The unit of power is called a watt (W) and is defined by

$$1\ \text{W} \equiv 1\ \text{J/s} = 1\ \text{N}\cdot\text{m/s} = 1\ \text{kg}\cdot\text{m}^2/\text{s}^3.$$

British Gravitational System. The British gravitational (BG) system adopts force rather than mass as a fundamental dimension. The unit of length is the foot (ft). The foot is defined with respect to the meter; 1 ft = 0.3048 m. The unit of time is the second (sec).* The unit of temperature is either the degree Fahrenheit (°F) or the degree Rankine (°R). The unit of force is the pound (lb). If we rewrite Newton's second law,

$$m = F/a,$$

the dimensions of mass become

$$[m] = [F]/[a] = \left[\frac{FT^2}{L}\right].$$

The unit of mass is the slug (slug), defined by

$$1\ \text{slug} = 1\ \text{lb}\cdot\text{sec}^2/\text{ft}.$$

Since earth standard gravity is 32.174 ft/sec^2 in BG units, a mass of 1 slug weighs 32.174 lb under standard gravity. The unit of energy is the ft·lb, and the unit of power is the ft·lb/sec.

English Engineering System. The English engineering (EE) system is similar to the BG system in most respects; however, the mass-weight problem is solved by defining units for *both* mass and weight such that 1 unit of mass has a weight of 1 unit of force under conditions of *standard gravity*. The length, time, and temperature units are the same as in the BG system (i.e., foot, second, degree Fahrenheit or degree Rankine). The mass unit is the pound mass (lbm), and the force unit is the pound force (lb).† The pound force (in the EE system) and the pound (in the BG system) are equivalent units. *One pound mass has a weight of one pound force under conditions of standard gravity.* One pound mass has a weight other than one pound force at values of gravity other than "earth standard." Using Newton's second law,

$$W = mg,$$

we can calculate the weight of 1 lbm under conditions of standard gravity, which, *by definition,* is 1 lb:

$$1\ \text{lb} = 1\ \text{lbm} \times 32.174\ \text{ft/sec}^2.$$

We seem to have trouble with this equation because the units are not the same on both sides and 1 does not equal 32.174. We correct the problem by dividing the right side by a *conversion factor* equal to

* Note that "second" is abbreviated "s" in SI units and "sec" in BG and EE units.

† In the EE system, the symbol lb_f is usually employed for the pound force. Since we use both the EE and BG systems in this book, we use lbm for the pound mass and lb for the pound force.

32.174 ft·lbm/lb·sec^2, and we write:

$$1 \text{ lb} = \frac{1 \text{ lbm} \times 32.174 \text{ ft/sec}^2}{32.174 \text{ ft}\cdot\text{lbm/lb}\cdot\text{sec}^2}.$$

The conversion factor is assigned the symbol g_c, and is a *constant* factor that can be used *at any time* to relate pounds force and pounds mass. We *could* write Newton's second law as

$$F = \frac{ma}{g_c};$$

however, since g_c is only a conversion factor, it need not be written in equations. It would be possible to introduce g_c into the SI and BG systems:

$$g_c\,(\text{SI}) = 1.0 \text{ m}\cdot\text{kg/N}\cdot\text{s}^2 \quad \text{and} \quad g_c\,(\text{BG}) = 1.0 \text{ ft}\cdot\text{slug/lb}\cdot\text{sec}^2.$$

In the SI and BG systems, the combinations m·kg/s^2 and lb·s^2/ft are named "newton" and "slug" rather than "converted" to them, certainly a simpler procedure; however, in these systems, a unit of mass does not have a weight equal to a unit of force. When making engineering calculations you should remember that

$$g_c = 32.174 \text{ ft}\cdot\text{lbm/lb}\cdot\text{sec}^2 = 1.$$

Since you can multiply any term in any equation by 1 at any time, you can multiply or divide by g_c any time you need to convert between units involving mass and units involving force.

Other units of measurement can be obtained by subdividing or combining the basic units. Examples include

- Length

  1 inch = 1/12 ft (BG, EE)

  1 yard = 3 ft (BG, EE)

- Volume

  231 in^3 = 1 gallon (BG, EE)

- Pressure, stress

  1 pascal (Pa) = 1 N/m^2 (SI)

  1 lb/in^2 (psi) = 144 lb/ft^2 (BG, EE)

- Energy

  1 BTU = 778.16 ft·lb (BG, EE)

- Power

  1 horsepower (hp) = 550 ft·lb/sec (BG, EE)

Table 1.1 lists dimensions, basic units, and other common units for several quantities of interest in fluid mechanics. Appendix C contains conversion factors, both between unit systems and between alternative units within a given system.