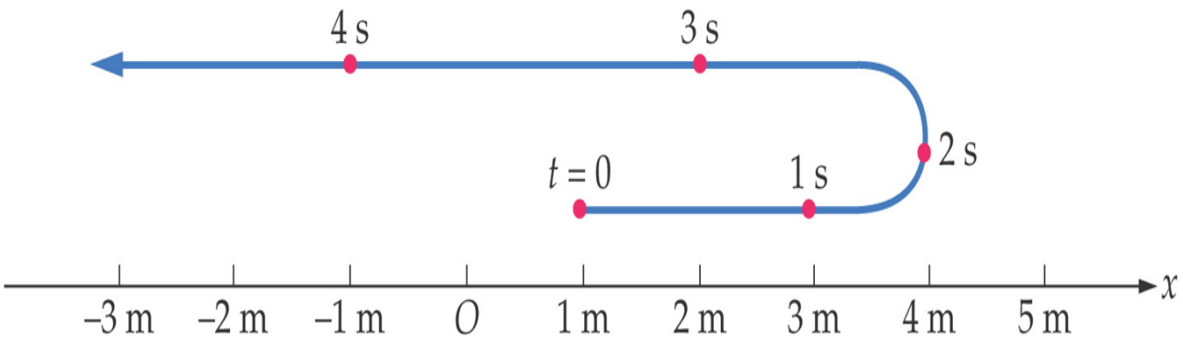
Chapter 2

2-1 One-Dimensional Kinematics

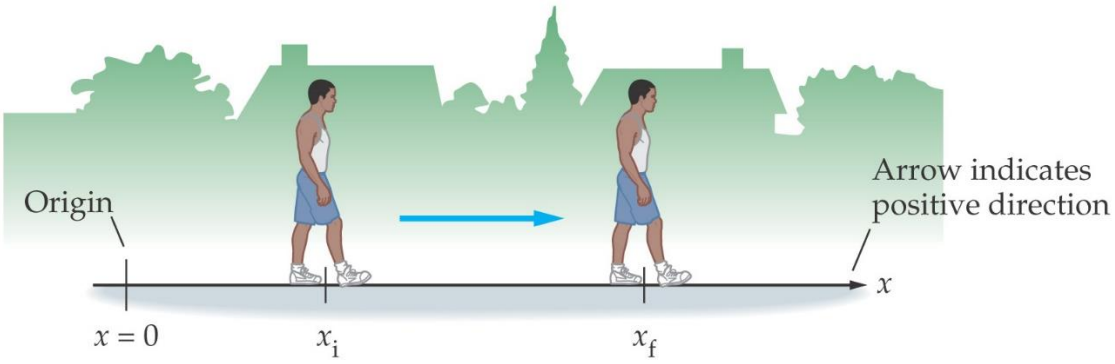


Contents

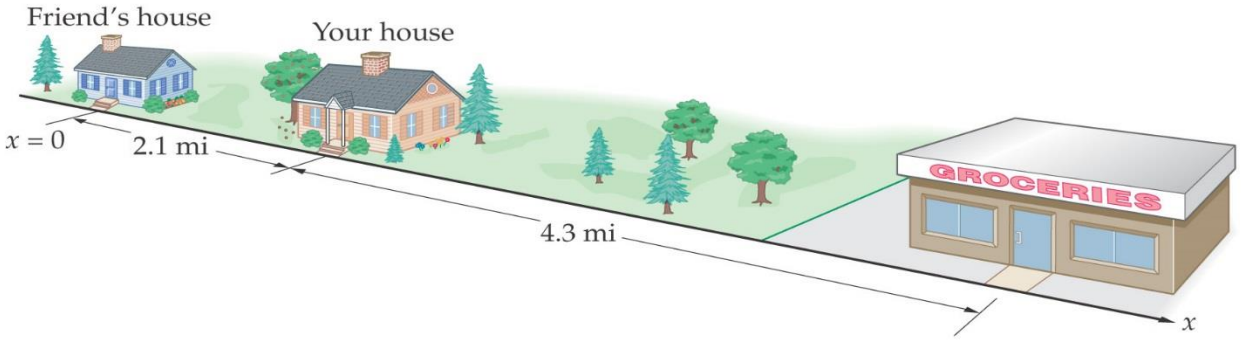
- Position, Distance, and Displacement
- Average Speed and Velocity
- Instantaneous Velocity
- Acceleration
- Motion with Constant Acceleration
- Freely Falling Objects

