General Physics I

chapter 3

Sharif University of Technology
Mehr 1395 (Winter Semester 2016-2017)

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Chapter II

Motion in One Dimension

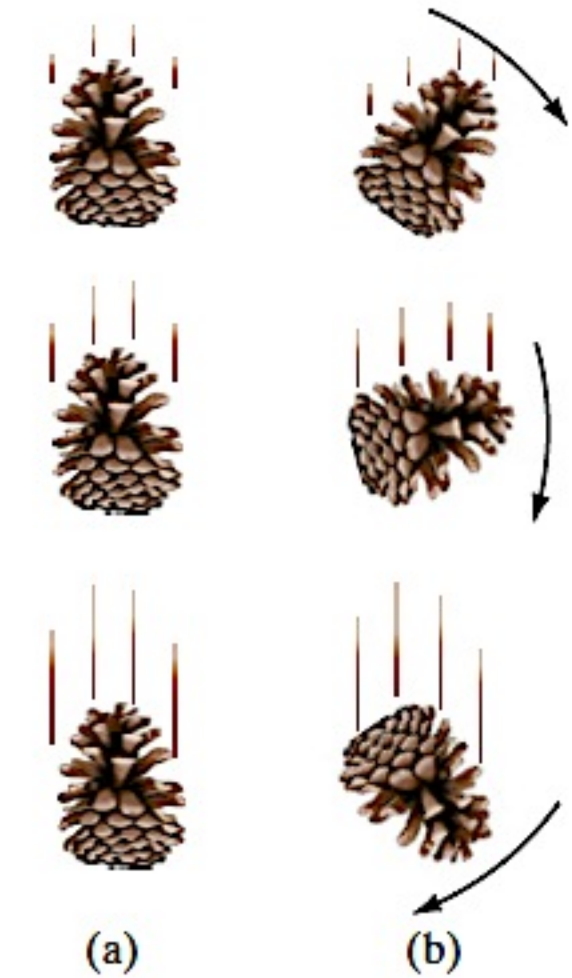


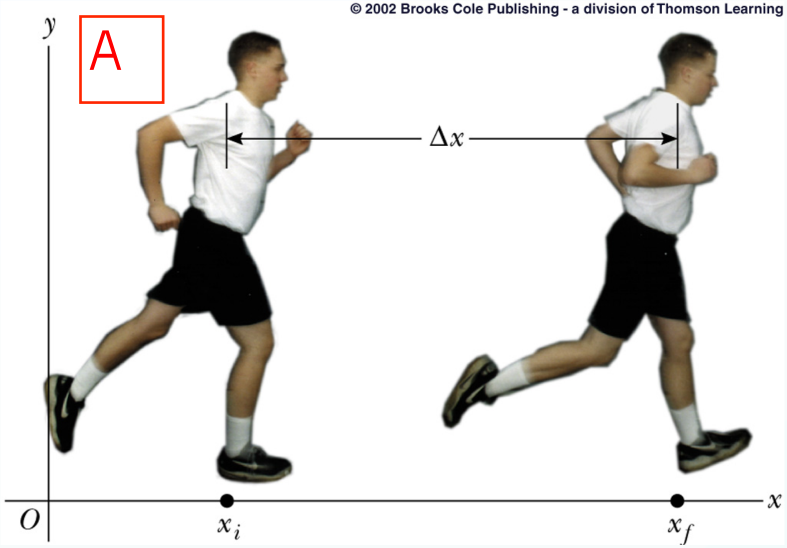
FIGURE 2–1 A falling pinecone undergoes (a) pure translation; (b) it is rotating as well as translating.

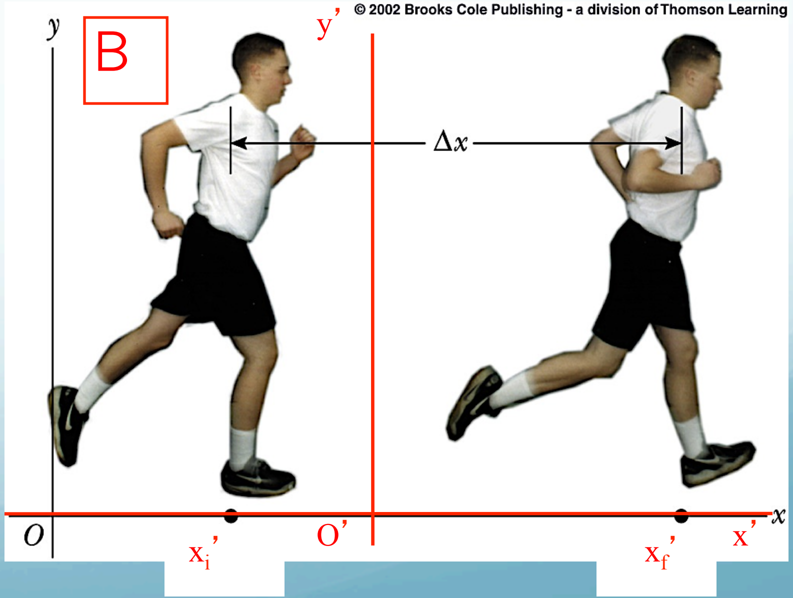
Kinematics

- Kinematics
  - In kinematics, you are interested in the description of motion
  - Not concerned with the cause of the motion

Position and Displacement

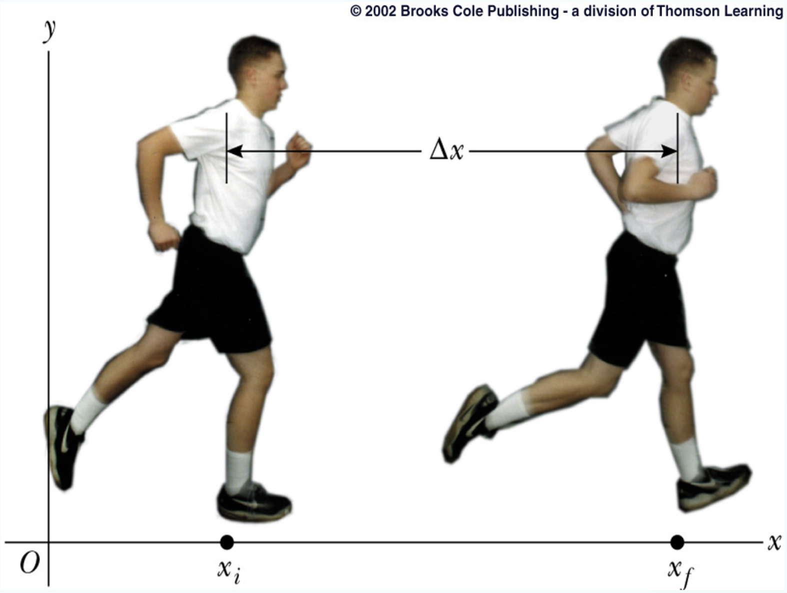
- Position is defined in terms of a **frame of reference**
- **Frame A:** $x_i>0$ and $x_f>0$
- **Frame B:** $x'_i<0$ but $x'_f>0$
- One dimensional, so generally the x- or y-axis





Position and Displacement

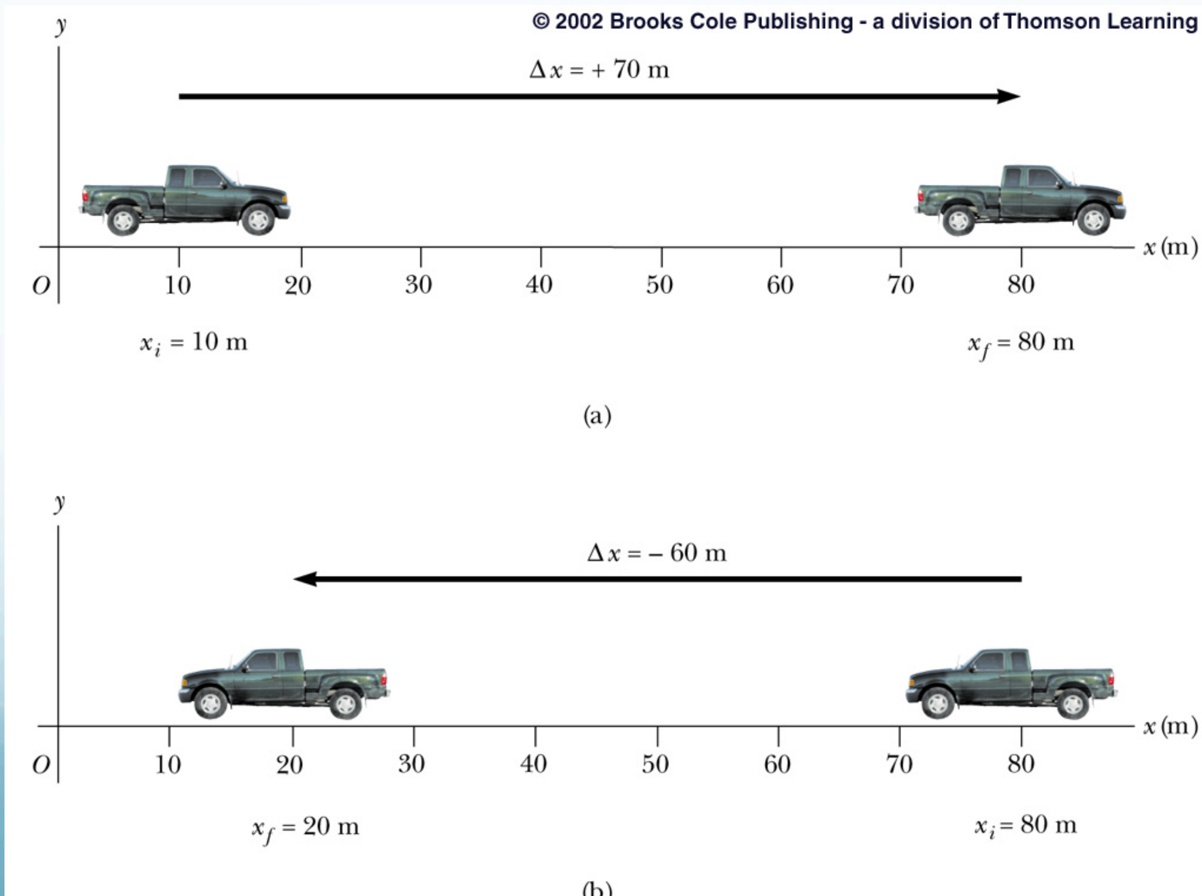
- Position is defined in terms of a **frame of reference**
  - One dimensional, so generally the x- or y-axis
- Displacement measures the change in position
  - Represented as Δx (if horizontal) or Δy (if vertical)
  - Vector quantity
    - + or - is generally sufficient to indicate direction for one-dimensional motion



Units	
SI	Meters (m)
CGS	Centimeters (cm)

Displacement (example)

- **Displacement measures the change in position**
  - represented as Δx or Δy



$$\begin{aligned}\Delta x_1 &= x_f - x_i \\ &= 80\,m - 10\,m \\ &= \underline{+70\,m}\ \checkmark\end{aligned}$$

$$\begin{aligned}\Delta x_2 &= x_f - x_i \\ &= 20\,m - 80\,m \\ &= \underline{-60\,m}\ \checkmark\end{aligned}$$

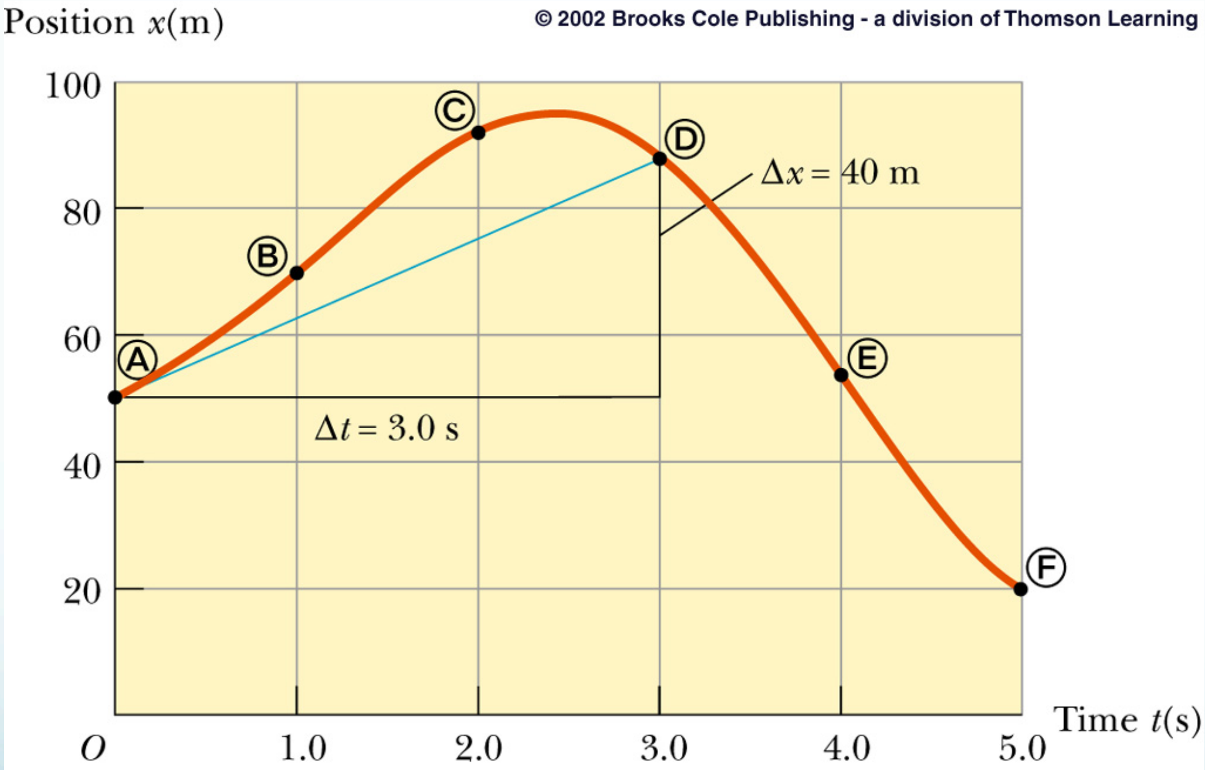
Distance or Displacement?

