

## Section Summary

### 2.1 Displacement

- Kinematics is the study of motion without considering its causes. In this chapter, it is limited to motion along a straight line, called one-dimensional motion.
- Displacement is the change in position of an object.
- In symbols, displacement  $\Delta x$  is defined to be
- $\Delta x = x_f - x_0$ ,

where  $x_0$  is the initial position and  $x_f$  is the final position. In this text, the Greek letter  $\Delta$  (delta) always means “change in” whatever quantity follows it. The SI unit for displacement is the meter (m). Displacement has a direction as well as a magnitude.

- When you start a problem, assign which direction will be positive.
- Distance is the magnitude of displacement between two positions.
- Distance traveled is the total length of the path traveled between two positions.

### 2.2 Vectors, Scalars, and Coordinate Systems

- A vector is any quantity that has magnitude and direction.
- A scalar is any quantity that has magnitude but no direction.
- Displacement and velocity are vectors, whereas distance and speed are scalars.
- In one-dimensional motion, direction is specified by a plus or minus sign to signify left or right, up or down, and the like.

### 2.3 Time, Velocity, and Speed

- Time is measured in terms of change, and its SI unit is the second (s). Elapsed time for an event is
- $\Delta t = t_f - t_0$ ,  
where  $t_f$  is the final time and  $t_0$  is the initial time. The initial time is often taken to be zero, as if measured with a stopwatch; the elapsed time is then just  $t$ .
- Average velocity  $\bar{v}$  is defined as displacement divided by the travel time. In symbols, average velocity is
- $\bar{v} = \frac{\Delta x}{\Delta t} = \frac{x_f - x_0}{t_f - t_0}$ .
- The SI unit for velocity is m/s.
- Velocity is a vector and thus has a direction.
- Instantaneous velocity  $v$  is the velocity at a specific instant or the average velocity for an infinitesimal interval.

- Instantaneous speed is the magnitude of the instantaneous velocity.
- Instantaneous speed is a scalar quantity, as it has no direction specified.
- Average speed is the total distance traveled divided by the elapsed time. (Average speed is *not* the magnitude of the average velocity.) Speed is a scalar quantity; it has no direction associated with it.

## 2.4 Acceleration

- Acceleration is the rate at which velocity changes. In symbols, average acceleration  $\bar{a}$  is
- $\bar{a} = \frac{\Delta v}{\Delta t} = \frac{v_f - v_0}{t_f - t_0}$ .
- The SI unit for acceleration is  $\text{m/s}^2$ .
- Acceleration is a vector, and thus has both a magnitude and direction.
- Acceleration can be caused by either a change in the magnitude or the direction of the velocity.
- Instantaneous acceleration  $a$  is the acceleration at a specific instant in time.
- Deceleration is an acceleration with a direction opposite to that of the velocity.

## 2.5 Motion Equations for Constant Acceleration in One Dimension

- To simplify calculations we take acceleration to be constant, so that  $\bar{a} = a$  at all times.
- We also take initial time to be zero.
- Initial position and velocity are given a subscript 0; final values have no subscript. Thus,

$$\left. \begin{aligned} \Delta t &= t \\ \Delta x &= x - x_0 \\ \Delta v &= v - v_0 \end{aligned} \right\}$$

- The following kinematic equations for motion with constant  $a$  are useful:

$$x = x_0 + \bar{v}t$$

$$\bar{v} = \frac{v_0 + v}{2}$$

$$v = v_0 + at$$

$$x = x_0 + v_0t + \frac{1}{2}at^2$$

$$v^2 = v_0^2 + 2a(x - x_0)$$

- In vertical motion,  $y$  is substituted for  $x$ .

## 2.6 Problem-Solving Basics for One-Dimensional Kinematics

- *The six basic problem solving steps for physics are:*
- *Step 1.* Examine the situation to determine which physical principles are involved.
- *Step 2.* Make a list of what is given or can be inferred from the problem as stated (identify the knowns).
- *Step 3.* Identify exactly what needs to be determined in the problem (identify the unknowns).
- *Step 4.* Find an equation or set of equations that can help you solve the problem.
- *Step 5.* Substitute the knowns along with their units into the appropriate equation, and obtain numerical solutions complete with units.
- *Step 6.* Check the answer to see if it is reasonable: Does it make sense?

## 2.7 Falling Objects

- An object in free-fall experiences constant acceleration if air resistance is negligible.
- On Earth, all free-falling objects have an acceleration due to gravity  $g$ , which averages
- $g = 9.80 \text{ m/s}^2$ .
- Whether the acceleration  $a$  should be taken as  $+g$  or  $-g$  is determined by your choice of coordinate system. If you choose the upward direction as positive,  $a = -g = -9.80 \text{ m/s}^2$  is negative. In the opposite case,  $a = +g = 9.80 \text{ m/s}^2$  is positive. Since acceleration is constant, the kinematic equations above can be applied with the appropriate  $+g$  or  $-g$  substituted for  $a$ .
- For objects in free-fall, up is normally taken as positive for displacement, velocity, and acceleration.

## 2.8 Graphical Analysis of One-Dimensional Motion

- Graphs of motion can be used to analyze motion.
- Graphical solutions yield identical solutions to mathematical methods for deriving motion equations.
- The slope of a graph of displacement  $x$  vs. time  $t$  is velocity  $v$ .
- The slope of a graph of velocity  $v$  vs. time  $t$  graph is acceleration  $a$ .
- Average velocity, instantaneous velocity, and acceleration can all be obtained by analyzing graphs.