2-1 Position, Distance, and Displacement

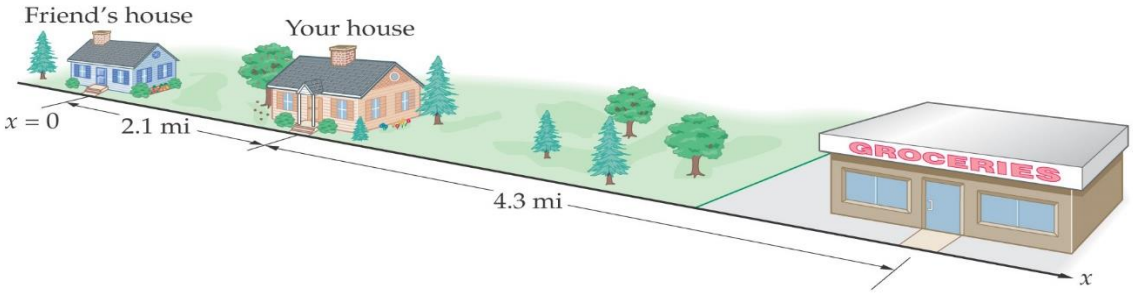
Before describing motion, you must set up a coordinate system – define an origin and a positive direction.



The distance is the total length of travel; if you drive from your house to the grocery store and back, you have covered a distance of 8.6 mi.



- Displacement is the change in position. If you drive from your house to the grocery store and then to your friend's house, your displacement is 2.1 mi and the distance you have traveled is 10.7 mi.

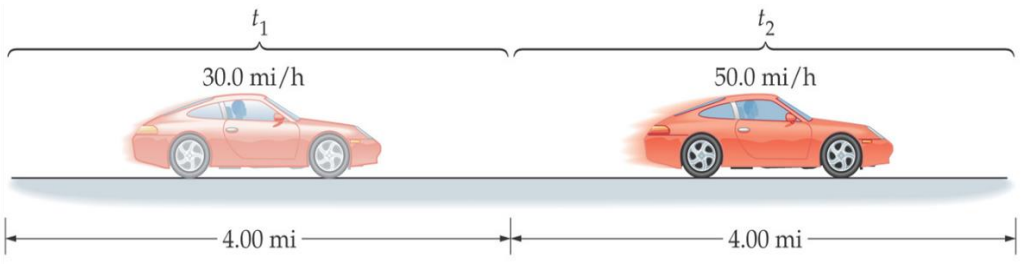


2-2 Average Speed and Velocity

The average speed is defined as the distance traveled divided by the time the trip took:

