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**

\[
\Delta x \equiv x_2 - x_1
\]  

(2-1)

- **Distance**

\[
|\Delta x| \equiv |x_2 - x_1|
\]  

(2-2)

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

\[
\overline{v} \equiv \frac{\text{displacement}}{\text{time interval}} = \frac{\Delta x}{\Delta t} = \frac{x_2 - x_1}{t_2 - t_1}
\]  

(2-3)

- **Average* speed**

\[
\equiv \frac{\text{total distance traveled}}{\text{total time interval}}
\]  

(2-4)

- **Instantaneous velocity**

\[
v \equiv \lim_{\Delta t \to 0} \overline{v} \equiv \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t}
\]  

(2-5)

- **Average* acceleration**

\[
\overline{a} \equiv \frac{\Delta \overline{v}}{\Delta t} \equiv \frac{\overline{v}_2 - \overline{v}_1}{t_2 - t_1}
\]  

(2-7)

- **Instantaneous acceleration**
\[ a = \lim_{{\Delta t \to 0}} \frac{\Delta v}{\Delta t} \]  
\[ \bar{v} = \lim_{{\Delta t \to 0}} \frac{\Delta x}{\Delta t} \]  

(*averaged over \( \Delta t \))

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

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

\begin{center}
\begin{tabular}{ccc}
For a graph of … & The slope of a (secant/tangent) gives … & And the vertical intercept gives …
\hline
\( x \text{ versus } t \) & (Avg./instantaneous) velocity & Initial position \\
\( v \text{ versus } t \) & (Avg./instantaneous) acceleration & Initial velocity \\
\end{tabular}
\end{center}

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 \( x \text{ versus } t \) and \( v \text{ versus } t \). The tables in those sections summarize key points.

From the definition of average velocity, it follows that

\[ x - x_0 = \bar{v}t \]  
\( \text{(2-6)} \)

which for constant velocity situations becomes

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

Whenever the \textit{acceleration} is constant,

\[ c_{\text{condition for constant acceleration:}} \quad \bar{v} = \frac{v_0 + v}{2} \]  
\( \text{(2-10)} \)

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

\textbf{Equations of motion (kinematic equations) for constant (uniform) }a\textit{ only:}

\[ v = v_0 + at \]  
\( \text{(2-9)} \)

\[ x - x_0 = v_0 t + \frac{1}{2}at^2 \]  
\( \text{(2-11)} \)

\[ v^2 = v_0^2 + 2a(x - x_0) \]  
\( \text{(2-12)} \)

Things to remember when solving problems:

\begin{itemize}
  \item Make sure you get the picture—sketch the situation.
  \item Know how the relevant quantities are defined and be able to use the definitions.
  \item Think first about what is happening—what physical concepts or principles apply to the situation—and let that guide your
\end{itemize}
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 \textbf{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 \textbf{gravitational acceleration} near Earth's surface

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

To apply the constant acceleration equations of motion to \textit{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.

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

\( Q_1 = \Box \) when \( Q_2 = \Box \) (Form 2-1)