ENGLISH UNIT SUPPLEMENT

The traditional system of units used in the United States is termed the English Engineering System. In this system, the unit of time is the second, which has been discussed in Section 2.5. The basic unit of length is the foot (ft), which at present is defined in terms of the meter as

$$1 \text{ ft} = 0.3048 \text{ m}$$

The inch (in.) is defined in terms of the foot

$$12 \text{ in.} = 1 \text{ ft}$$

The unit of mass in this system is the pound mass (lbm), originally the mass of a certain platinum cylinder kept in the Tower of London, but now defined in terms of the kilogram as

$$1 \text{ lbm} = 0.453\,592\,37 \text{ kg}$$

A related unit is the pound mole (lb mol), which is an amount of substance in pounds mass numerically equal to the molecular weight of that substance. It is important to distinguish between a pound mole and a mole (gram mole).

In the English Engineering System of Units, the concept of force is not defined from Newton's second law, but is instead established as an independent quantity. Thus, for this system, unlike other systems of units, a conversion constant g_c is necessary in Newton's second law. The unit for force is defined in terms of an experimental procedure as follows. Let the standard pound mass be suspended in the earth's gravitational field at a location where the acceleration due to gravity is 32.1740 ft/s^2. The force with which the standard pound mass is attracted to the earth (the buoyant effects of the atmosphere on the standard pound mass must also be standardized) is defined as the unit for force and is termed a pound force (lbf). Note that we must be careful to distinguish between a lbm and a lbf, and we do not use the term pound alone. Now, since we have independently defined the units for force, mass, length, and time, we have the relation, from Newton's second law,

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

or

$$1 \text{ lbf} = \frac{1 \text{ lbm} \times 32.174 \text{ ft/s}^2}{g_c}$$

or

$$g_c = 32.174 \frac{\text{lbm ft}}{\text{lbf s}^2}$$

Note that the conversion constant g_c has both a numerical value and dimensions. We also note that for gravitational accelerations that are not too different from the standard value (32.174 ft/s^2 or 9.806 65 m/s^2), the lbf is approximately numerically equal to the lbm. This is the reason that people often drop the designation, which can lead to confusion and inconsistencies. To illustrate, let us calculate the force due to gravity on a one-pound mass at a location where the acceleration due to gravity is 32.14 ft/s^2 (about 10 000 ft above sea level).

$$F = \frac{ma}{g_c} = \frac{1 \text{ lbm} \times 32.14 \text{ ft/s}^2}{32.174 \text{ lbm ft/lbf s}^2}$$
$$= 0.999 \text{ lbf}$$

We further note that the pound force could very well have been defined as

$$1 \text{ lbf} = 32.174 \text{ lbm ft/s}^2$$

in a manner analogous to that for the newton in the SI system. It then follows that

$$1 = 32.174 \frac{\text{lbm ft}}{\text{lbf s}^2}$$

Comparing this with the conversion constant g_c,

$$g_c = 32.174 \frac{\text{lbm ft}}{\text{lbf s}^2} = 1$$

Since a pure number can be substituted into an equation at any point, we can therefore substitute this unit conversion constant g_c, as necessary. As an example, consider the kinetic energy of a 5-lbm mass moving at a velocity of 10 ft/s. From Eq. 5.8,

$$\text{KE} = \frac{1}{2} m\mathbf{V}^2 = \frac{1}{2}(5 \text{ lbm})\left(10 \frac{\text{ft}}{\text{s}}\right)^2 = 25 \text{ lbm ft}^2/\text{s}^2$$

Substituting the expression for g_c into the denominator,

$$\text{KE} = \frac{1}{2} m\mathbf{V}^2 = \frac{25 \text{ lbm ft}^2/\text{s}^2}{32.174 \text{ lbm ft/lbf s}^2} = 0.777 \text{ ft lbf}$$

The temperature scale in the English Engineering System is the Fahrenheit scale, on which the normal freezing point of water (0°C) is 32 F, and the normal boiling point (100°C) is 212 F. Thus a 100° change on the Celsius scale corresponds to a 180° change on the Fahrenheit scale. The absolute temperature scale related to the Fahrenheit scale is named the Rankine scale, which is designated R. The relation between the two is

$$°\text{R} = °\text{F} + 459.67$$