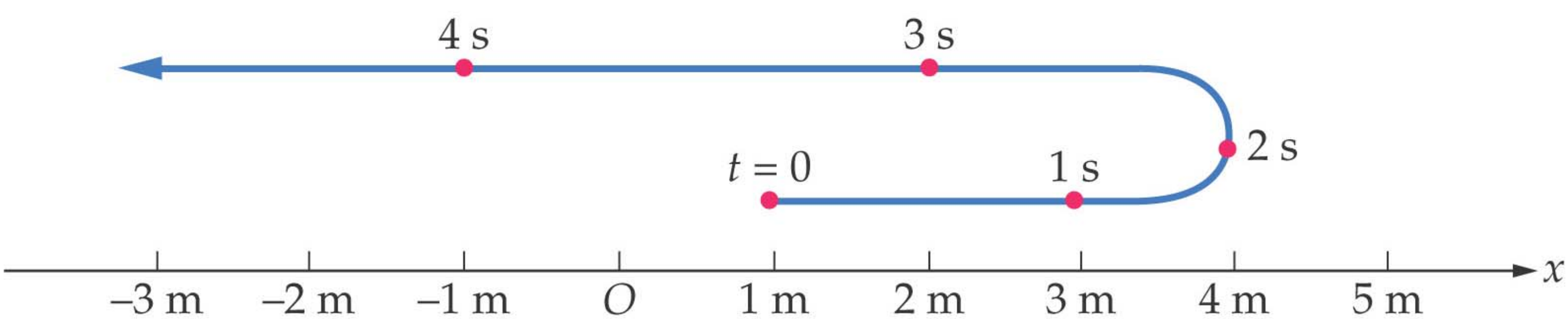
Chapter 2

One-Dimensional Kinematics



Description of motion in one dimension

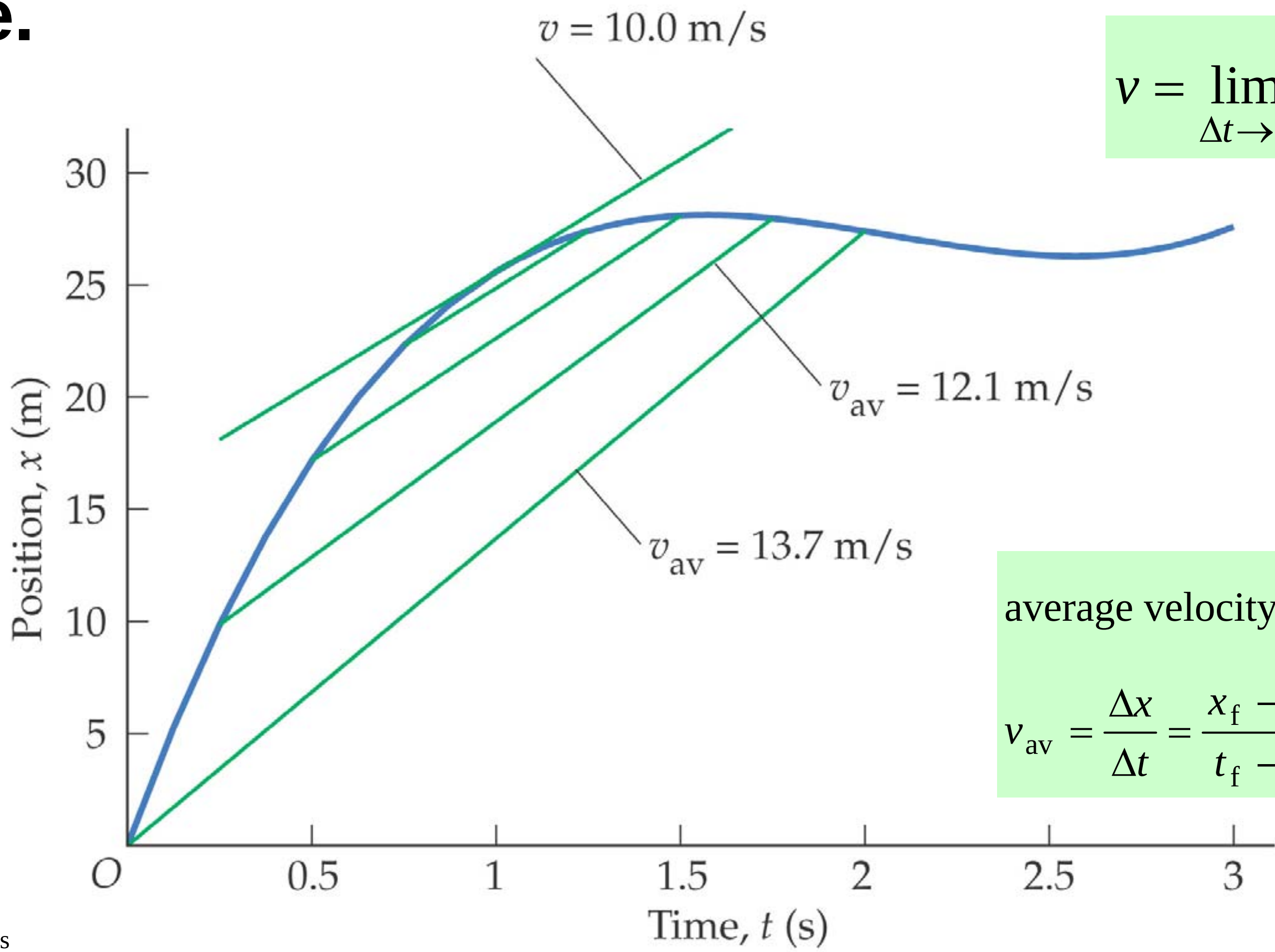
Units of Chapter 2

- Position, Distance, and Displacement
- Average Speed and Velocity
- Instantaneous Velocity
- Acceleration
- **Motion with Constant Acceleration**
- **Applications of the Equations of Motion**
