

10-7 Buoyancy and Archimedes' Principle

Objects submerged in a fluid appear to weigh less than they do when outside the fluid. For example, a large rock that you would have difficulty lifting off the ground can often be easily lifted from the bottom of a stream. When the rock breaks through the surface of the water, it suddenly seems to be much heavier. Many objects, such as wood, float on the surface of water. These are two examples of *buoyancy*. In each example, the force of gravity is acting downward. But in addition, an upward *buoyant force* is exerted by the liquid. The buoyant force on fish and underwater divers (as in the chapter-opening photo) almost exactly balances the force of gravity downward, and allows them to “hover” in equilibrium.

Rocks seem to weigh less under water

Wood floats

The buoyant force occurs because the pressure in a fluid increases with depth. Thus the upward pressure on the bottom surface of a submerged object is greater than the downward pressure on its top surface. To see this effect, consider a cylinder of height Δh whose top and bottom ends have an area A and which is completely submerged in a fluid of density ρ_F , as shown in Fig. 10-11. The fluid exerts a pressure $P_1 = \rho_F g h_1$ at the top surface of the

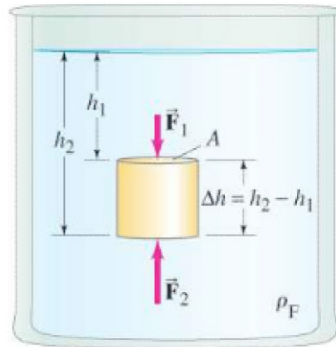


FIGURE 10-11 Determination of the buoyant force.

cylinder (Eq. 10-3a). The force due to this pressure on top of the cylinder is $F_1 = P_1 A = \rho_F g h_1 A$, and it is directed downward. Similarly, the fluid exerts an upward force on the bottom of the cylinder equal to $F_2 = P_2 A = \rho_F g h_2 A$. The net force on the cylinder exerted by the fluid pressure, which is the **buoyant force**, \vec{F}_B , acts upward and has the magnitude

$$\begin{aligned} F_B &= F_2 - F_1 = \rho_F g A (h_2 - h_1) \\ &= \rho_F g A \Delta h \\ &= \rho_F V g \\ &= m_F g, \end{aligned}$$

where $V = A \Delta h$ is the volume of the cylinder, the product $\rho_F V$ is its mass, and $\rho_F V g = m_F g$ is the weight of fluid which takes up a volume equal to the volume of the cylinder. Thus the buoyant force on the cylinder is equal to the weight of fluid displaced by the cylinder. This result is valid no matter what the shape of the object. Its discovery is credited to Archimedes (287?–212 B.C.), and it is called **Archimedes' principle**: *the buoyant force on an object immersed in a fluid is equal to the weight of the fluid displaced by that object.*

Archimedes' principle

By “fluid displaced,” we mean a volume of fluid equal to the volume of the submerged object, or that part of the object submerged if it floats or is only partly submerged (the fluid that used to be where the object is). If the object is placed in a glass or tub initially filled to the brim with water, the water that flows over the top represents the water displaced by the object.