3.6: Work in a Gravitational Field

Figure 3.9 depicts a spherical body, such as a glass marble, immersed in a liquid or gas in the presence of an external gravitational field. The vessel is stationary on a lab bench, and the local reference frame for work is a stationary lab frame. The variable z is the body's elevation above the bottom of the vessel. All displacements are parallel to the vertical z axis. From Eq. 3.1.1, the work is given by $đw = F_z^{\text{sur}}\,\mathrm{d}z$ where F_z^{sur} is the upward component of the net contact force exerted by the surroundings on the system at the moving portion of the boundary. There is also a downward gravitational force on the body, but as explained in Sec. 3.1.1, this force does not contribute to F_z^{sur}.

Consider first the simple process in Fig. 3.9(a) in which the body falls freely through the fluid. This process is clearly spontaneous. Here are two choices for the definition of the system:

- The buoyant force is a consequence of the pressure gradient that exists in the fluid in a gravitational field (see Sec. 8.1.4). We ignore this gradient when we treat the fluid as a uniform phase.

  Next, consider the arrangement in Fig. 3.9(b) in which the body is suspended by a thin string. The string is in the surroundings and provides a means for the surroundings to exert an upward contact force on the system. As before, there are two appropriate choices for the system:

  - When we compare Eqs. 3.6.3 and 3.6.5, we see that the work when the system is the body is greater by the quantity $(F_{\text{buoy}} + F_{\text{fric}})\,\mathrm{d}z$ than the work when the system is the combination of body and fluid, just as in the case of the freely-falling body. The difference in the quantity of work is due to the different choices of the system boundary where contact forces are exerted by the surroundings.