- **Freely Falling Objects**

Review: 2-3 Instantaneous Velocity

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

$$v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t}$$



$$\text{average velocity} = \frac{\text{displacement}}{\text{elapsed time}}$$

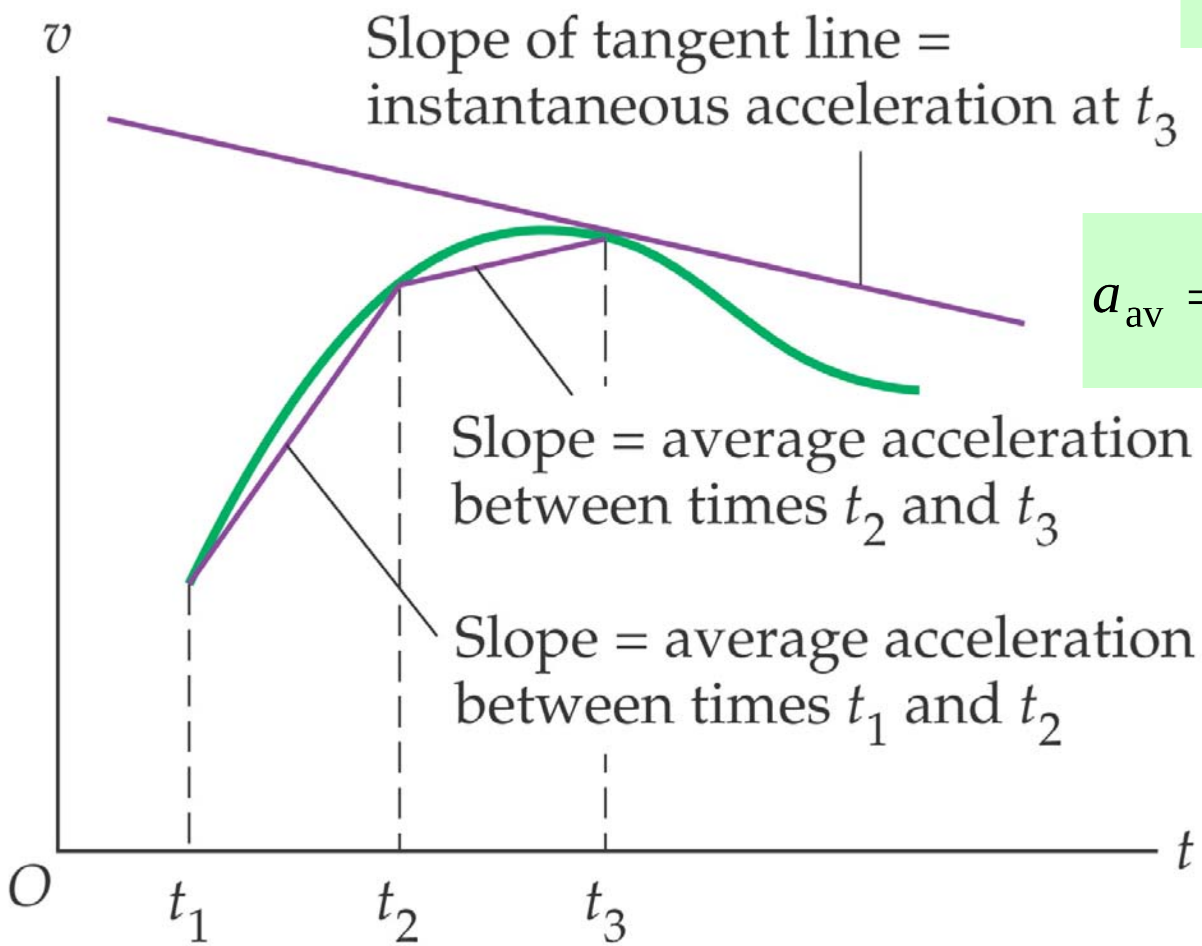
$$v_{av} = \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{t_f - t_i}$$