- Distance may be, but is not necessarily, the magnitude of the displacement

Displacement

Distance
(blue line)

Position-time graphs



- Note: position-time graph is not necessarily a straight line, even though the motion is along x-direction

ConcepTest 1

An object (say, car) goes from one point in space to another. After it arrives to its destination, its displacement is

- either greater than or equal to
- always greater than
- always equal to
- either smaller or equal to
- either smaller or larger

than the distance it traveled.

Average Velocity

- It takes time for an object to undergo a displacement
- The **average velocity** is rate at which the displacement occurs

$$\boxed{\vec{v}_{average} = \frac{\Delta\vec{x}}{\Delta t} = \frac{\vec{x}_f - \vec{x}_i}{\Delta t}}$$

- It is a vector, direction will be the same as the direction of the displacement (Δt is always positive)
  - + or - is sufficient for one-dimensional motion

More About Average Velocity

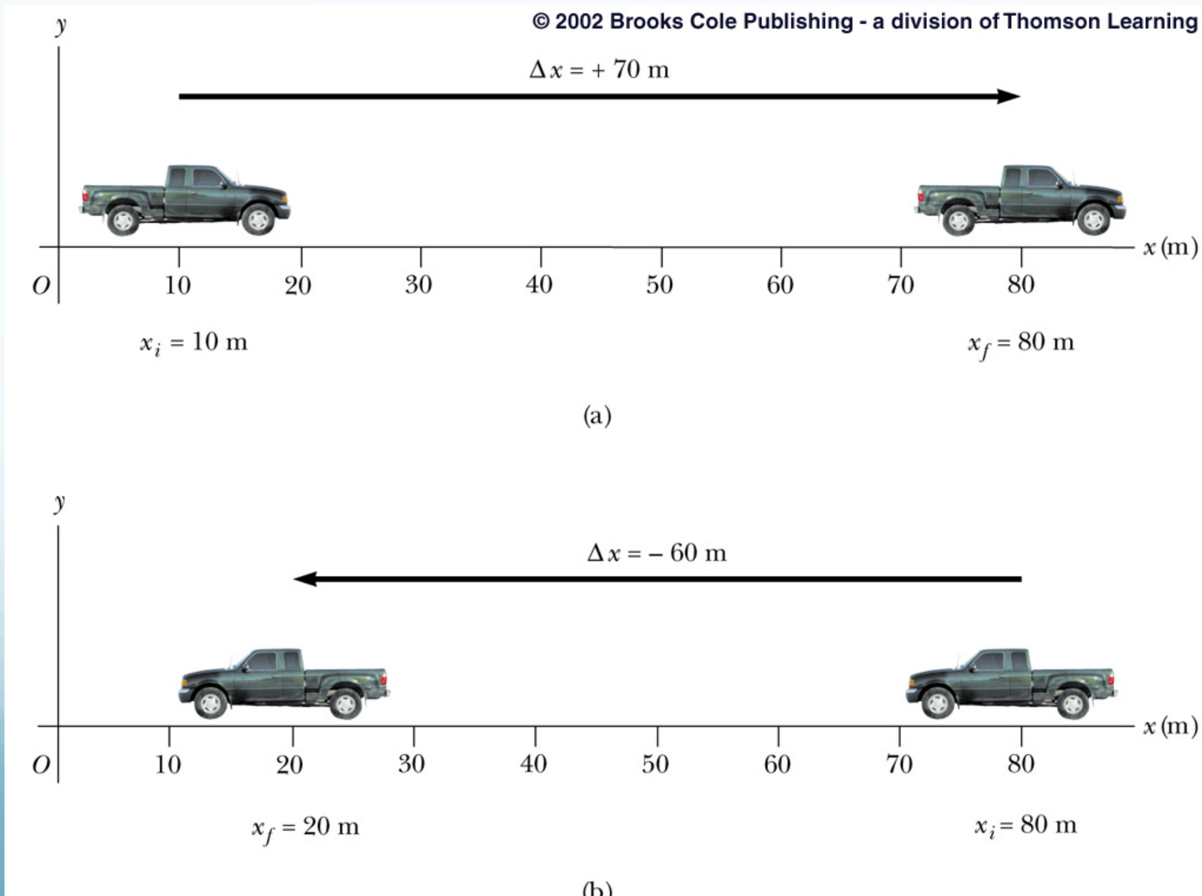
- Units of velocity:

Units	
SI	Meters per second (m/s)
CGS	Centimeters per second (cm/s)

- Note: other units may be given in a problem, but generally will need to be converted to these

Example:

Suppose that in both cases truck covers the distance in 10 seconds:



$$\vec{v}_{1\,average} = \frac{\Delta\vec{x}_1}{\Delta t} = \frac{+70m}{10s} = \underline{+7\,m/s}$$

$$\vec{v}_{2\,average} = \frac{\Delta\vec{x}_2}{\Delta t} = \frac{-60m}{10s} = \underline{-6\,m/s}$$

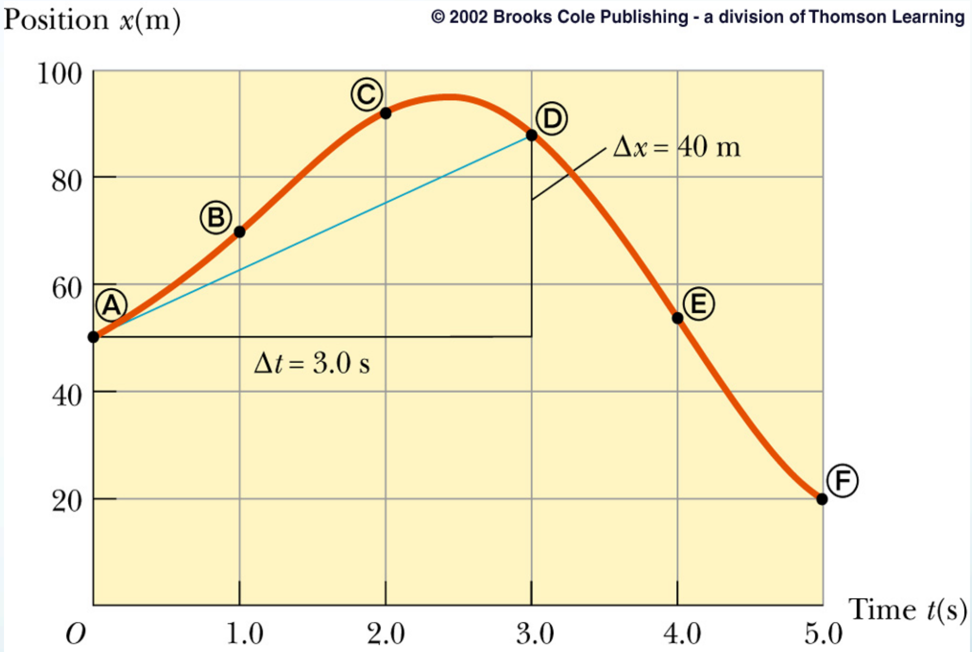
Speed

- Speed is a scalar quantity
  - same units as velocity
  - speed = total distance / total time

Graphical Interpretation of Average Velocity

- Average velocity can be determined from a position-time graph

$$\vec{v}_{average} = \frac{\Delta\vec{x}}{\Delta t} = \frac{+40m}{3.0s}$$
$$= \underline{+13\, m/s}$$



- Average velocity equals the slope of the line joining the initial and final positions

Instantaneous Velocity

- Instantaneous velocity is defined as the limit of the average velocity as the time interval becomes infinitesimally short, or as the time interval approaches zero

$$\vec{v}_{inst} = \lim_{\Delta t \to 0} \frac{\Delta \vec{x}}{\Delta t} = \lim_{\Delta t \to 0} \frac{\vec{x}_f - \vec{x}_i}{\Delta t}$$

FIGURE 2–8 Car speedometer showing mi/h in white, and km/h in orange.

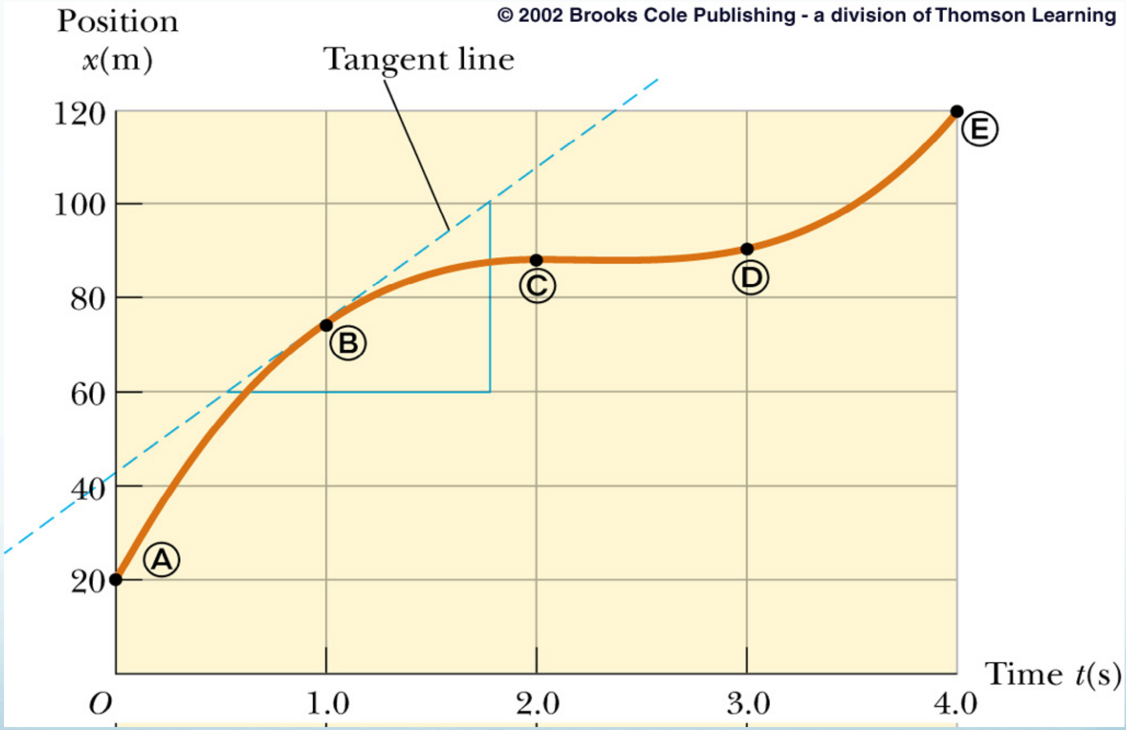
- The instantaneous velocity indicates what is happening at every point of time

Uniform Velocity

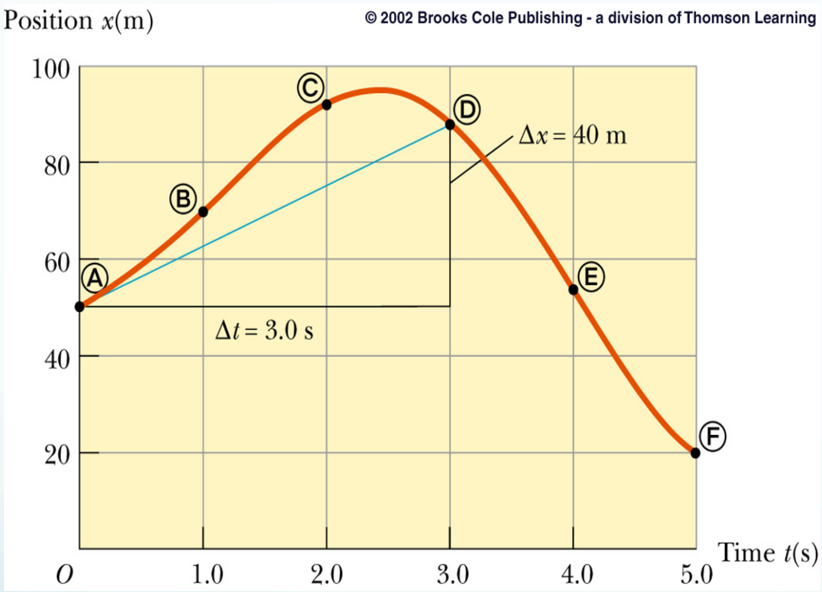
- Uniform velocity is constant velocity
- The instantaneous velocities are always the same
  - All the instantaneous velocities will also equal the average velocity