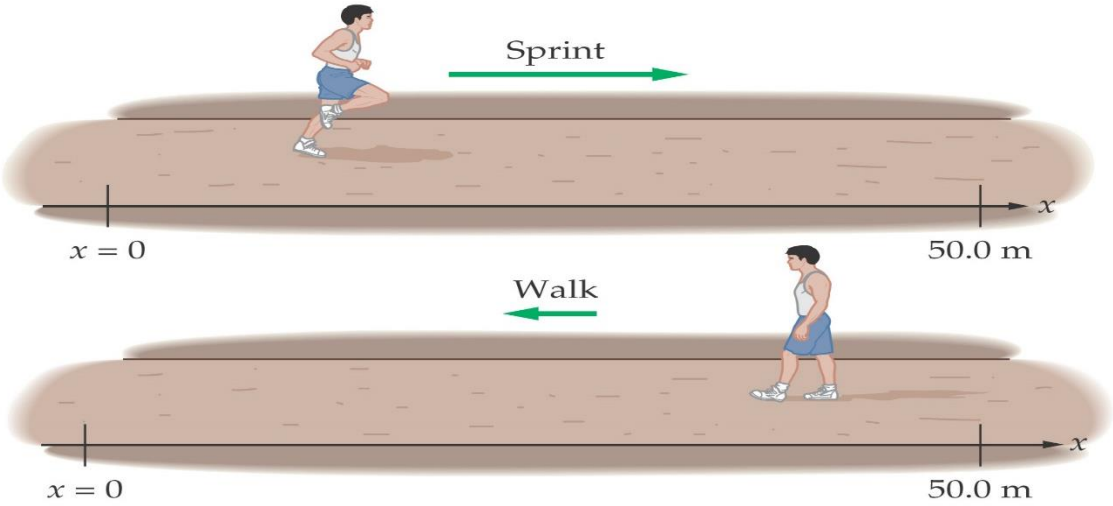
Average speed = distance / elapsed time

Is the average speed of the red car 40.0 mi/h, more than 40.0 mi/h, or less than 40.0 mi/h?



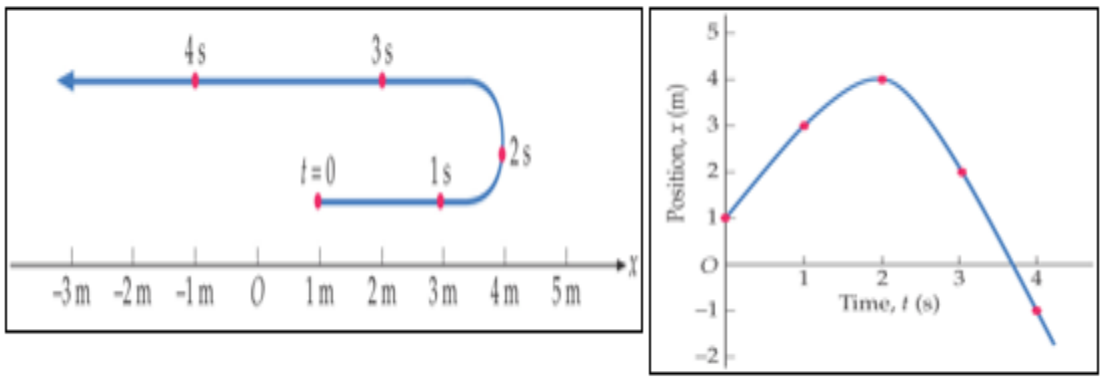
Average velocity = displacement / elapsed time

If you return to your starting point, your average velocity is zero.



Graphical Interpretation of Average Velocity

The same motion, plotted one-dimensionally and as an x-t graph:

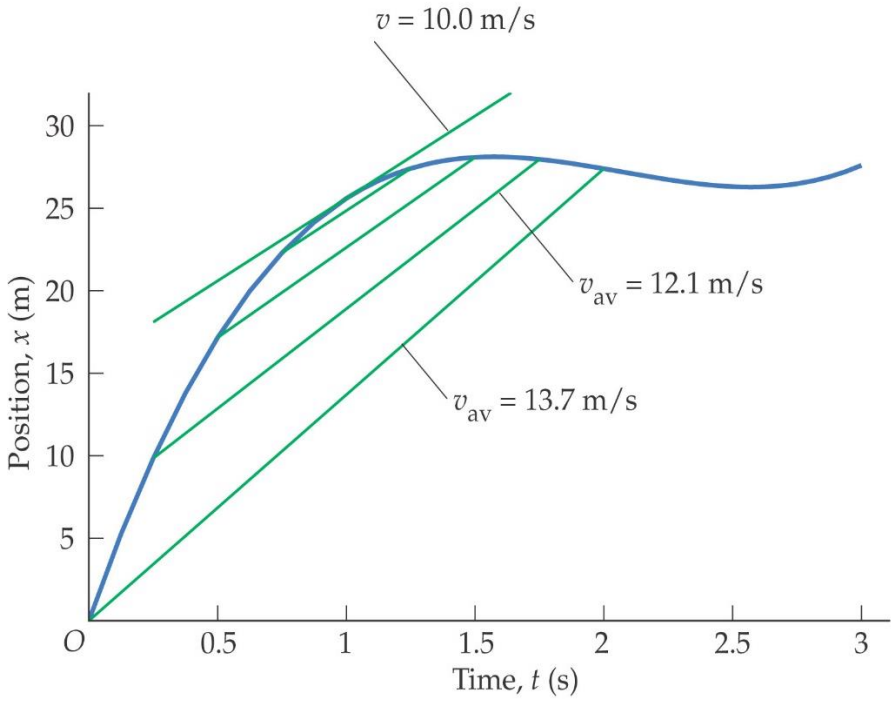


2-3 Instantaneous Velocity

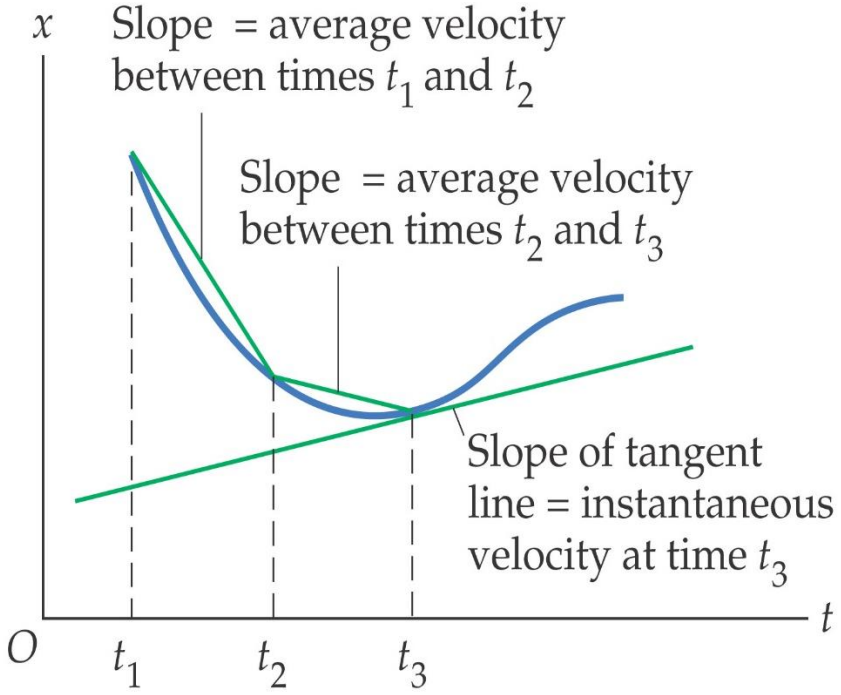
Definition: $$v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} \quad (2\text{-}4)$$

This means that we evaluate the average velocity over a shorter and shorter period of time; as that time becomes infinitesimally small, we have the instantaneous velocity.

Next plot shows the average velocity being measured over shorter and shorter intervals. The instantaneous velocity is tangent to the curve.



