

### Problem 1.7 i

A simple oscillator consists of a linear spring fixed at one end and a mass attached at the other end, which is free to move. Suppose that the periodic motion of a simple oscillator is described by the relation  $y = Y_0 \sin(2\pi\omega_0 t)$ , where  $y$  has units of length and denotes the vertical position of the oscillator,  $Y_0$  is called the oscillation amplitude,  $\omega_0$  is the oscillation frequency, and  $t$  is time. Recalling that the argument of a trigonometric function is an angle, determine the dimensions of  $Y_0$  and  $\omega_0$ , as well as their units in both the SI and the U.S. Customary systems.



#### Solution

Because the value of a trigonometric function must be nondimensional and because  $y$  has dimensions of length,  $Y_0$  must also have dimensions of length:

$$[Y_0] = [L].$$

As such, the units to express the quantity  $Y_0$  in the SI and the U.S. Customary systems are

Units of  $Y_0$  in the SI system: m.  
Units of  $Y_0$  in the US Customary system: ft.

The quantity  $(2\pi\omega_0 t)$  is the argument of a trigonometric function and as such it must be nondimensional. Therefore we have

$$[2\pi\omega_0 t] = 1 \quad \Rightarrow \quad [\omega_0][t] = 1.$$

$$[\omega_0] = \frac{1}{[T]}.$$

If we were to infer the units of  $\omega_0$  directly from its dimensions, we would conclude that the units of  $\omega_0$  are seconds to the power negative one. However, in this particular problem, this would lead to an erroneous conclusion. The reason for this is that, as indicated in the problem statement, the term  $\omega_0$  appears as part of the argument  $2\pi\omega_0 t$ . When this happens,  $\omega_0$  is typically seen as the “number of  $2\pi$  rad per unit time,” that is as a quantity that measures the number of oscillation *cycles* per unit time (for additional details, see the discussion about Eqs. (9.4) and (9.8) on p. 674 of the textbook). In both the SI and the U.S. Customary systems, the number of cycles per unit time are measured in hertz, which is a unit corresponding to 1 cycle per second. Hence, we have

In both the SI and the U.S. Customary systems,  $\omega_0$  has units of Hz (hertz), i.e., cycles per second.

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**Jicheng Xie**



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