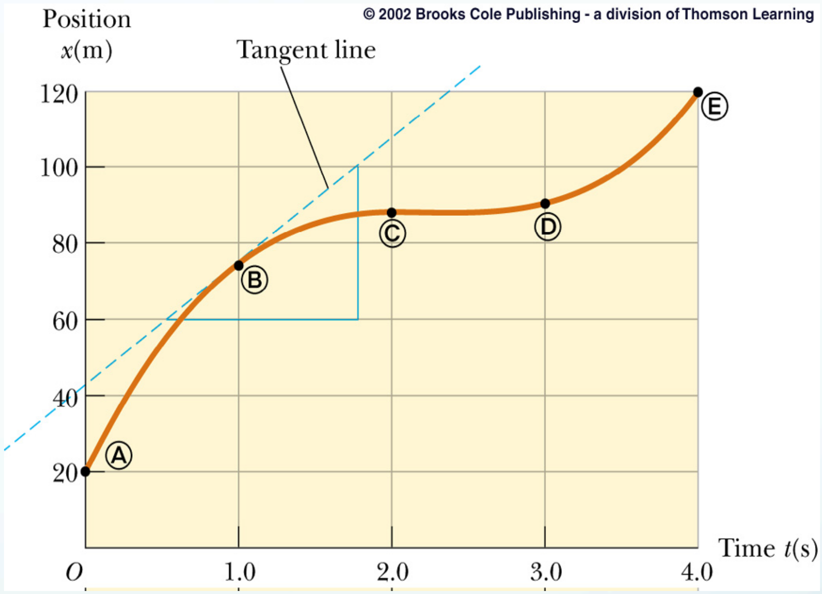
Graphical Interpretation of Instantaneous Velocity

- Instantaneous velocity is the slope of the tangent to the curve at the time of interest



Average vs Instantaneous Velocity



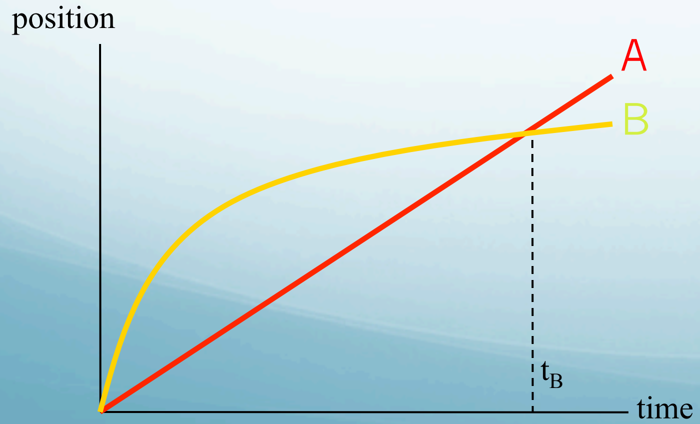


Average velocity Instantaneous velocity

ConcepTest 2

The graph shows position as a function of time for two trains running on parallel tracks. Which of the following is true:

1. at time t_B both trains have the same velocity
2. both trains speed up all the time
3. both trains have the same velocity at some time before t_B
4. train A is longer than train B
5. all of the above statements are true



ConcepTest 2

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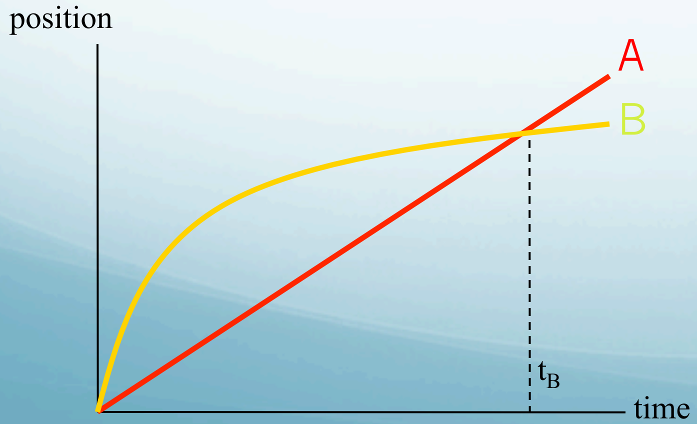

ConcepTest 2 (answer)

The graph shows position as a function of time for two trains running on parallel tracks. Which of the following is true:

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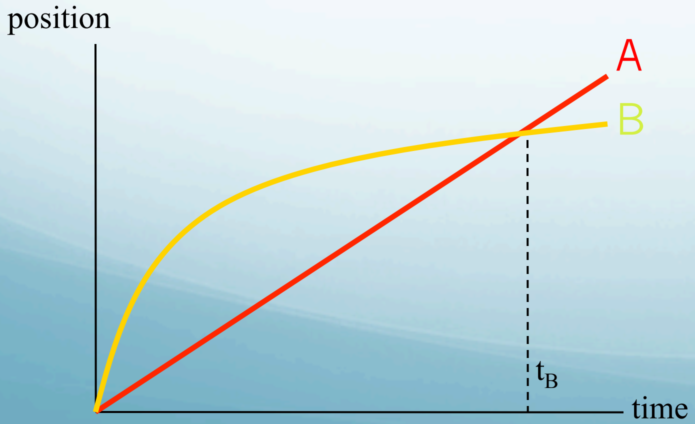


Note: the slope of curve B is parallel to line A at some point $t < t_B$

Average Acceleration

- Changing velocity (non-uniform) means an acceleration is present
- Average acceleration is the rate of change of the velocity

$$\vec{a}_{average} = \frac{\Delta \vec{v}}{\Delta t} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$$

- Average acceleration is a vector quantity

Average Acceleration

- When the sign of the velocity and the acceleration are the same (either positive or negative), then the speed is increasing
- When the sign of the velocity and the acceleration are opposite, the speed is decreasing

Units	
SI	Meters per second squared (m/s^2)
CGS	Centimeters per second squared (cm/s^2)


$\vec{a}$
$\vec{v}$
United States

Instantaneous and Uniform Acceleration

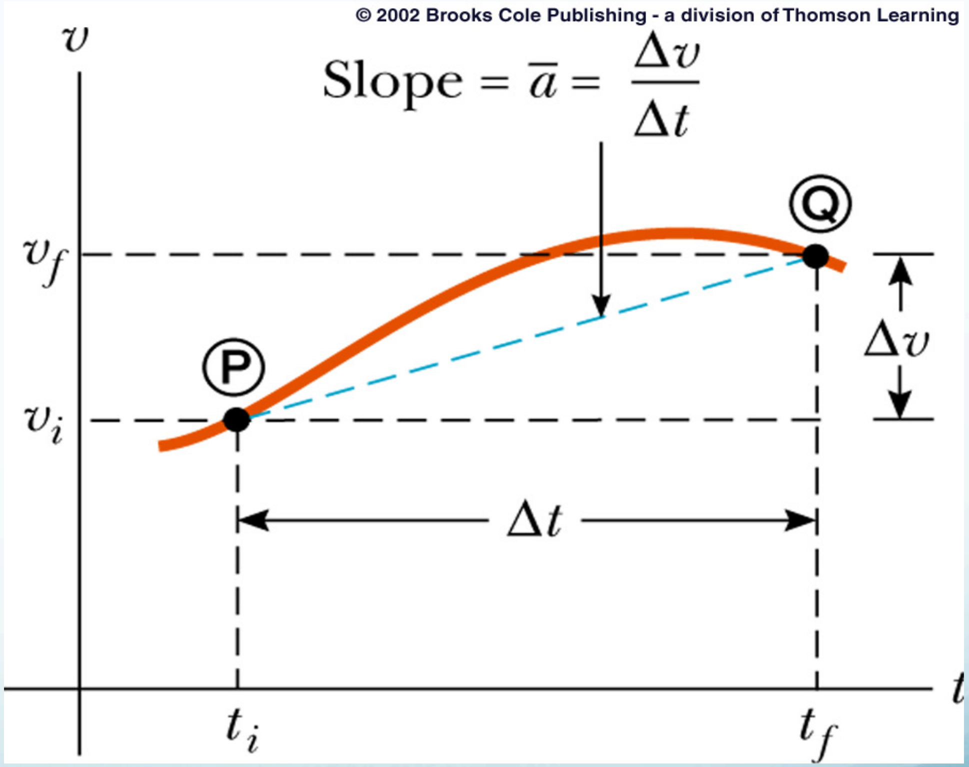
- Instantaneous acceleration is the limit of the average acceleration as the time interval goes to zero

$$\vec{a}_{inst} = \lim_{\Delta t \to 0} \frac{\Delta \vec{v}}{\Delta t} = \lim_{\Delta t \to 0} \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$$

- When the instantaneous accelerations are always the same, the acceleration will be uniform
  - The instantaneous accelerations will all be equal to the average acceleration

Graphical Interpretation of Acceleration

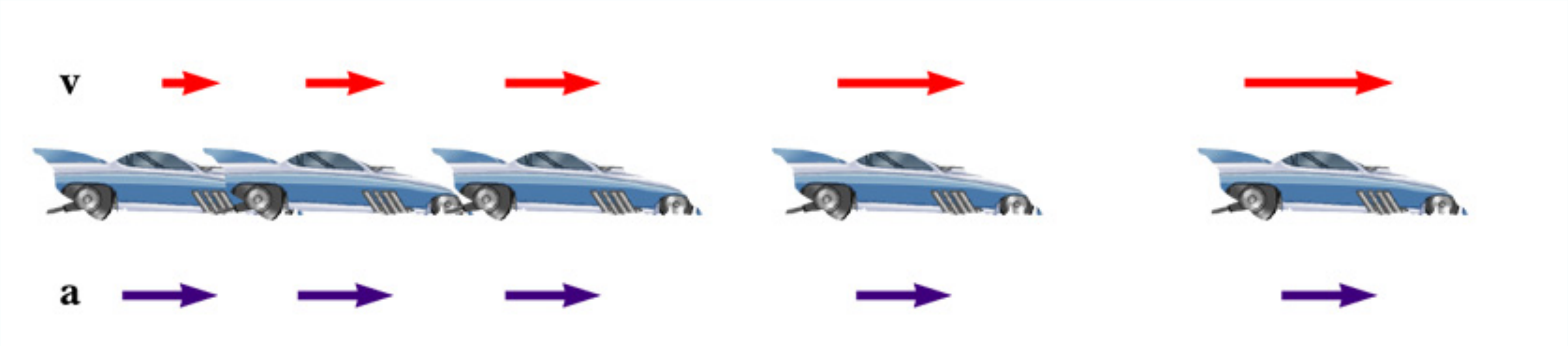
- Average acceleration is the slope of the line connecting the initial and final velocities on a velocity-time graph
- Instantaneous acceleration is the slope of the tangent to the curve of the velocity-time graph



Example: Motion Diagrams

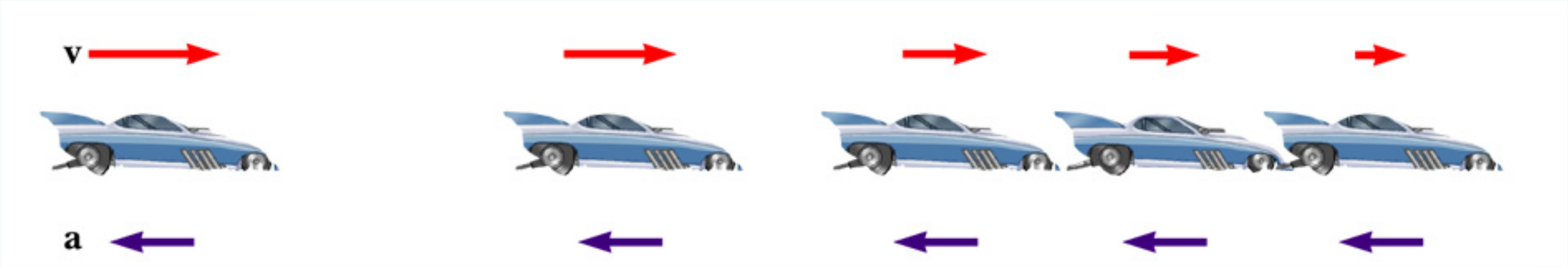
- Uniform velocity (shown by red arrows maintaining the same size)
- Acceleration equals zero

Example:



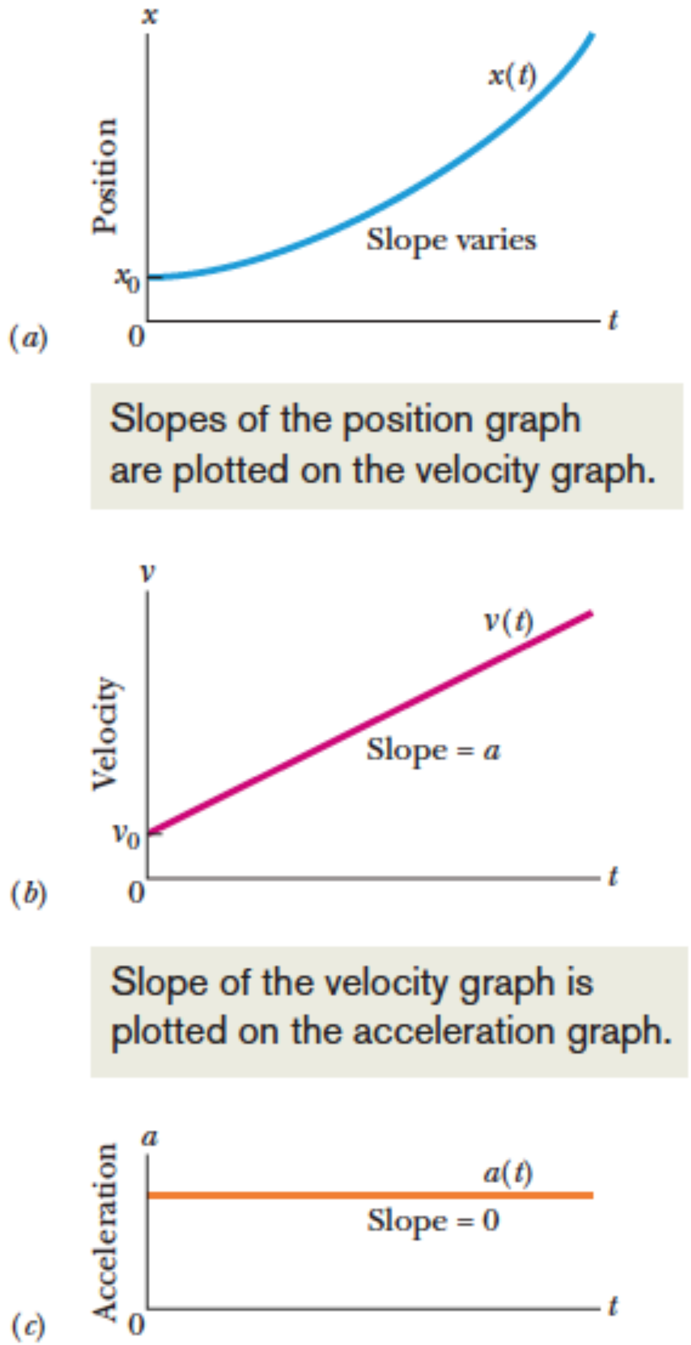
- Velocity and acceleration are in the same direction
- Acceleration is uniform (blue arrows maintain the same length)
- Velocity is increasing (red arrows are getting longer)

