10–5 Pascal's Principle

The Earth's atmosphere exerts a pressure on all objects with which it is in contact, including other fluids. External pressure acting on a fluid is transmitted throughout that fluid. For instance, according to Eq. 10–3a, the pressure due to the water at a depth of 100 m below the surface of a lake is $P = \rho g\,\Delta h = (1000\,\mathrm{kg/m^3})(9.8\,\mathrm{m/s^2})(100\,\mathrm{m}) = 9.8 \times 10^5\,\mathrm{N/m^2}$, or 9.7 atm. However, the total pressure at this point is due to the pressure of water plus the pressure of the air above it. Hence the total pressure (if the lake is near sea level) is $9.7\,\mathrm{atm} + 1.0\,\mathrm{atm} = 10.7\,\mathrm{atm}$. This is just one example of a general principle attributed to the French philosopher and scientist Blaise Pascal (1623–1662).

Pascal's principles

Pascal's principle states that *if an external pressure is applied to a confined fluid, the pressure at every point within the fluid increases by that amount.*

PHYSICS APPLIED

Hydraulic lift

A number of practical devices make use of Pascal's principle. One example is the hydraulic lift, illustrated in Fig. 10–7a, in which a small input force is used to exert a large output force by making the area of the output piston larger than the area of the input piston. To see how this works, we assume the input and output pistons are at the same height (at least approximately). Then the external input force F_{in}, by Pascal's principle, increases the pressure equally throughout. Therefore, at the same level (see Fig. 10–7a),

$$P_{\mathrm{out}} = P_{\mathrm{in}}$$

where the input quantities are represented by the subscript "in" and the output by "out." Since $P = F/A$, we write the above equality as

$$\frac{F_{\mathrm{out}}}{A_{\mathrm{out}}} = \frac{F_{\mathrm{in}}}{A_{\mathrm{in}}},$$

or

$$\frac{F_{\mathrm{out}}}{F_{\mathrm{in}}} = \frac{A_{\mathrm{out}}}{A_{\mathrm{in}}}.$$

Mechanical advantage

The quantity $F_{\mathrm{out}}/F_{\mathrm{in}}$ is called the *mechanical advantage* of the hydraulic lift, and it is equal to the ratio of the areas. For example, if the area of the output piston is 20 times that of the input cylinder, the force is multiplied by a factor of 20: thus a force of 200 lb could lift a 4000-lb car.

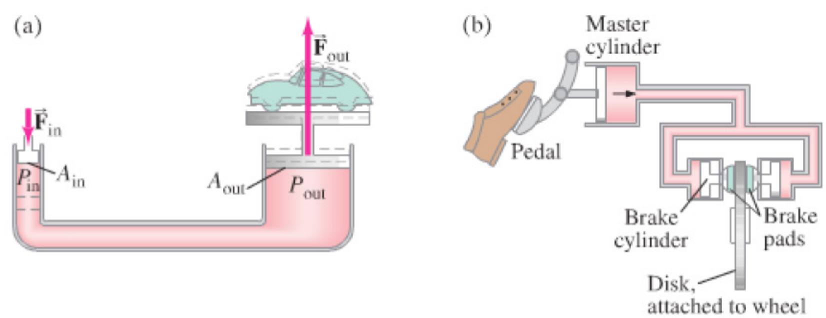

FIGURE 10–7 Applications of Pascal's principle: (a) hydraulic lift; (b) hydraulic brakes in a car.

PHYSICS APPLIED

Brakes

Figure 10–7b illustrates the brake system of a car. When the driver presses the brake pedal, the pressure in the master cylinder increases. This pressure increase occurs throughout the brake fluid, thus pushing the brake pads against the disk attached to the car's wheel.

10–6 Measurement of Pressure; Gauges and the Barometer

Manometer

Many devices have been invented to measure pressure, some of which are shown in Fig. 10–8. The simplest is the open-tube *manometer* (Fig. 10–8a), which is a U-shaped tube partially filled with a liquid, usually mercury or water. The pressure P being measured is related (by Eq. 10–3b) to the difference in