10–3 Pressure in Fluids

Pressure is defined as force per unit area, where the force F is understood to be the magnitude of the force acting perpendicular to the surface area A:

$$\text{pressure} = P = \frac{F}{A}. \quad \textbf{(10–2)}$$

Pressure defined

Although force is a vector, pressure is a scalar. Pressure has magnitude only. The SI unit of pressure is N/m^2. This unit has the official name **pascal** (Pa), in honor of Blaise Pascal (see Section 10–5); that is, $1\,Pa = 1\,N/m^2$. However, for simplicity, we will often use N/m^2. Other units sometimes used are $dynes/cm^2$, and $lb/in.^2$ (abbreviated "psi"). Several other units for pressure are discussed, along with conversions between them, in Section 10–6 (see also the Table inside the front cover).

CAUTION
Pressure is a scalar, not a vector

The pascal (unit)

EXAMPLE 10–2 Calculating pressure. The two feet of a 60-kg person cover an area of $500\,cm^2$. (*a*) Determine the pressure exerted by the two feet on the ground. (*b*) If the person stands on one foot, what will the pressure be under that foot?

APPROACH Assume the person is at rest. Then the ground pushes up on her with a force equal to her weight mg, and she exerts a force mg on the ground where her feet (or foot) contact it. Because $1\,cm^2 = (10^{-2}\,m)^2 = 10^{-4}\,m^2$, then $500\,cm^2 = 0.050\,m^2$.

SOLUTION (*a*) The pressure on the ground exerted by the two feet is

$$P = \frac{F}{A} = \frac{mg}{A} = \frac{(60\,kg)(9.8\,m/s^2)}{(0.050\,m^2)} = 12 \times 10^3\,N/m^2.$$

(*b*) If the person stands on one foot, the force is still equal to the person's weight, but the area will be half as much, so the pressure will be twice as much: $24 \times 10^3\,N/m^2$.

Pressure is particularly useful for dealing with fluids. It is an experimental observation that *a fluid can exert a pressure in any direction*. This is well known to swimmers and divers who feel the water pressure on all parts of their bodies. At any point in a fluid at rest, the pressure is the same in all directions at a given depth. This is illustrated in Fig. 10–1. Consider a tiny cube of the fluid which is so small that we can ignore the force of gravity on it. The pressure on one side of it must equal the pressure on the opposite side. If this weren't true, there would be a net force on the cube and it would start moving. If the fluid is not flowing, then the pressures must be equal.

Fluids exert pressure in all directions

Another important property of a fluid at rest is that the force due to fluid pressure always acts *perpendicular* to any solid surface it is in contact with. If there were a component of the force parallel to the surface, as shown in Fig. 10–2, then according to Newton's third law the solid surface would exert a force back on the fluid that also would have a component parallel to the surface. Such a component would cause the fluid to flow, in contradiction to our assumption that the fluid is at rest. Thus the force due to the pressure in a fluid at rest is always perpendicular to the surface.

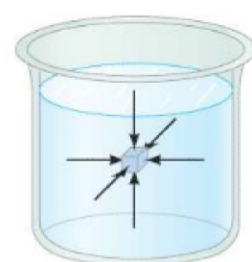

FIGURE 10–1 Pressure is the same in every direction in a fluid at a given depth; if it weren't, the fluid would be in motion.

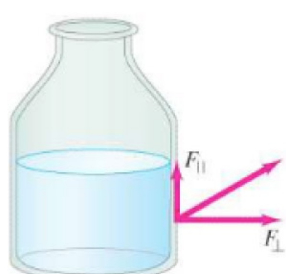

FIGURE 10–2 If there were a component of force parallel to the solid surface of the container, the liquid would move in response to it. For a liquid at rest, $F_{\parallel} = 0$.