(2-9) Pascal's principle

The pressure exerted on the bottom of a pool of water by the water itself is given by ρgh. However, there is also an atmosphere over the pool, and, as we saw in section 2-4, there is thus an additional pressure, normal atmospheric pressure p_o, exerted on the top of the pool. This pressure on the top of the pool is transmitted through the pool waters so that the total pressure at the bottom of the pool is the sum of the pressure of the water plus the pressure of the atmosphere, sections 2-5-2 and 2-6. The addition of both pressures is a special case of a principle, called **Pascal's principle and it states that a change in the pressure applied to a fluid is transmitted undiminished to every point of the fluid and to the walls of the container**.

As an example of the use of Pascal's principle, let us consider the hydraulic lift shown in figure 2-7. A noncompressible fluid fills both cylinders and the connecting pipe. The smaller cylinder has a piston of cross sectional area **a**, whereas the larger cylinder has a cross-sectional area **A**. As we can see in the figure, the cross-sectional area ***A*** of the larger cylinder is greater than the cross-sectional area **a** of the smaller cylinder. If a small force **f** is applied to the piston of the small cylinder, this creates a change in the pressure of the fluid given by

$$\Delta P = \frac{f}{a} \quad \dots\dots\dots\dots\dots\dots\dots (2-16)$$

But by Pascal's principle, this pressure change occurs at all points in the fluid, and in particular at the large piston on the right. This same pressure change applied to the right piston gives

$$\Delta P = \frac{F}{A} \quad \dots\dots\dots\dots\dots\dots\dots (2-17)$$

where **F** is the force that the fluid now exerts on the large piston of area A. Because these two pressure changes are equal by Pascal's principle, we can set equation 2-16 equal to equation 2-17. Thus,

$$\Delta P = \Delta P$$

$$\frac{F}{A} = \frac{f}{a}$$

The force **F** on the large piston is

$$F = \frac{A}{a} f \quad \dots\dots\dots\dots\dots\dots\dots (2-18)$$

Since the area **A** is greater than the area **a**, the force **F** will be greater than **f**. Thus, the hydraulic lift is a device that is capable of multiplying forces.

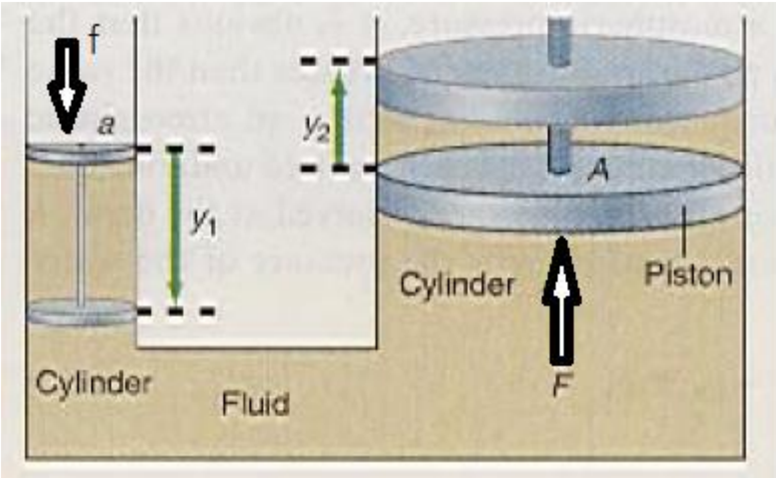

Figure 2-7

It is interesting to compute the work that is done when the force **f** is applied to the small piston in figure 2-7. When the force **f** is applied, the piston moves through a displacement $\mathbf{y_1}$, such that the work done is given by

$$W_1 = f\,y_1$$

But from equation 2-16,

$$f = a\,\Delta P$$

Hence, the work done is

$$W_1 = a\,\Delta P\,y_1 \quad \dots\dots\dots\dots\dots\dots\dots (2-19)$$

When the change in pressure is transmitted through the fluid, the force **F** is exerted against the large piston and the work done by the fluid on the large piston is

$$W_2 = Fy_2$$

where $\mathbf{y_2}$ is the distance that the large piston moves and is shown in figure 2-7. But the force **F**, found from equation 2-17, is

$$F = A\,\Delta P$$

The work done on the large piston by the fluid becomes

$$W_2 = A\,\Delta P\,y_2 \quad \dots\dots\dots\dots\dots\dots\dots (2-20)$$

Applying the law of conservation of energy to a frictionless hydraulic lift, the work done to the fluid at the small piston must equal the work done by the fluid at the large piston, hence

$$W_1 = W_2$$

$$a\,\Delta P\,y_1 = A\,\Delta P\,y_2$$

Because the pressure change ΔP is the same throughout the fluid, it cancels out, leaving

$$a\,y_1 = A\,y_2$$

Solving for the distance $\mathbf{y_1}$ that the small piston moves

$$y_1 = \frac{A}{a}\,y_2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2-21)$$

Since **A** is much greater than **a**, it follows that $\mathbf{y_1}$ must be much greater than $\mathbf{y_2}$.

Other example for use the Pascal's principle, the brake system of a car that shown in figure 2-8. 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.

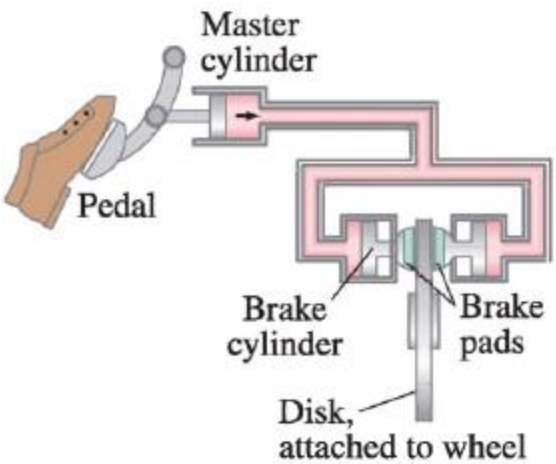

Figure 2-8

Example 18: The radius of the small piston in figure 2-7 is **5cm**, whereas the radius of the large piston is **30 cm**. If a force of **2 N** is applied to the small piston,

a) What force will occur at the large piston?

b) The large piston moves through a distance of **0.2 cm**. By how much must the small piston be moved?

Example 19: Find the force acting on a small piston in a hydraulic left in a station of cleaning cars whose area **10 cm²** to lift a car of **2000 kg**, the area of large piston is **1000 cm²**?

Example 20: In a hydraulic lift, the radii of the pistons are **2.5 cm** and **10 cm**. A car weighing **10 kN** is to be lifted by the force of the large piston,

a) What force must be applied to the small piston? H.W

b) When the small piston is pushed in by **10 cm**, how far is the car lifted?