Example:



- Acceleration and velocity are in opposite directions
- Acceleration is uniform (blue arrows maintain the same length)
- Velocity is decreasing (red arrows are getting shorter)

- Example



x
x(t)
Position
Slope varies
x_0
(a)
0
t
Slopes of the position graph
are plotted on the velocity graph.
v
v(t)
Velocity
Slope = a
v_0
(b)
0
t
Slope of the velocity graph is
plotted on the acceleration graph.
a
a(t)
Acceleration
Slope = 0
(c)
0
t

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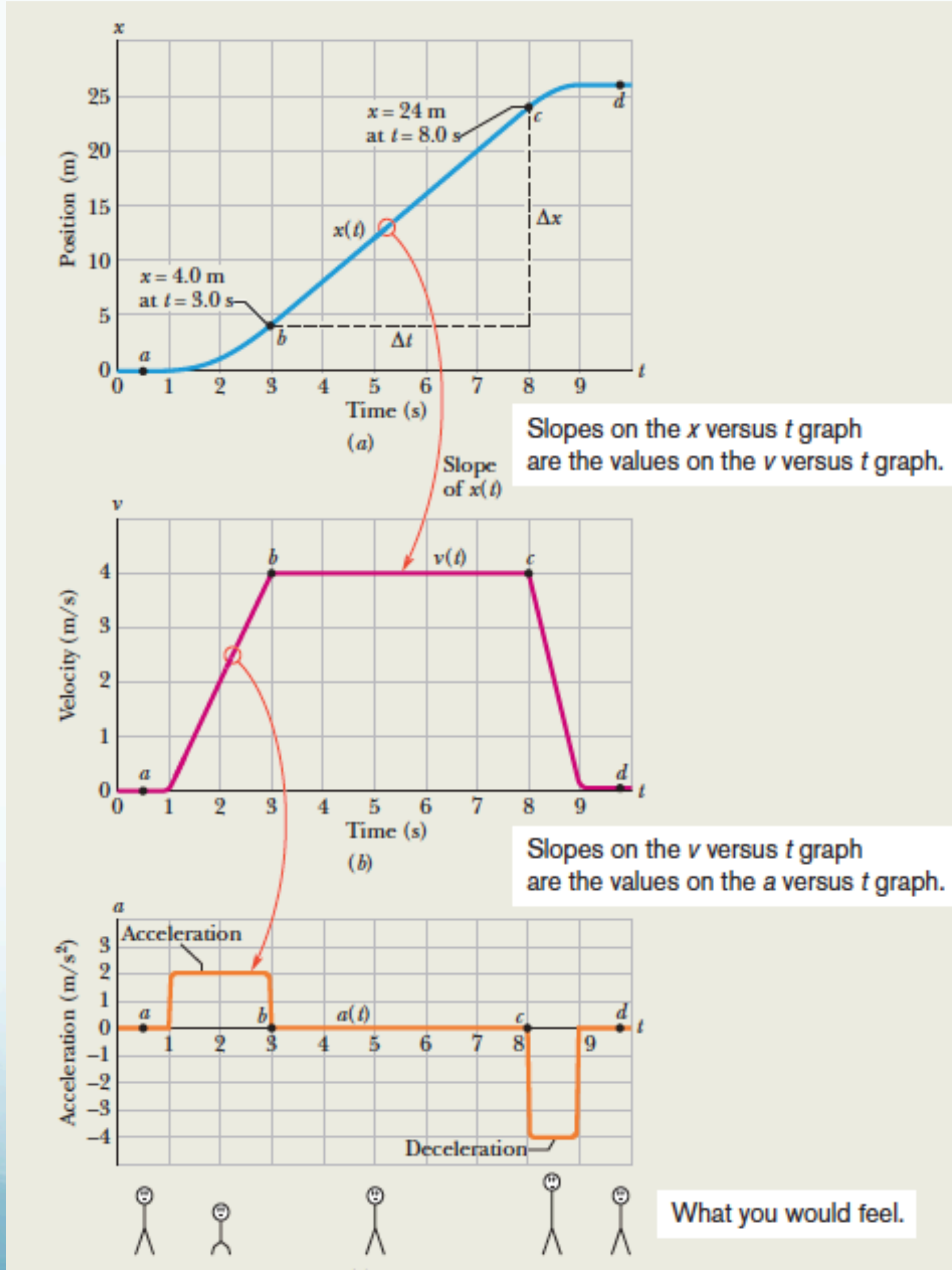
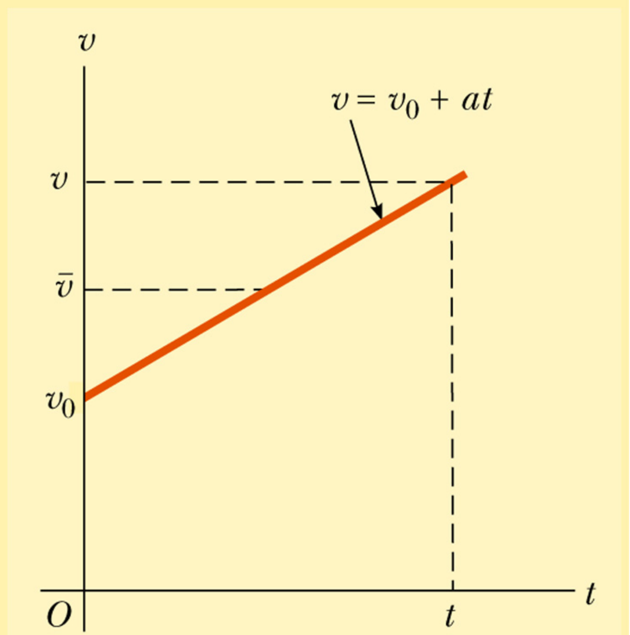
- Example


x
Position (m)
x = 24 m
at t = 8.0 s
x = 4.0 m
at t = 3.0 s
x(t)
Δx
Δt
Time (s)
(a)
Slope
of x(t)
Slopes on the x versus t graph
are the values on the v versus t graph.
v
Velocity (m/s)
v(t)
Time (s)
(b)
Slopes on the v versus t graph
are the values on the a versus t graph.
a
Acceleration (m/s²)
Acceleration
a(t)
Deceleration
What you would feel.

One-dimensional Motion With Constant Acceleration

- If acceleration is uniform ($\bar{a} = a$):



$$a = \frac{v_f - v_o}{t_f - t_0} = \frac{v_f - v_o}{t}$$

$$\boxed{v_f = v_o + at}$$

- Shows velocity as a function of acceleration and time

One-dimensional Motion With Constant Acceleration

- Used in situations with uniform acceleration

$$\Delta x = v_o t + \frac{1}{2} a t^2$$

$$v_f^2 = v_o^2 + 2a\Delta x$$

$$v_f = v_o + at$$

Velocity changes uniformly

Notes on the equations

$$\Delta x = v_{average}\, t = \left(\frac{v_o + v_f}{2}\right) t$$

- Gives displacement as a function of velocity and time

$$\Delta x = v_o t + \frac{1}{2} a t^2$$

- Gives displacement as a function of time, velocity and acceleration

$$v_f^2 = v_o^2 + 2a\Delta x$$

- Gives velocity as a function of acceleration and displacement

Summary of kinematic equations

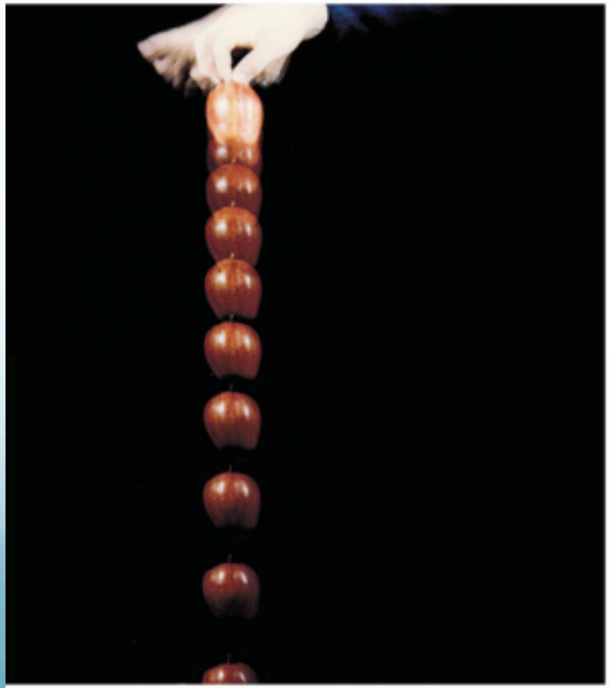
TABLE 2.3 Equations for Motion in a Straight Line Under Constant Acceleration

Equation	Information Given by Equation
$v = v_0 + at$	Velocity as a function of time
$\Delta x = \frac{1}{2}(v_0 + v)t$	Displacement as a function of velocity and time
$\Delta x = v_0 t + \frac{1}{2}at^2$	Displacement as a function of time
$v^2 = v_0^2 + 2a\,\Delta x$	Velocity as a function of displacement

Note: Motion is along the x axis. At $t = 0$, the velocity of the particle is v_0.

Free Fall

Near the surface of the Earth, all objects experience approximately the same acceleration due to gravity.



This is one of the most common examples of motion with constant acceleration.

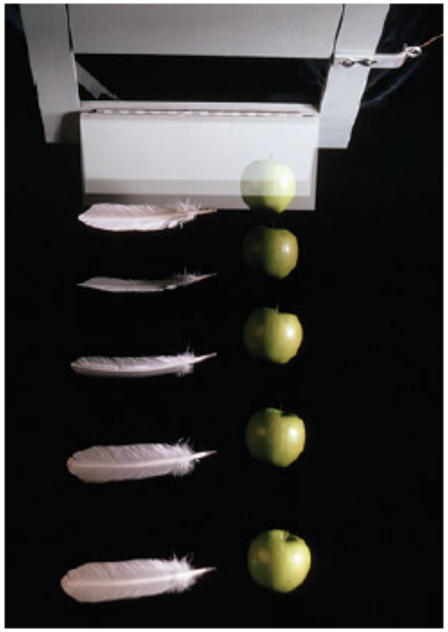


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Figure 2-12 A feather and an apple free fall in vacuum at the same magnitude of acceleration *g*. The acceleration increases the distance between successive images. In the absence of air, the feather and apple fall together.

In the absence of air resistance, all objects fall with the same acceleration, although this may be hard to tell by testing in an environment where there is air resistance.

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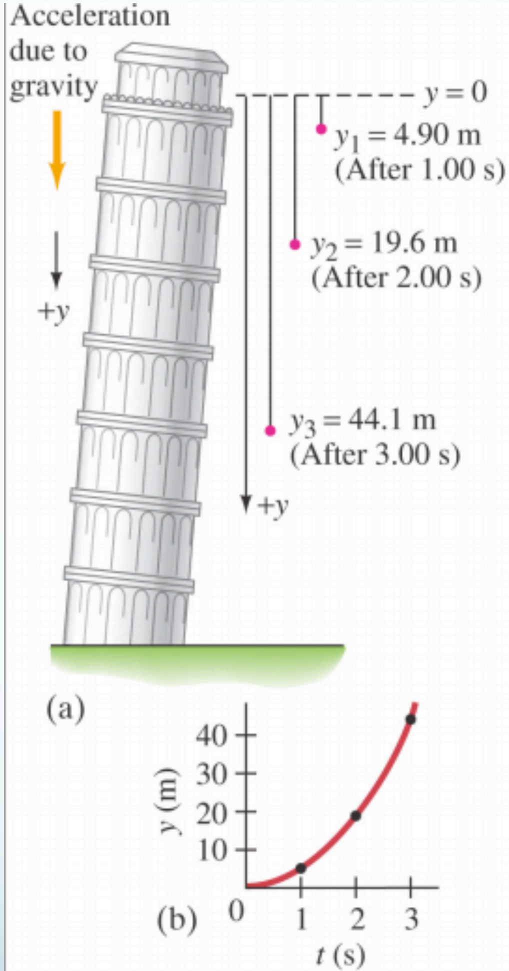
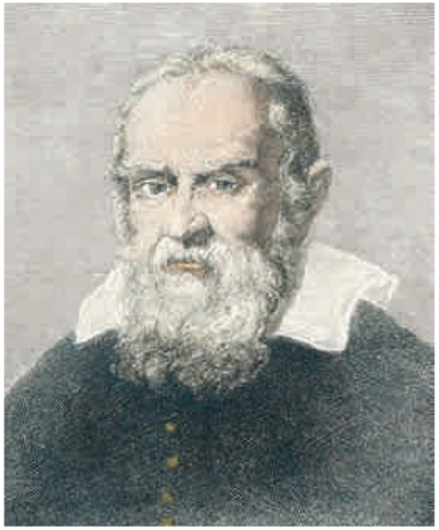


The acceleration due to gravity at the Earth's surface is approximately 9.80 m/s^2.