- Graphical Interpretation of Average and Instantaneous Velocity



2-4 Acceleration

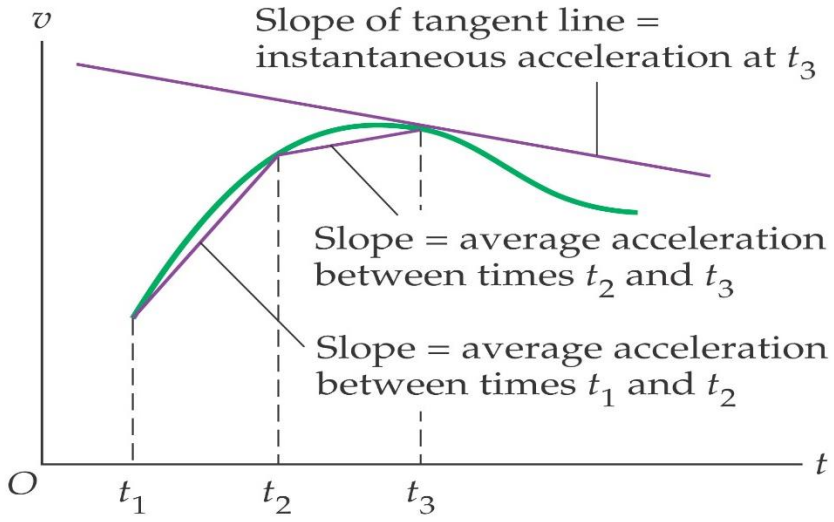
- **Average acceleration:**

$$a_{\text{av}} = \frac{\Delta v}{\Delta t} = \frac{v_{\text{f}} - v_{\text{i}}}{t_{\text{f}} - t_{\text{i}}} \quad \textbf{(2-5)}$$

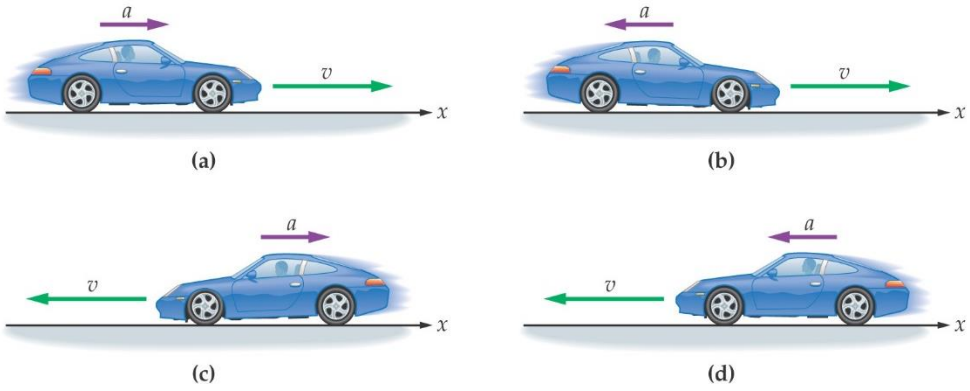
TABLE 2–3 Typical Accelerations (m/s^2)

Ultracentrifuge	3×10^6
Bullet fired from a rifle	4.4×10^5
Batted baseball	3×10^4
Click beetle righting itself	400
Acceleration required to deploy airbags	60
Bungee jump	30
High jump	15
Acceleration of gravity on Earth	9.81
Emergency stop in a car	8
Airplane during takeoff	5
An elevator	3
Acceleration of gravity on the Moon	1.62

- Graphical Interpretation of Average and Instantaneous Acceleration:



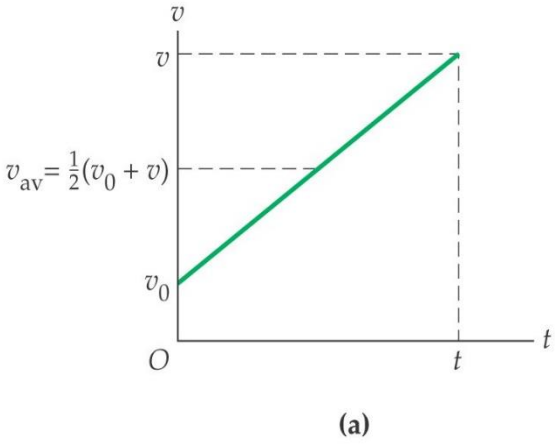
Acceleration (increasing speed) and deceleration (decreasing speed) should not be confused with the directions of velocity and acceleration:



2-5 Motion with Constant Acceleration

If the acceleration is constant, the velocity changes linearly:

$$v = v_0 + at \qquad \textbf{(2-7)}$$



- **Average velocity:**

Average velocity:

$$v_{av} = \tfrac{1}{2}(v_0 + v) \qquad \textbf{(2-9)}$$

Position as a function of time:

$$x = x_0 + \tfrac{1}{2}(v_0 + v)t \qquad \textbf{(2-10)}$$

$$x = x_0 + v_0 t + \tfrac{1}{2}at^2 \qquad \textbf{(2-11)}$$

Velocity as a function of position:

