27.3: Pressure in a Fluid

When a shear force is applied to the surface of fluid, the fluid will undergo flow. When a fluid is static, the force on any surface within fluid must be perpendicular (normal) to each side of that surface. This force is due to the collisions between the molecules of the fluid on one side of the surface with molecules on the other side. For a static fluid, these forces must sum to zero. Consider a small portion of a static fluid shown in Figure 27.1. That portion of the fluid is divided into two parts, which we shall designate 1 and 2, by a small mathematical shared surface element S of area A_S. The force $\overrightarrow{\mathbf{F}}_{1,2}(S)$ on the S surface of region 2 due to the collisions between the molecules of 1 and 2 is perpendicular to the surface.

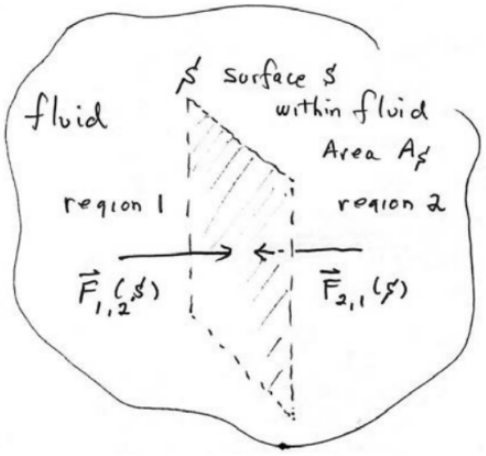

Figure 27.1: Forces on a surface within a fluid

The force $\overrightarrow{\mathbf{F}}_{21}(S)$ on the surface of region 1 due to the collisions between the molecules of 1 and 2 by Newton's Third Law satisfies

$$\overrightarrow{\mathbf{F}}_{1,2}(S) = -\overrightarrow{\mathbf{F}}_{2,1}(S)$$

Denote the magnitude of these forces that form this interaction pair by

$$F_{\perp}(S) = \left|\overrightarrow{\mathbf{F}}_{1,2}(S)\right| = \left|\overrightarrow{\mathbf{F}}_{2,1}(S)\right|$$

Define the hydrostatic pressure at those points within the fluid that lie on the surface S by

$$P \equiv \frac{F_{\perp}(S)}{A_S}$$

The pressure at a point on the surface S is the limit

$$P = \lim_{A_S \to 0} \frac{F_{\perp}(S)}{A_S}$$

The SI units for pressure are $\mathrm{N \cdot m^{-2}}$ and is called the pascal (Pa), where

$$1\mathrm{Pa} = 1\mathrm{N \cdot m^{-2}} = 10^{-5}\mathrm{bar}$$

Atmospheric pressure at a point is the force per unit area exerted on a small surface containing that point by the weight of air above that surface. In most circumstances atmospheric pressure is closely approximated by the hydrostatic pressure caused by the weight of air above the measurement point. On a given surface area, low-pressure areas have less atmospheric mass above their location, whereas high-pressure areas have more atmospheric mass above their location. Likewise, as elevation increases, there is less overlying atmospheric mass, so that atmospheric pressure decreases with increasing elevation. On average, a column of air one square centimeter in cross-section, measured from sea level to the top of the atmosphere, has a mass of about 1.03 kg and weight of about 10.1 N. (A column one square inch in cross-section would have a weight of about 14.7 lbs, or about 65.4 N). The standard atmosphere [atm] is a unit of pressure such that

$$1\text{atm} = 1.01325 \times 10^5 \text{Pa} = 1.01325\text{bar}$$