Galileo Galilei
Italian physicist and astronomer
(1564–1642)

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- Animation 1 (free fall)

- http://physics.wfu.edu/demolabs/demos/avimov/bychptr/chptr1_motion.html

Free Fall

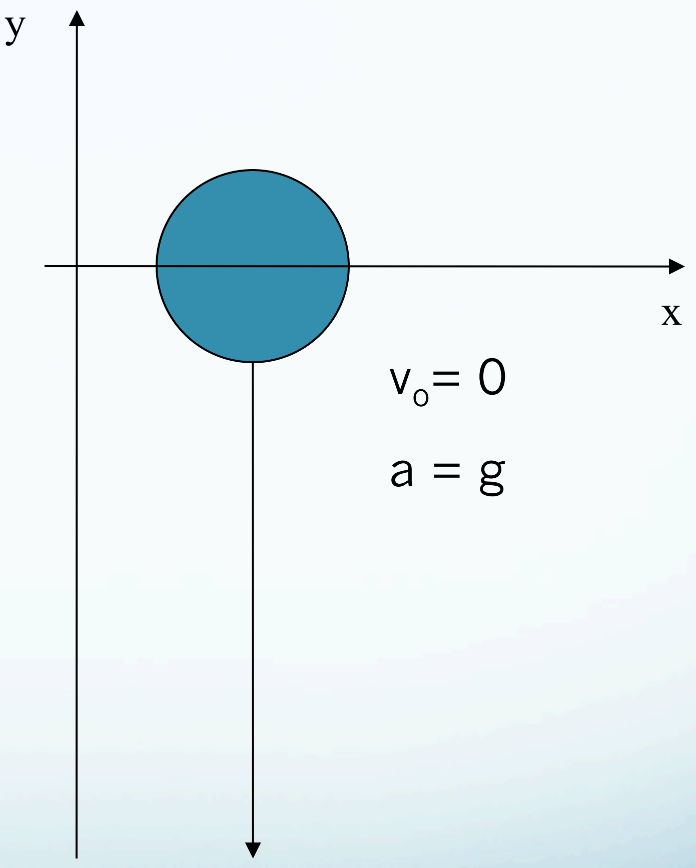
- All objects moving under the influence of only gravity are said to be in free fall
- All objects falling near the earth's surface fall with a constant acceleration
- This acceleration is called the acceleration due to gravity, and indicated by g

Acceleration due to Gravity

- Symbolized by g
- $g = 9.8\ m/s^2$ (can use $g = 10\ m/s^2$ for estimates)
- g is always directed downward
  - toward the center of the earth!

Free Fall -- an Object Dropped

- Initial velocity is zero
- Frame: let up be positive
- Use the kinematic equations
  - Generally use y instead
  - of x since vertical

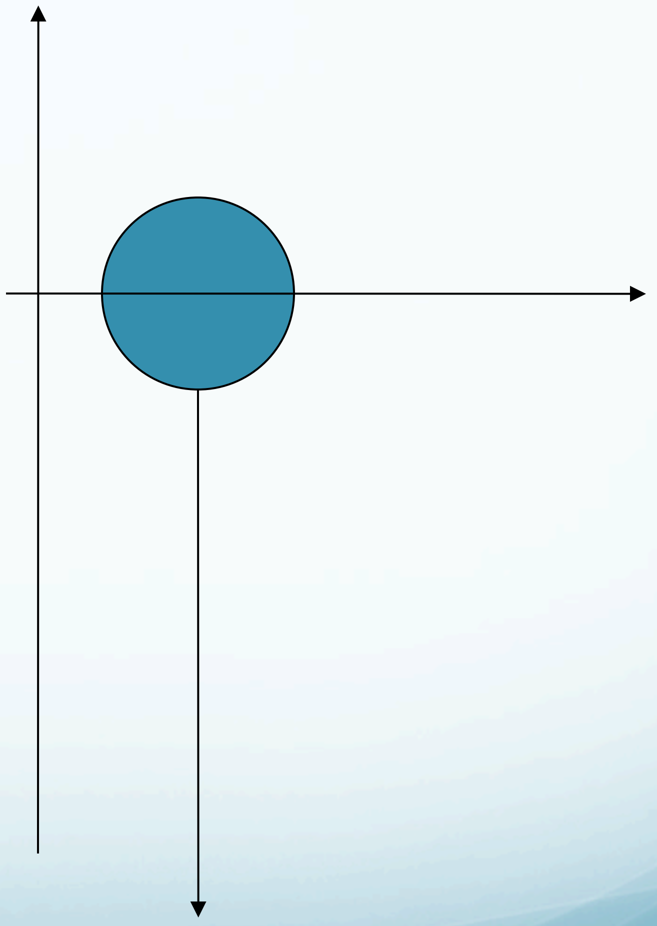


$$\Delta y = \frac{1}{2} a t^2$$

$$a = -9.8\, m/s^2$$

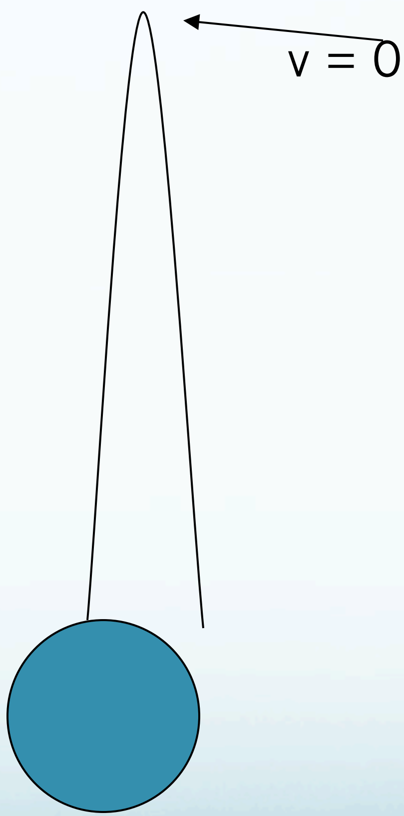
Free Fall -- an Object Thrown Downward

- $a = g$
  - With upward being positive, acceleration will be negative, $g = -9.8\ m/s^2$
- Initial velocity $\neq 0$
  - With upward being positive, initial velocity will be negative



Free Fall -- object thrown upward

- Initial velocity is upward, so positive
- The instantaneous velocity at the maximum height is zero
- a = g everywhere in the motion
  - g is always downward, negative

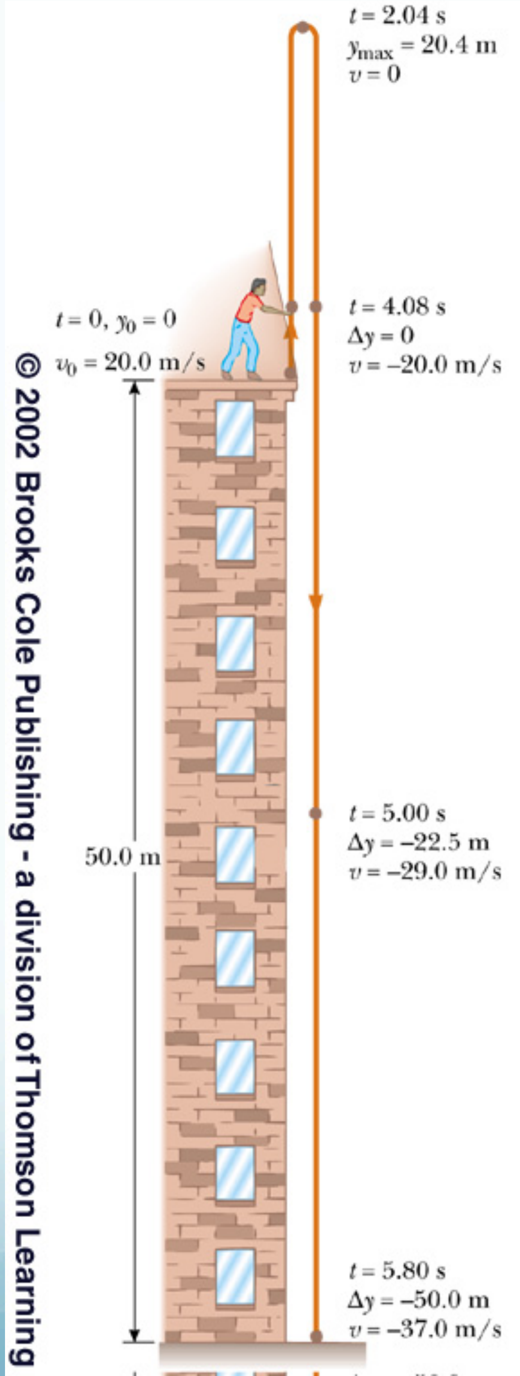


Thrown upward

- The motion may be symmetrical
  - then $t_{up} = t_{down}$
  - then $v_f = -v_o$
- The motion may not be symmetrical
  - Break the motion into various parts
    - generally up and down

Non-symmetrical Free Fall

- Need to divide the motion into segments
- Possibilities include
  - Upward and downward portions
  - The symmetrical portion back to the release point and then the non-symmetrical portion



Example

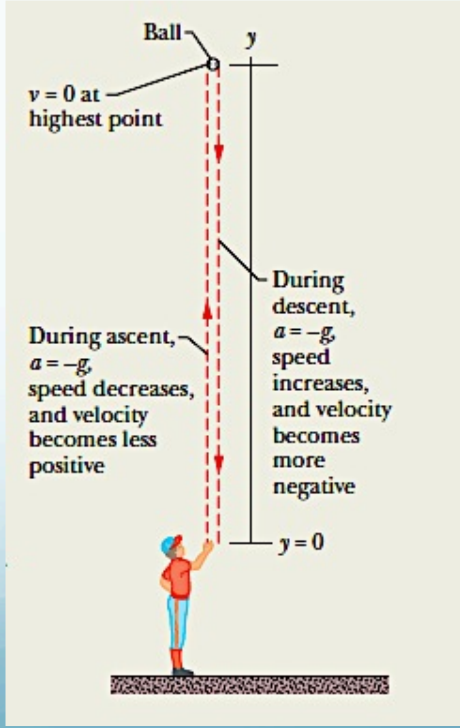
Sample Problem 2.05 Time for full up-down flight, baseball toss

In Fig. 2-13, a pitcher tosses a baseball up along a y axis, with an initial speed of 12 m/s.

(a) How long does the ball take to reach its maximum height?

(b) What is the ball's maximum height above its release point?

(c) How long does the ball take to reach a point 5.0 m above its release point?



Sample Problem 2.05 Time for full up-down flight, baseball toss

In Fig. 2-13, a pitcher tosses a baseball up along a y axis, with an initial speed of 12 m/s.

(a) How long does the ball take to reach its maximum height?

KEY IDEAS

(1) Once the ball leaves the pitcher and before it returns to his hand, its acceleration is the free-fall acceleration $a = -g$. Because this is constant, Table 2-1 applies to the motion. (2) The velocity v at the maximum height must be 0.

Calculation: Knowing v, a, and the initial velocity $v_0 = 12$ m/s, and seeking t, we solve Eq. 2-11, which contains those four variables. This yields

$$t = \frac{v - v_0}{a} = \frac{0 - 12 \text{ m/s}}{-9.8 \text{ m/s}^2} = 1.2 \text{ s.} \qquad \text{(Answer)}$$

(b) What is the ball's maximum height above its release point?

Calculation: We can take the ball's release point to be $y_0 = 0$. We can then write Eq. 2-16 in y notation, set $y - y_0 = y$ and $v = 0$ (at the maximum height), and solve for y. We get

$$y = \frac{v^2 - v_0^2}{2a} = \frac{0 - (12 \text{ m/s})^2}{2(-9.8 \text{ m/s}^2)} = 7.3 \text{ m.} \qquad \text{(Answer)}$$

(c) How long does the ball take to reach a point 5.0 m above its release point?