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

- **The relationship between position and time follows a characteristic curve.**

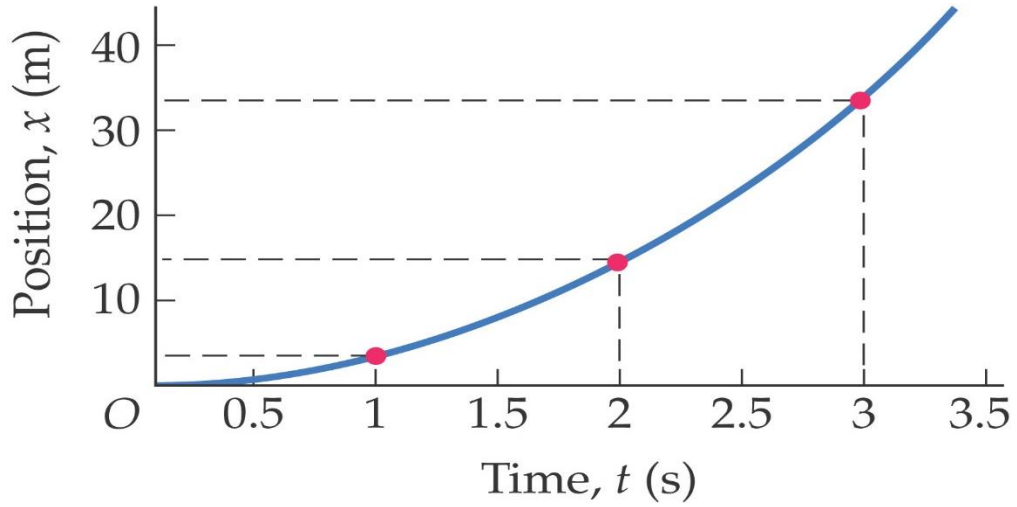


TABLE 2–4 Constant-Acceleration Equations of Motion

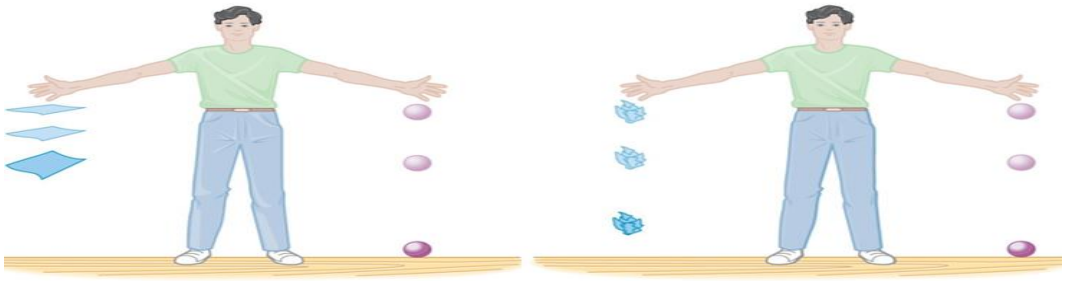
Variables related	Equation	Number
velocity, time, acceleration	$v = v_0 + at$	2–7
initial, final, and average velocity	$v_{av} = \frac{1}{2}(v_0 + v)$	2–9
position, time, velocity	$x = x_0 + \frac{1}{2}(v_0 + v)t$	2–10
position, time, acceleration	$x = x_0 + v_0t + \frac{1}{2}at^2$	2–11
velocity, position, acceleration	$v^2 = v_0^2 + 2a(x - x_0) = v_0^2 + 2a\Delta x$	2–12

2-7 Freely Falling Objects

Free fall is the motion of an object subject only to the influence of gravity. The acceleration due to gravity is a constant, g.

