these changes can be

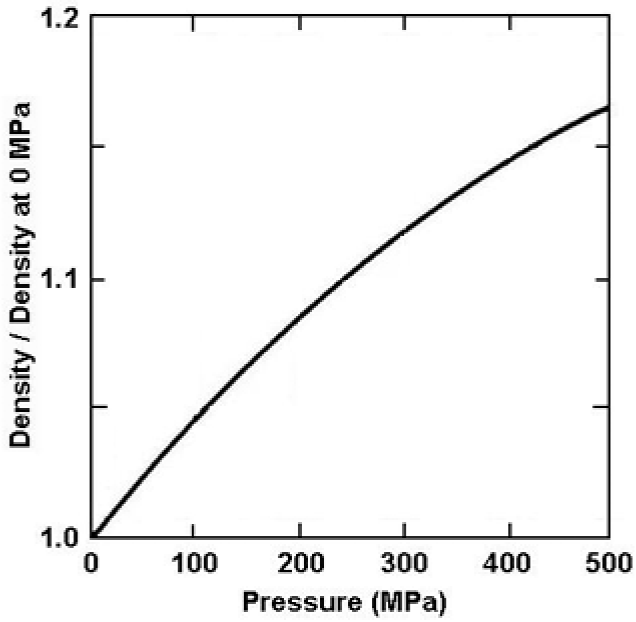


Figure 2: The variation in the density of water with pressure at $0°C$.

taken into account by assuming that the **density**, $\rho$, **temperature**, $T$, and **pressure**, $p$, can be related through the **perfect gas** law:

$$p = \rho \mathcal{R} T \qquad \text{(Abb1)}$$

where $\mathcal{R}$ is the gas constant for the gas in question.

In most of this book we will focus one of two characteristic though simplistic fluids: (a) an incompressible fluid (usually representing water) whose density, $\rho$, is known, constant and uniform throughout the fluid flow and (b) a perfect gas (usually representing air whose pressure, $p$, temperature, $T$, and density, $\rho$, are related by the perfect gas law, $p = \rho \mathcal{R} T$). While many departures from these two idealized fluids will need to be considered we shall do so as the circumstances demand it.