Calculations: We know v_0, $a = -g$, and displacement $y - y_0 = 5.0$ m, and we want t, so we choose Eq. 2-15. Rewriting it for y and setting $y_0 = 0$ give us

$$y = v_0 t - \tfrac{1}{2} g t^2,$$

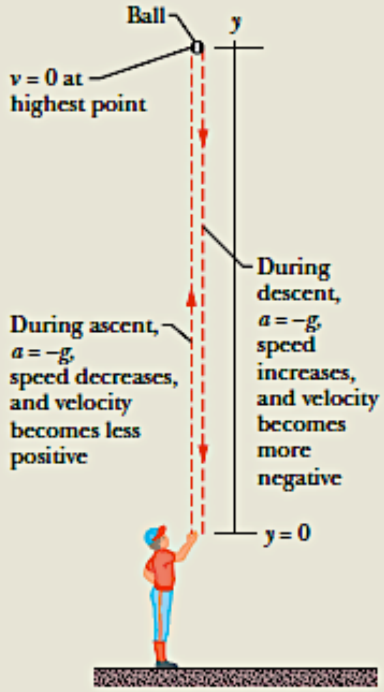


Figure 2-13 A pitcher tosses a baseball straight up into the air. The equations of free fall apply for rising as well as for falling objects, provided any effects from the air can be neglected.

or $$5.0 \text{ m} = (12 \text{ m/s})t - (\tfrac{1}{2})(9.8 \text{ m/s}^2)t^2.$$

If we temporarily omit the units (having noted that they are consistent), we can rewrite this as

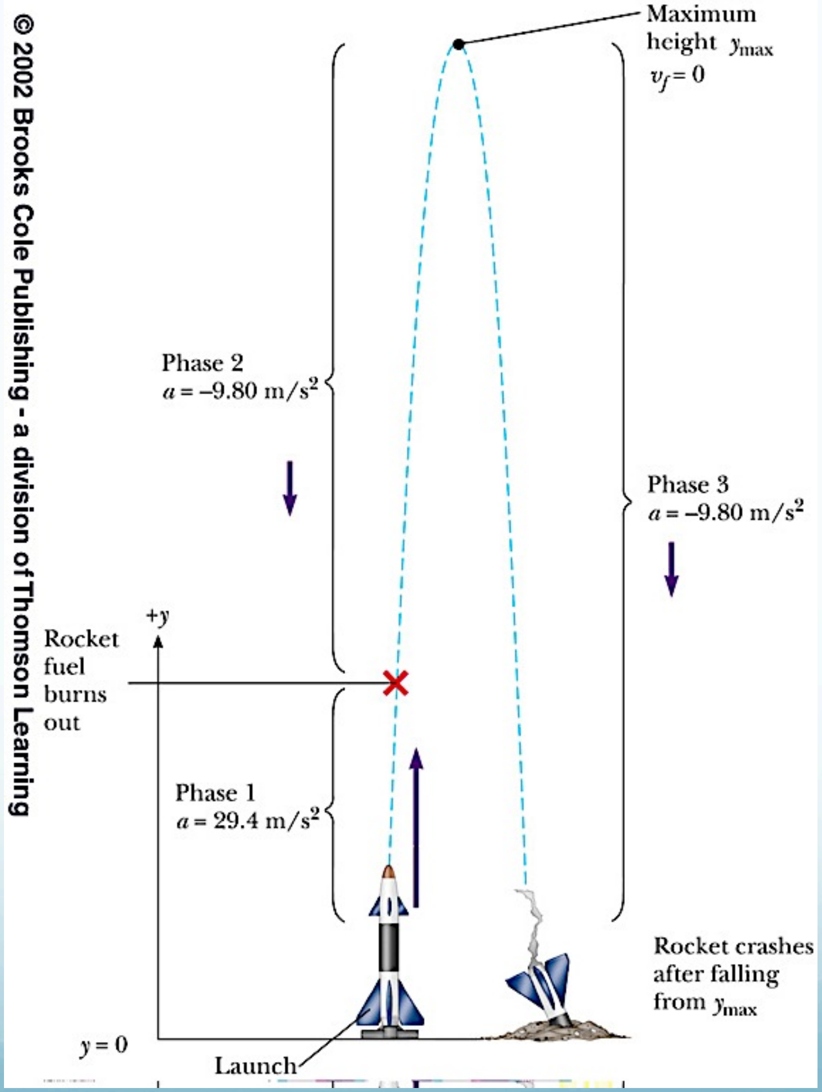
$$4.9t^2 - 12t + 5.0 = 0.$$

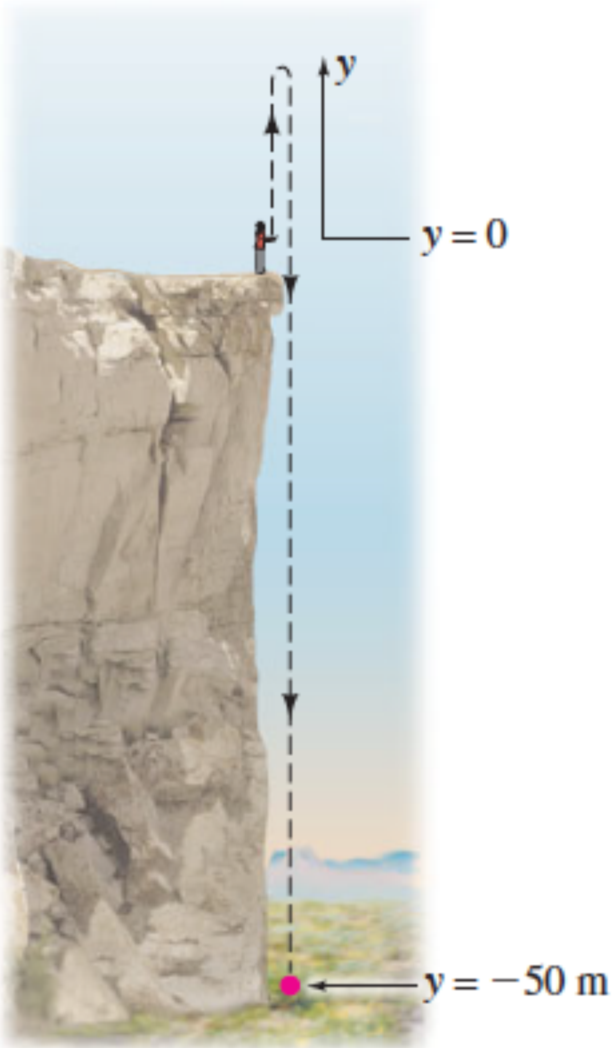
Solving this quadratic equation for t yields

$$t = 0.53 \text{ s} \quad \text{and} \quad t = 1.9 \text{ s.} \qquad \text{(Answer)}$$

There are two such times! This is not really surprising because the ball passes twice through $y = 5.0$ m, once on the way up and once on the way down.

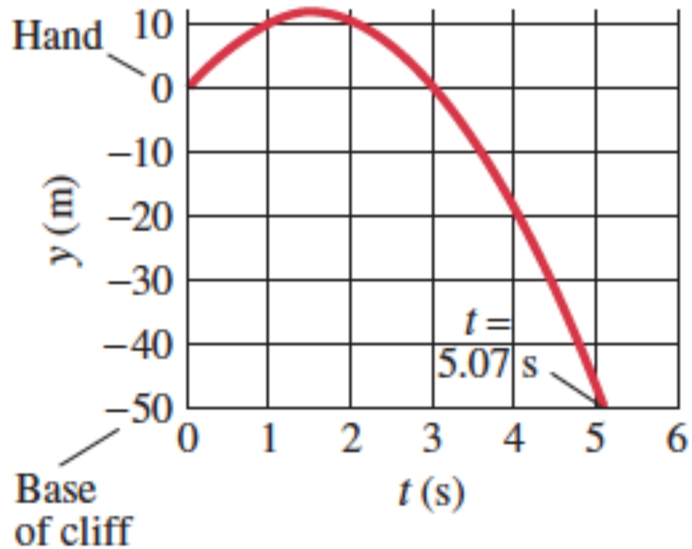
Combination Motions





y
y = 0
y = −50 m

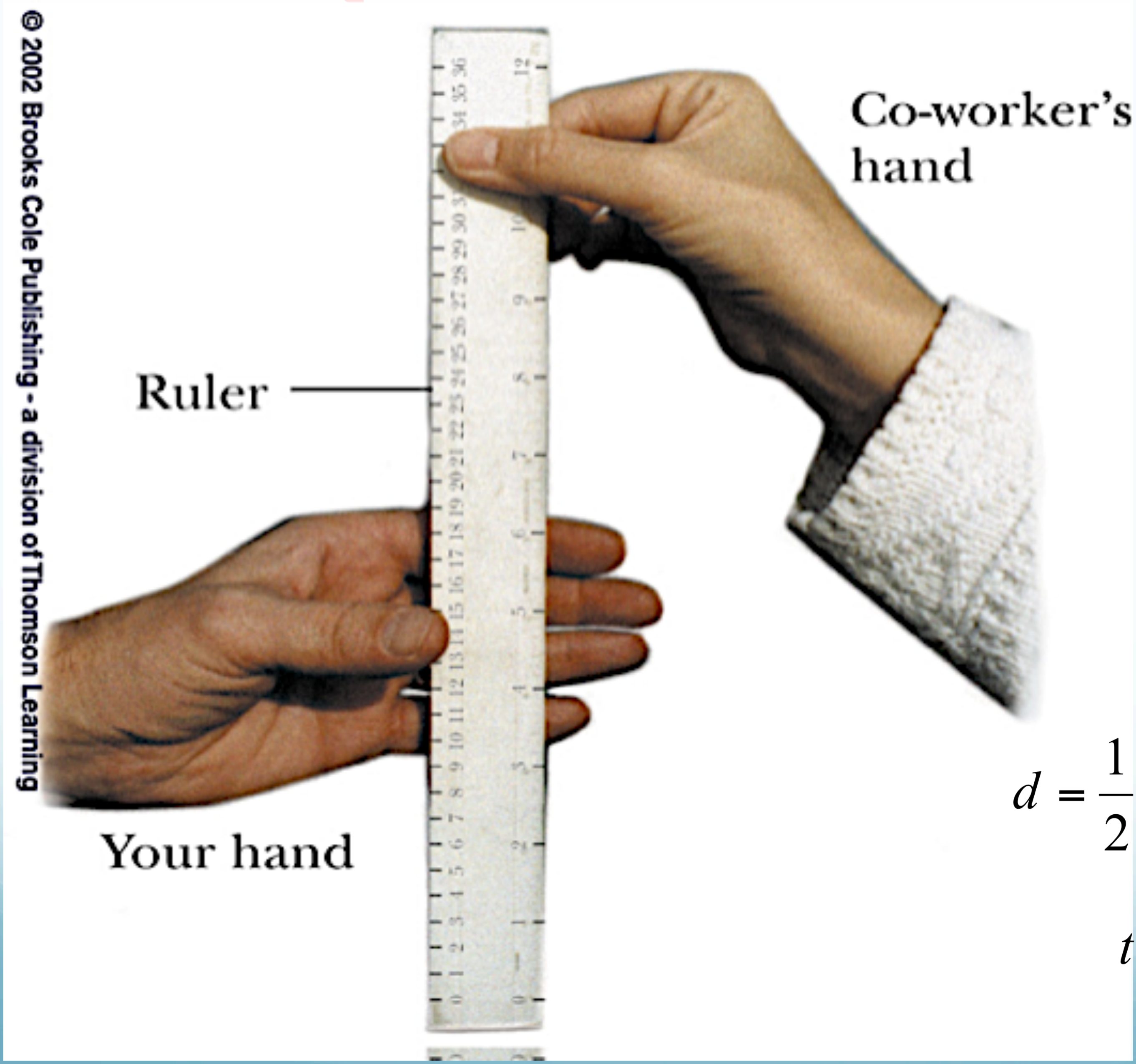
(a)



Hand
10
0
−10
−20
−30
−40
−50
y (m)
t =
5.07 s
0
1
2
3
4
5
6
t (s)
Base
of cliff

(b)

Fun QuickLab: Reaction time



$$d = \frac{1}{2} g t^2, g = 9.8 m/s^2$$

$$t = \sqrt{\frac{2d}{g}}$$

Another Look at Constant Acceleration*

The first two equations in Table 2-1 are the basic equations from which the others are derived. Those two can be obtained by integration of the acceleration with the condition that a is constant. To find Eq. 2-11, we rewrite the definition of acceleration (Eq. 2-8) as

$$dv = a\,dt.$$

We next write the *indefinite integral* (or *antiderivative*) of both sides:

$$\int dv = \int a\,dt.$$

Since acceleration a is a constant, it can be taken outside the integration. We obtain

$$\int dv = a\int dt$$

or

$$v = at + C. \tag{2-25}$$

To evaluate the constant of integration C, we let $t = 0$, at which time $v = v_0$. Substituting these values into Eq. 2-25 (which must hold for all values of t, including $t = 0$) yields

$$v_0 = (a)(0) + C = C.$$

To derive Eq. 2-15, we rewrite the definition of velocity (Eq. 2-4) as

$$dx = v\,dt$$

and then take the indefinite integral of both sides to obtain

$$\int dx = \int v\,dt.$$

Next, we substitute for v with Eq. 2-11:

$$\int dx = \int (v_0 + at)\,dt.$$

Since v_0 is a constant, as is the acceleration a, this can be rewritten as

$$\int dx = v_0 \int dt + a \int t\,dt.$$

Integration now yields

$$x = v_0 t + \tfrac{1}{2}at^2 + C', \tag{2-26}$$

where C' is another constant of integration. At time $t = 0$, we have $x = x_0$. Substituting these values in Eq. 2-26 yields $x_0 = C'$. Replacing C' with x_0 in Eq. 2-26 gives us Eq. 2-15.