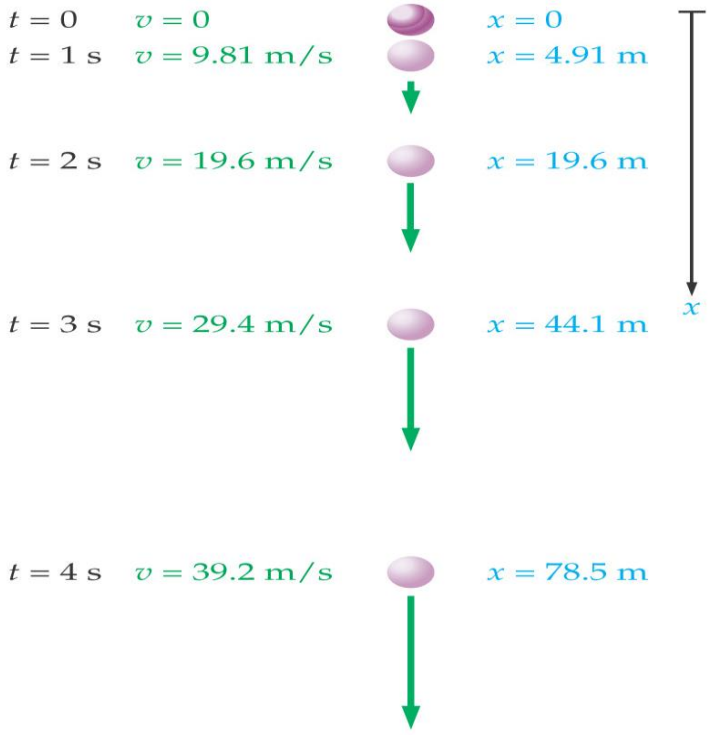
TABLE 2–5 Values of g at Different Locations on Earth (m/s^2)		
Location	**Latitude**	**g**
North Pole	90° N	9.832
Oslo, Norway	60° N	9.819
Hong Kong	30° N	9.793
Quito, Ecuador	0°	9.780

An object falling in air is subject to air resistance (and therefore is not freely falling).

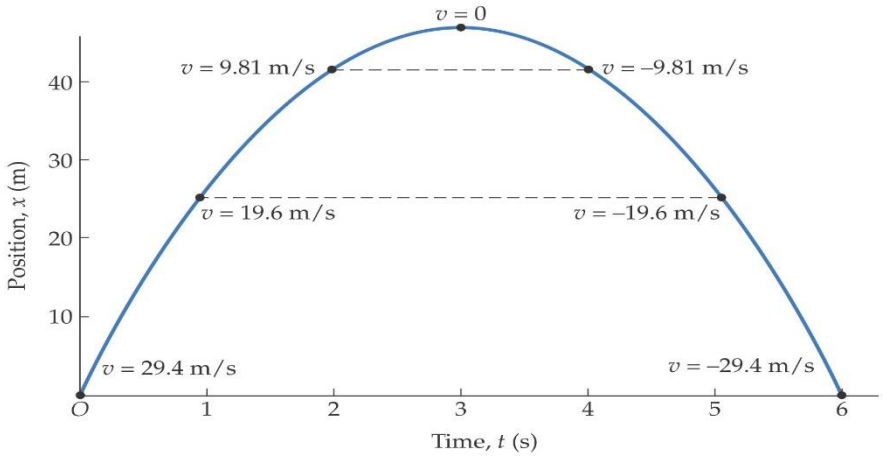


(a) (b)

Free fall from rest:



- Trajectory of a projectile:



Summary of Chapter 2

Distance: total length of travel

Displacement: change in position

Average speed: distance / time

Average velocity: displacement / time

Instantaneous velocity: average velocity measured over an infinitesimally small time

Instantaneous acceleration: average acceleration measured over an infinitesimally small time

Average acceleration: change in velocity divided by change in time

Deceleration: velocity and acceleration have opposite signs

Constant acceleration: equations of motion relate position, velocity, acceleration, and time

Freely falling objects: constant acceleration "g = 9.81 m/s^2"