6.2 PRESSURE

The contact forces such as the normal force, frictional force, push, etc, act at the surface of a body. An important characteristics of fluids is that there is no significant reaction force from the fluid when you apply a force horizontal to the surface of the fluid. The fluid simply flows under such a force.

A vertical force, however, compresses or expands the fluid. Suppose you try to compress a fluid, then you would find that a reaction force develops at each point inside the fluid in the outward direction that balances the force applied on the molecules at the boundary. **Pressure** (p) is defined to be the normal force ($F_\perp$) divided by the area (A) over which the force acts (Fig. 6.3):

$$p = F_\perp / A. \tag{6.3}$$

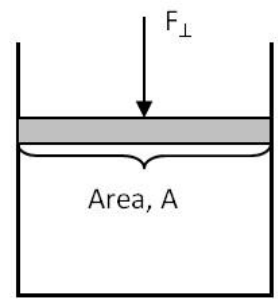

Figure 6.3: Defining pressure. Pressure is equal to the perpendicular component of force divided by area over which the force acts.

The dimension of pressure is

$$[M][L]^{-1}[T]^{-2},$$

and therefore the unit in SI system is kg/m.s^2 or N/m^2, which is named **Pascal (Pa)** in honor of the French mathematician and physicist Blaise Pascal (1623-1662). Actually, other units of pressure are in more common use in physics and engineering. For instance, the ambient pressure due to the atmosphere is called **one atmosphere (atm)** which is approximately 1.013×10^5 Pa. We will see below that the pressure at the bottom of a 760-mm high column of mercury at 0°C in a container where the top part is evacuated is equal to the atmospheric pressure. Thus, 760-mmHg is also used in place of 1 atmospheric pressure.

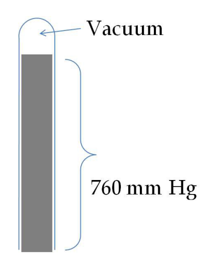

Figure 6.4: Atmospheric pressure can support the weight of a 760 mm column of mercury.

In vacuum physics labs, one often uses another unit called Torr, named after the Italian inventor Evangelista Torricelli (1608-1647), who invented the mercury manometer for measuring pressure. One Torr is equal to a pressure of 1-mmHg. Low pressure in SI units is sometimes expressed in yet another unit called millibar or mbar, which is equal to 100 Pa, with a bar being 10^5 Pa. The multitude of units for pressure is certainly very confusing to students. A summary of their relations is provided in the margin for a quick reference.

The inverse area in the definition of pressure has interesting physical implications. For instance, a force applied on an area of 1 mm^2 has a pressure that is 100 times as great as the same force applied on an area of 1 cm^2. That is why a sharp pin is able to poke though skin when a small force is exerted while a blunted metal rod cannot

Table 6.2: Pressures in universe (Source: various)

Place	Pressure (Pa)
Center of the Sun	$\approx 3x10^{16}$
Mechanical Vacuum Pump	100 to 10^{-4}
Center of the Earth	$\approx 4x1011$
Cryopump molecular beam epitaxy	10^{-9}
Atmosphere	1.013×10^5
On the Moon	10^{-9}
Vacuum cleaner	$\approx 8 \times 10^4$
Interstellar space	10^{-15}

with the same force. When a force is applied to the pin, the pressure applied on the skin is balanced up to a maximum. But, since the area of the tip of the pin is small, the pressure from the applied force is great. Pressure form the outside agent on the area of the skin at the tip far exceeds the pressure on the skin from inside the body and that applied by adjoining parts of the skin. This makes it possible for a sharp needle to pierce the skin more easily than a dull needle.

Many units of pressure
SI unit:
1 Pa = 1 N/m^2
English unit:
pounds per square inch (lbs/in^2 or psi),
1 psi = 7.015×10^3 Pa

Other units of pressure:
1 atm = 760 mmHg = 1.013 $\times10^5$ Pa = 14.7 psi = 29.9 inches of Hg
1 Torr = 1 mmHg = 133.29 Pa
1 bar = 10^5 Pa