2-10 Graphical Integration in Motion Analysis

When we have a graph of an object's acceleration versus time, we can integrate on the graph to find the object's velocity at any given time. Because acceleration a is defined in terms of velocity as $a = dv/dt$, the Fundamental Theorem of Calculus tells us that

$$v_1 - v_0 = \int_{t_0}^{t_1} a\,dt. \tag{2-22}$$

The right side of the equation is a definite integral (it gives a numerical result rather than a function), v_0 is the velocity at time t_0, and v_1 is the velocity at later time t_1. The definite integral can be evaluated from an $a(t)$ graph, such as in Fig. 2-12*a*. In particular,

$$\int_{t_0}^{t_1} a\,dt = \begin{pmatrix}\text{area between acceleration curve}\\ \text{and time axis, from } t_0 \text{ to } t_1\end{pmatrix}. \tag{2-23}$$

If a unit of acceleration is 1 m/s^2 and a unit of time is 1 s, then the corresponding unit of area on the graph is

$$(1\ \text{m/s}^2)(1\ \text{s}) = 1\ \text{m/s},$$

which is (properly) a unit of velocity. When the acceleration curve is above the time axis, the area is positive; when the curve is below the time axis, the area is negative.

Similarly, because velocity v is defined in terms of the position x as $v = dx/dt$, then

$$x_1 - x_0 = \int_{t_0}^{t_1} v\,dt, \tag{2-24}$$

$$x_1 - x_0 = \int_{t_0}^{t_1} v\,dt, \tag{2-29}$$

where x_0 is the position at time t_0 and x_1 is the position at time t_1. The definite integral on the right side of Eq. 2-29 can be evaluated from a $v(t)$ graph, like that shown in Fig. 2-14*b*. In particular,

$$\int_{t_0}^{t_1} v\,dt = \begin{pmatrix}\text{area between velocity curve}\\ \text{and time axis, from } t_0 \text{ to } t_1\end{pmatrix}. \tag{2-30}$$

If the unit of velocity is 1 m/s and the unit of time is 1 s, then the corresponding unit of area on the graph is

$$(1 \text{ m/s})(1 \text{ s}) = 1 \text{ m},$$

which is (properly) a unit of position and displacement. Whether this area is positive or negative is determined as described for the $a(t)$ curve of Fig. 2-14*a*.

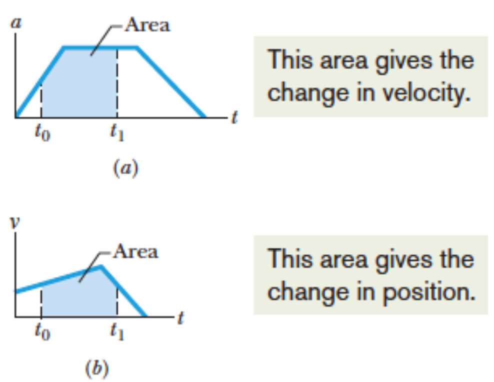


Figure 2-14 The area between a plotted curve and the horizontal time axis, from time t_0 to time t_1, is indicated for (*a*) a graph of acceleration a versus t and (*b*) a graph of velocity v versus t.

Examples:

- 1

This is a graph of position x versus time t.

To find average velocity, first draw a straight line, start to end, and then find the slope of the line.

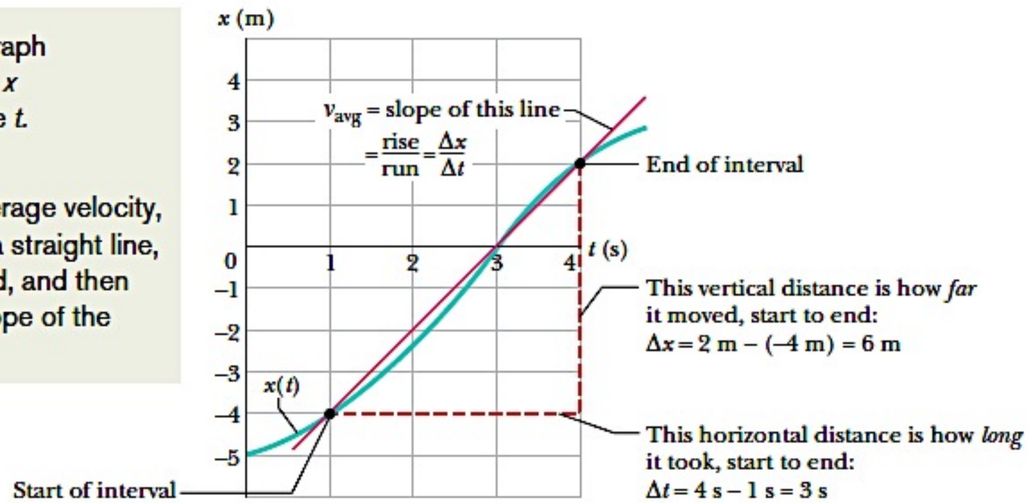


Figure 2-4 Calculation of the average velocity between $t = 1$ s and $t = 4$ s as the slope of the line that connects the points on the $x(t)$ curve representing those times. The swirling icon indicates that a figure is available in *WileyPLUS* as an animation with voiceover.

Examples:

- 2

17. Describe in words the motion of the object graphed in Fig. 2–33.

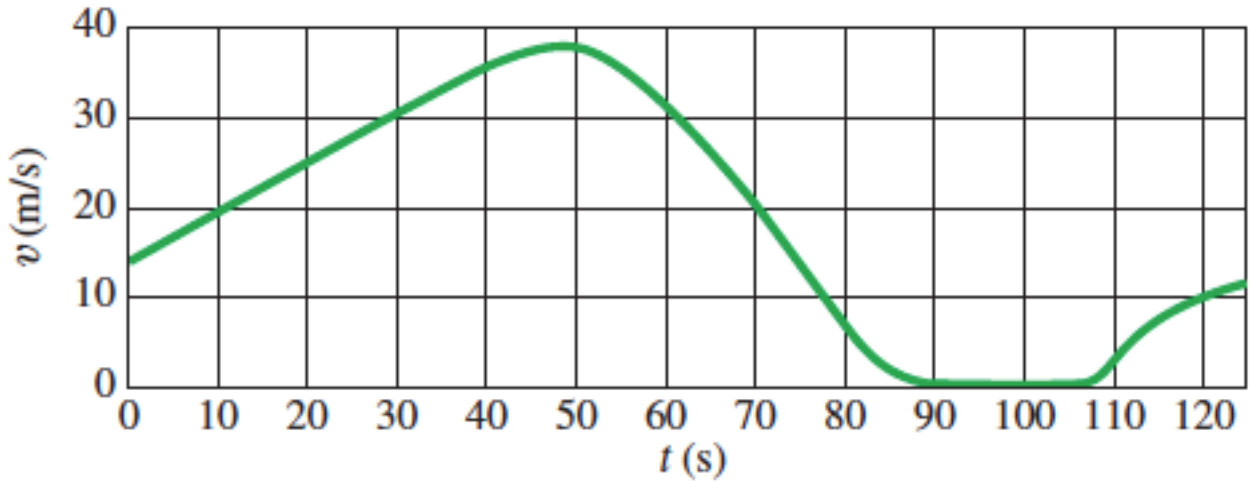


FIGURE 2–33 Question 17.

- 3

Sample Problem 2.03 Acceleration and *dv/dt*

A particle's position on the x axis of Fig. 2-1 is given by

$$x = 4 - 27t + t^3,$$

with x in meters and t in seconds.

(a) Because position x depends on time t, the particle must be moving. Find the particle's velocity function $v(t)$ and acceleration function $a(t)$.

(1) To get the velocity function $v(t)$, we differentiate the position function $x(t)$ with respect to time. (2) To get the acceleration function $a(t)$, we differentiate the velocity function $v(t)$ with respect to time.

Calculations: Differentiating the position function, we find

$$v = -27 + 3t^2, \qquad \text{(Answer)}$$

with v in meters per second. Differentiating the velocity function then gives us

$$a = +6t, \qquad \text{(Answer)}$$

with a in meters per second squared.

(b) Is there ever a time when $v = 0$?

Calculation: Setting $v(t) = 0$ yields

$$0 = -27 + 3t^2,$$

which has the solution

$$t = \pm 3 \text{ s}. \qquad \text{(Answer)}$$

Thus, the velocity is zero both 3 s before and 3 s after the clock reads 0.

(c) Describe the particle's motion for $t \geq 0$.

- 4

Table 2-1 Equations for Motion with Constant Acceleration[a]

Equation Number	Equation	Missing Quantity
2-11	$v = v_0 + at$	$x - x_0$
2-15	$x - x_0 = v_0 t + \frac{1}{2}at^2$	v
2-16	$v^2 = v_0^2 + 2a(x - x_0)$	t
2-17	$x - x_0 = \frac{1}{2}(v_0 + v)t$	a
2-18	$x - x_0 = vt - \frac{1}{2}at^2$	v_0

[a]Make sure that the acceleration is indeed constant before using the equations in this table.

Checkpoint 4

The following equations give the position $x(t)$ of a particle in four situations: (1) $x = 3t - 4$; (2) $x = -5t^3 + 4t^2 + 6$; (3) $x = 2/t^2 - 4/t$; (4) $x = 5t^2 - 3$. To which of these situations do the equations of Table 2-1 apply?

13. (II) Two locomotives approach each other on parallel tracks. Each has a speed of 155 km/h with respect to the ground. If they are initially 8.5 km apart, how long will it be before they reach each other? (See Fig. 2–35.)

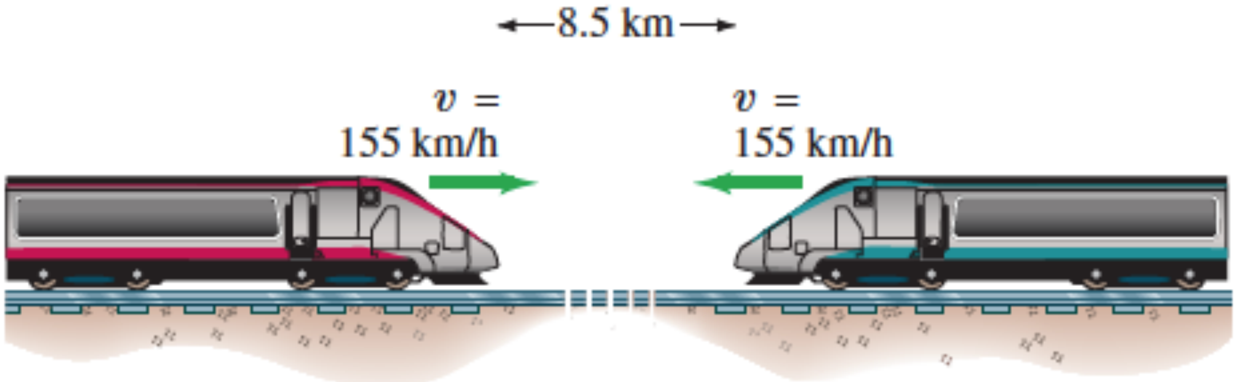


FIGURE 2–35 Problem 13.

53. (III) A falling stone takes 0.31 s to travel past a window 2.2 m tall (Fig. 2–41). From what height above the top of the window did the stone fall?

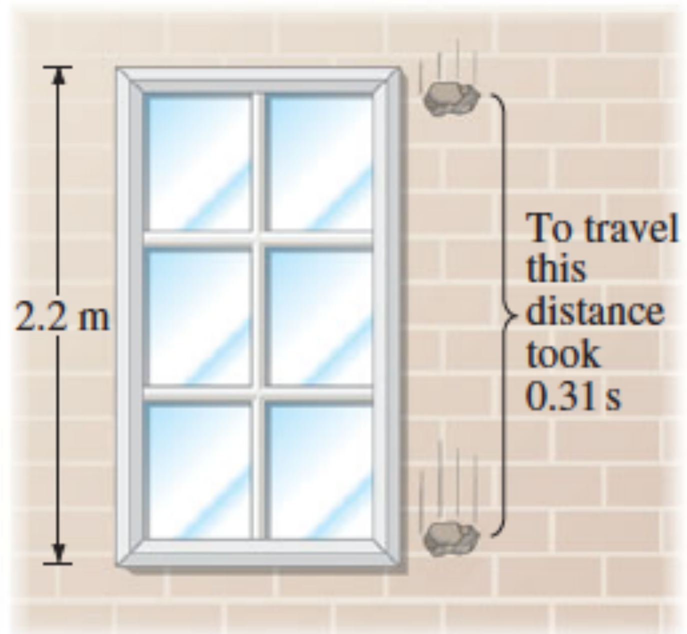


FIGURE 2–41
Problem 53.

51. (II) Suppose you adjust your garden hose nozzle for a fast stream of water. You point the nozzle vertically upward at a height of 1.8 m above the ground (Fig. 2–40). When you quickly turn off the nozzle, you hear the water striking the ground next to you for another 2.5 s. What is the water speed as it leaves the nozzle?

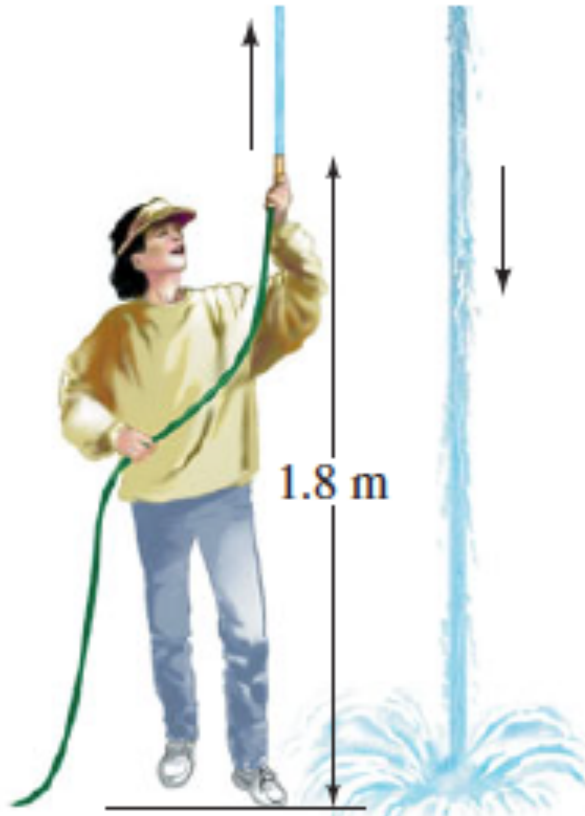


FIGURE 2–40
Problem 51.

