SUMMARY

In this chapter we defined the terms needed to describe quantitatively the motion of **point objects** (or objects that can be treated as point objects) in one dimension (see also Table 2-1).

Definitions

- **Instant** $t \equiv$ a single clock reading
  (a single point on a time line or axis)
- **Time interval** $\Delta t \equiv t_2 - t_1$
  (distance between two points on a time line or axis)

In one dimension

- **Position** (x or y) is a coordinate along an arbitrarily placed real number line with successive integers (in SI) 1 m apart.
- **Displacement**

$$\Delta x \equiv x_2 - x_1 \tag{2-1}$$

- **Distance**

$$|\Delta x| \equiv |x_2 - x_1| \tag{2-2}$$

  for path segments where there is no reversal of travel direction. Distances are always positive.
- **Average* velocity**

$$\equiv \bar{v} \equiv \frac{displacement}{time\ interval} = \frac{\Delta x}{\Delta t} = \frac{x_2 - x_1}{t_2 - t_1} \tag{2-3}$$

- **Average* speed**

$$\equiv \frac{total\ distance\ traveled}{total\ time\ interval} \tag{2-4}$$

- **Instantaneous velocity**

$$v \equiv \lim_{\Delta t \to 0} \bar{v} \equiv \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} \tag{2-5}$$

- **Average* acceleration**

$$\bar{a} \equiv \frac{\Delta v}{\Delta t} \equiv \frac{v_2 - v_1}{t_2 - t_1} \tag{2-7}$$

- **Instantaneous acceleration**

$$a \equiv \lim_{\Delta t \to 0} \overline{a} \equiv \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} \tag{2-8}$$

(*averaged over Δt)

Table 2-1 in Section 2-2 summarizes the relationships among these quantities and the type of question each quantity addresses.

Graphs of x, v, and a versus t can provide meaningful descriptions of an object's motion. *Slopes* and *vertical intercepts* of these graphs have particular meaning. Because the *slope* always gives a *rate of change* and the vertical intercept always give an initial value, it follows that

For a graph of …	The slope of a (secant/tangent) gives …	And the vertical intercept gives …
x versus t	(Avg./instantaneous) velocity	Initial position
v versus t	(Avg./instantaneous) acceleration	Initial velocity

For straight lines (uniform slope), the average and instantaneous values are the same. Sections 2-3 and 2-4 provide further guidelines for interpreting graphs of x versus t and v versus t. The tables in those sections summarize key points.

From the definition of average velocity, it follows that

$$x - x_0 = \overline{v}t \tag{2-6}$$

which for constant velocity situations becomes

$$x - x_0 + vt \quad \text{(uniform motion only)} \tag{2-6u}$$

Whenever the *acceleration* is constant,

$$\begin{array}{c}\text{condition for}\\ \text{constant acceleration:}\end{array} \quad \overline{v} = \frac{v_0 + v}{2} \tag{2-10}$$

From the definitions, we can use algebraic reasoning to obtain *equations of motion* that describe the motion of an object under particular conditions. When the condition is constant acceleration,

Equations of motion (kinematic equations) for constant (uniform) *a* only:

$$v = v_0 + at \tag{2-9}$$

$$x - x_0 = v_0 t + \tfrac{1}{2}at^2 \tag{2-11}$$

$$v^2 = v_0^2 + 2a(x - x_0) \tag{2-12}$$

Things to remember when solving problems:

- Make sure you get the picture—sketch the situation.
- Know how the relevant quantities are defined and be able to use the definitions.
- Think first about what is happening—what physical concepts or principles apply to the situation—and let that guide your

choice of equations.

- To further guide your choice in deciding which definitions or principles or other equations relating known and unknown quantities to use, it is generally useful to restate the question in a form that directly connects known and unknown quantities, such as

$$Q_1 = \underline{\ ?\ } \text{ when } Q_2 = \underline{\qquad} \tag{Form 2-1}$$

In words: *What is the value of Quantity 1 when Quantity 2 = a known value?*

Measurements made with a sonic range finder demonstrate that there are a range of situations where *a* is very nearly constant, so that Equations 2-9 through 2-12 are applicable. They can be used, for example, when an object is in **free fall,** affected only by a gravitational pull. If the upward direction is taken as positive, objects falling freely to Earth have an acceleration $-g$, where g itself is always positive.

Magnitude of **gravitational acceleration** near Earth's surface

$$g = 9.8 \text{ (m/s)} / \text{s} = 9.8 \text{ m} / \text{s}^2$$

To apply the constant acceleration equations of motion to *free fall,*

1. If you choose the positive direction to be upward, let $a = -g$ in all the equations (let $a = +g$ if downward is positive).
2. Because we tend to label the vertical axis *y*, it is common—though not necessary—to replace *x* with *y* in all the equations to indicate vertical position.