73. A person driving her car at 35 km/h approaches an intersection just as the traffic light turns yellow. She knows that the yellow light lasts only 2.0 s before turning to red, and she is 28 m away from the near side of the intersection (Fig. 2–49). Should she try to stop, or should she speed up to cross the intersection before the light turns red? The intersection is 15 m wide. Her car's maximum deceleration is $-5.8\ \mathrm{m/s^2}$, whereas it can accelerate from 45 km/h to 65 km/h in 6.0 s. Ignore the length of her car and her reaction time.

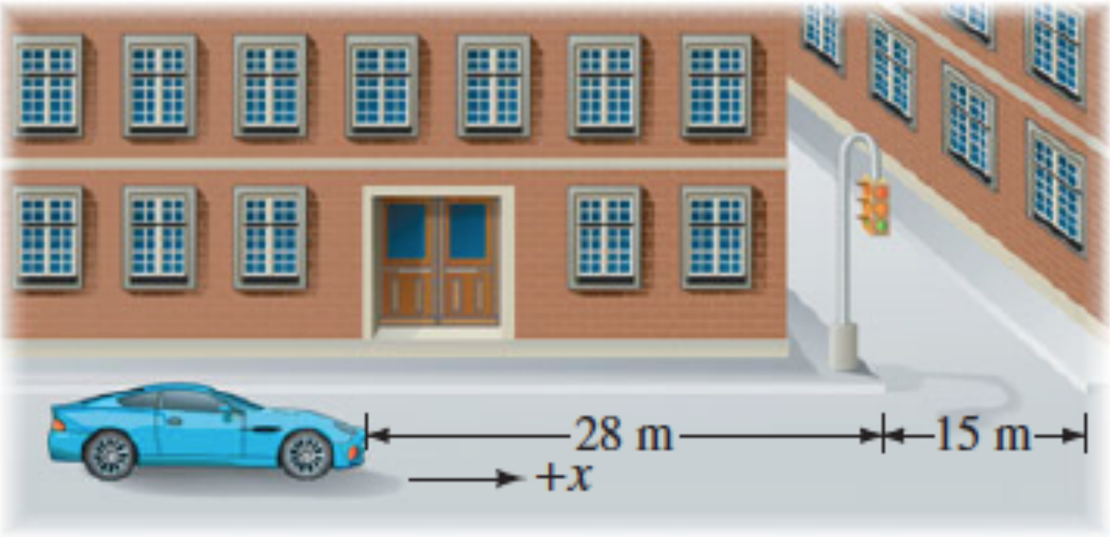


FIGURE 2–49 Problem 73.

- 8

••8 *Panic escape.* Figure 2-24 shows a general situation in which a stream of people attempt to escape through an exit door that turns out to be locked. The people move toward the door at speed $v_s = 3.50$ m/s, are each $d = 0.25$ m in depth, and are separated by $L = 1.75$ m. The arrangement in Fig. 2-24 occurs at time $t = 0$. (a) At what average rate does the layer of people at the door increase? (b) At what time does the layer's depth reach 5.0 m? (The answers reveal how quickly such a situation becomes dangerous.)

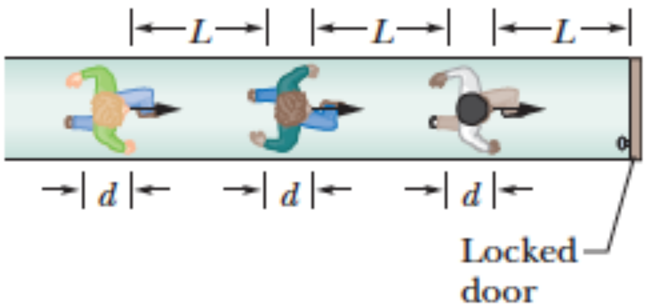


Figure 2-24 Problem 8.

- 10

Module 2-4 Constant Acceleration

•23 SSM An electron with an initial velocity $v_0 = 1.50 \times 10^5$ m/s enters a region of length $L = 1.00$ cm where it is electrically accelerated (Fig. 2-26). It emerges with $v = 5.70 \times 10^6$ m/s. What is its acceleration, assumed constant?

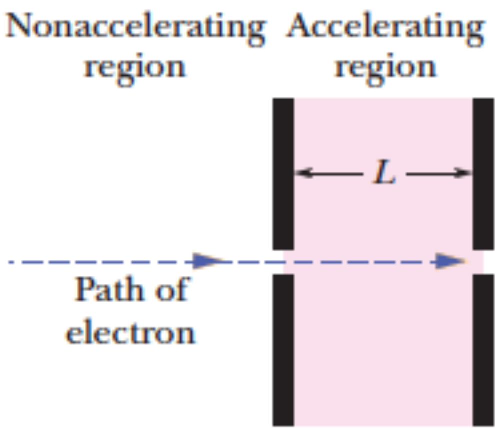


Figure 2-26 Problem 23.

- 11

74 A pilot flies horizontally at 1300 km/h, at height $h = 35$ m above initially level ground. However, at time $t = 0$, the pilot begins to fly over ground sloping upward at angle $\theta = 4.3°$ (Fig. 2-41). If the pilot does not change the airplane's heading, at what time t does the plane strike the ground?

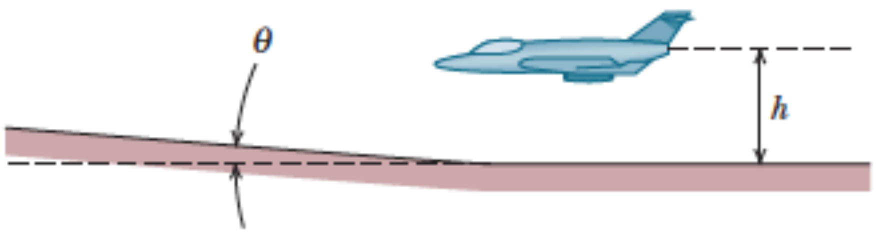


Figure 2-41 Problem 74.

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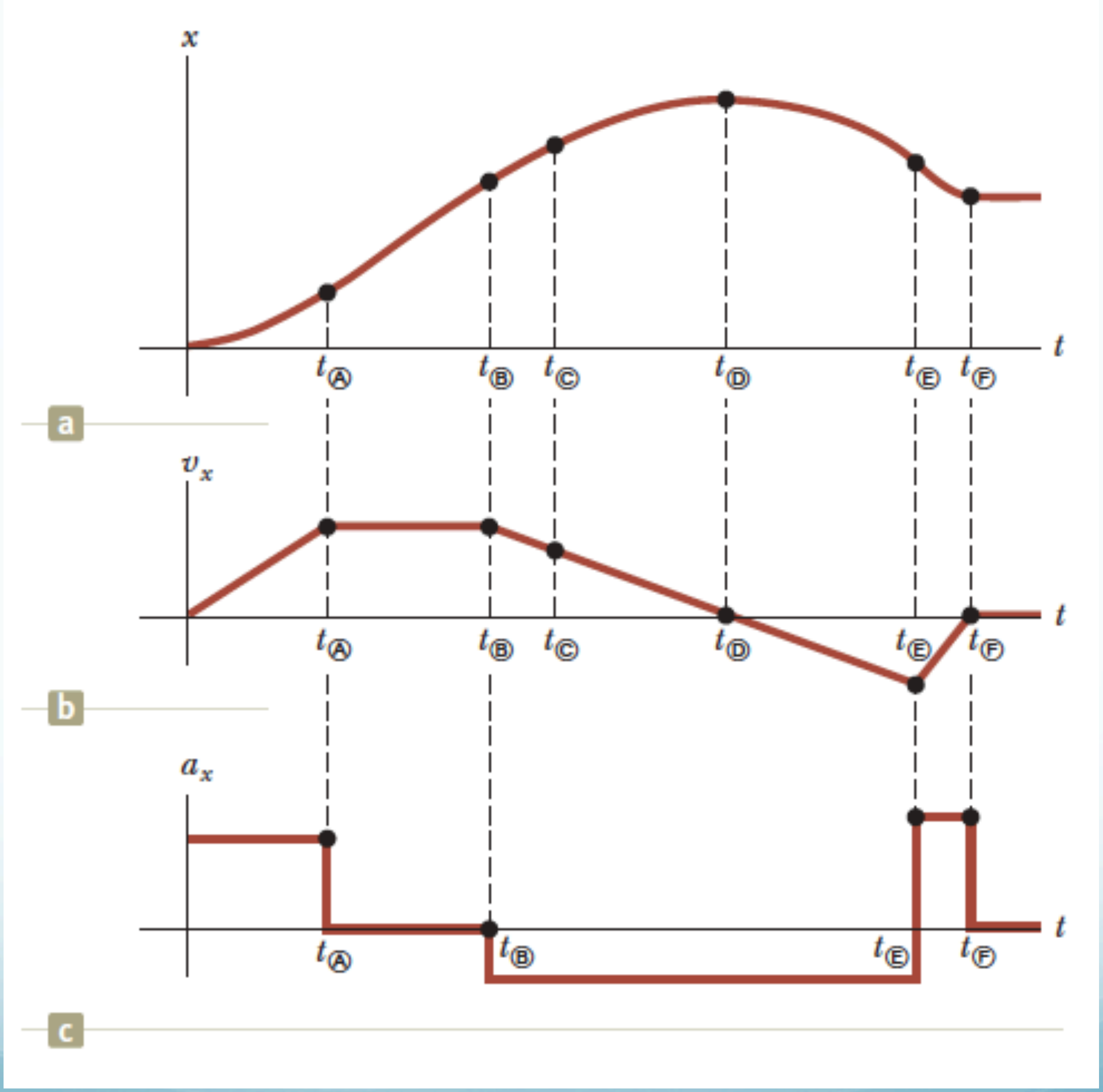
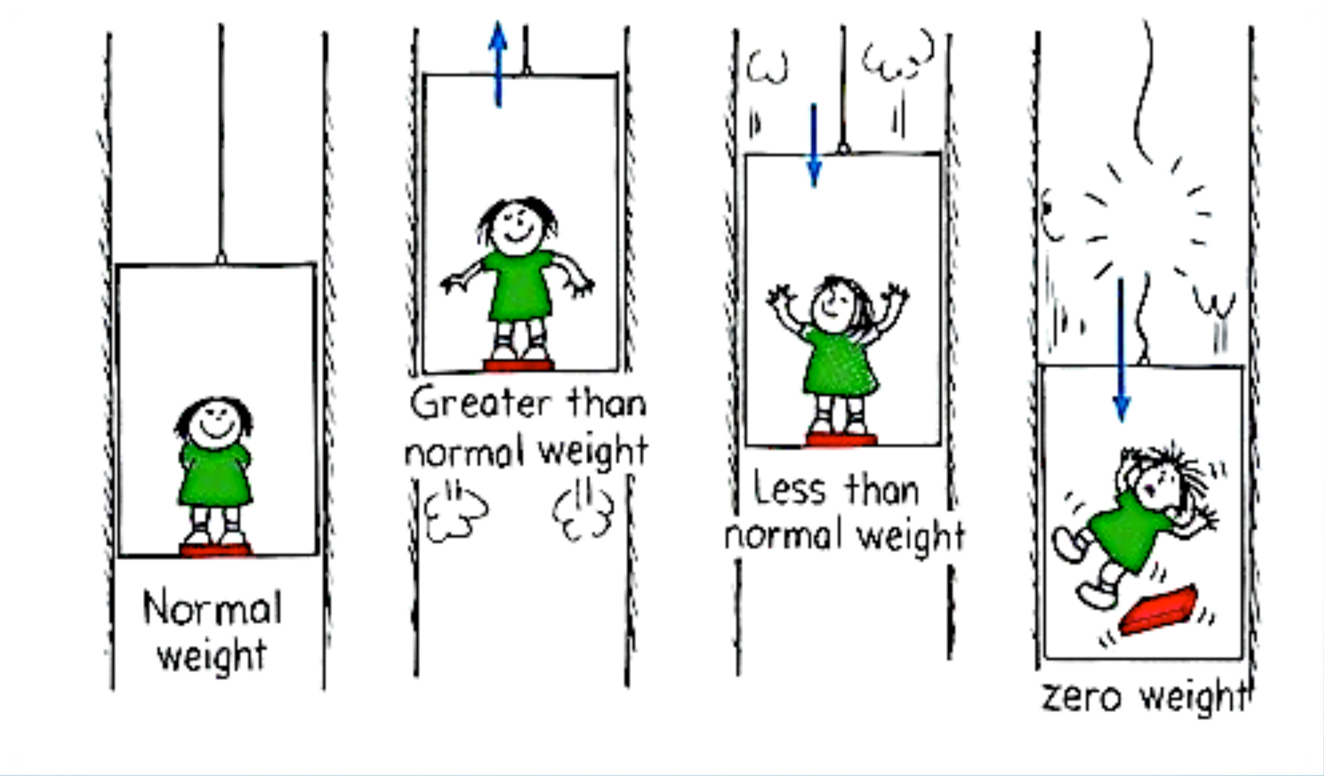


Take-Home 2



Normal weight
Greater than normal weight
Less than normal weight
zero weight