Review: 2-4 Acceleration

Graphical Interpretation of Average and Instantaneous Acceleration:

$$a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t}$$

$$a_{\text{av}} = \frac{\Delta v}{\Delta t} = \frac{v_{\text{f}} - v_{\text{i}}}{t_{\text{f}} - t_{\text{i}}}$$



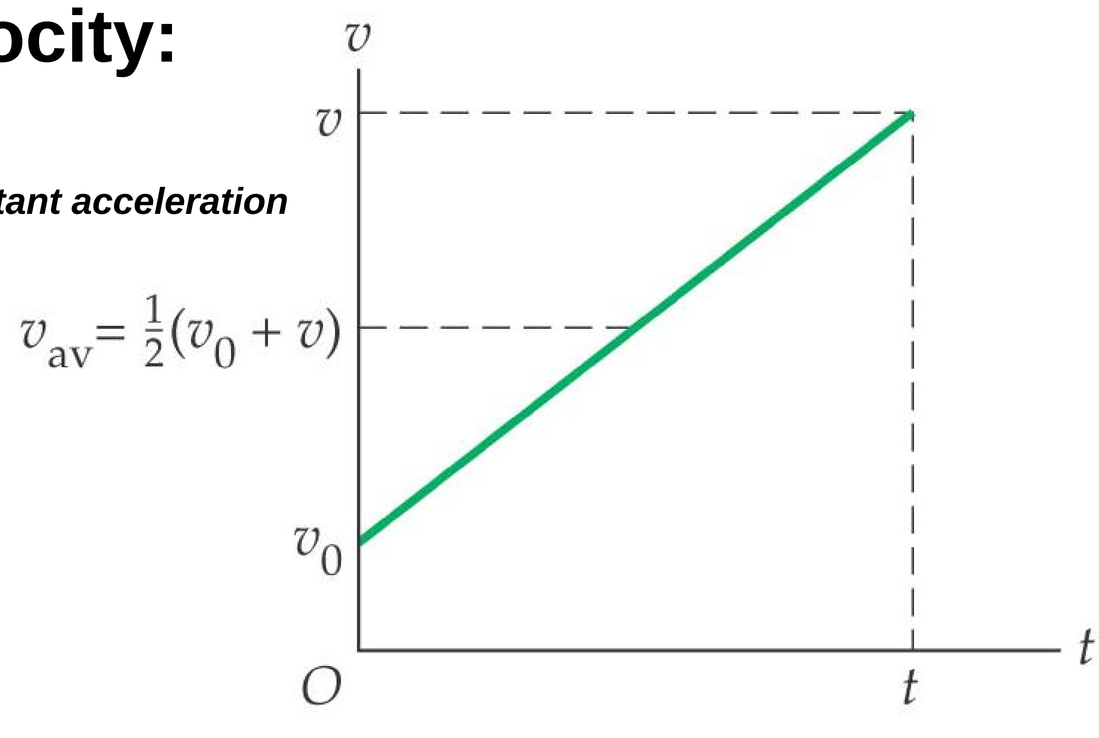
2-5 Motion with Constant Acceleration

If the acceleration is constant, the velocity changes linearly:

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

Average velocity:

Note: valid only for constant acceleration



(a)

2-5 Motion with Constant Acceleration

Average velocity:

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

Position as a function of time:

$$x = x_0 + v_{av}t$$

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

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

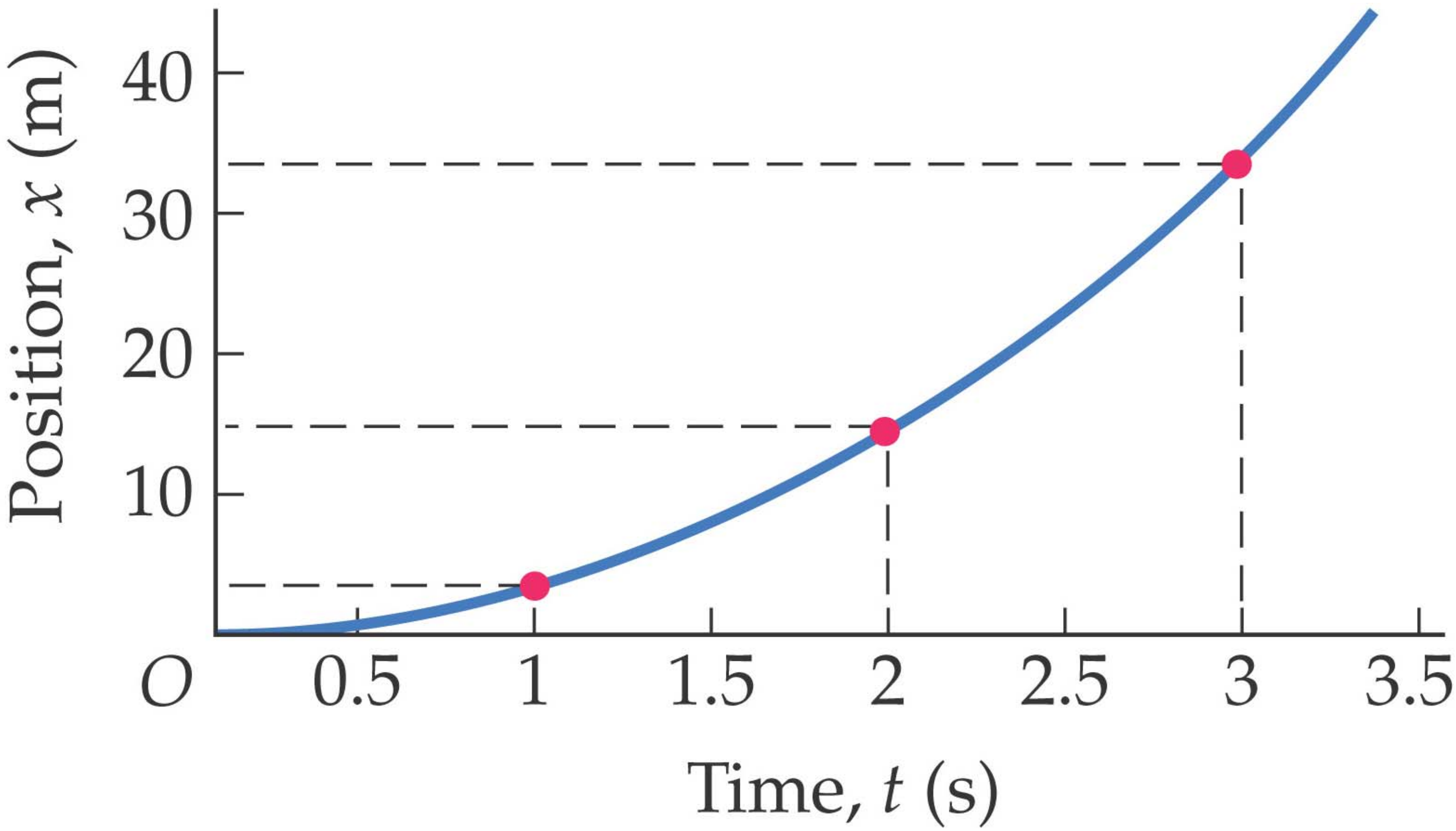
Velocity as a function of position:

$$v = v_0 + at$$

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

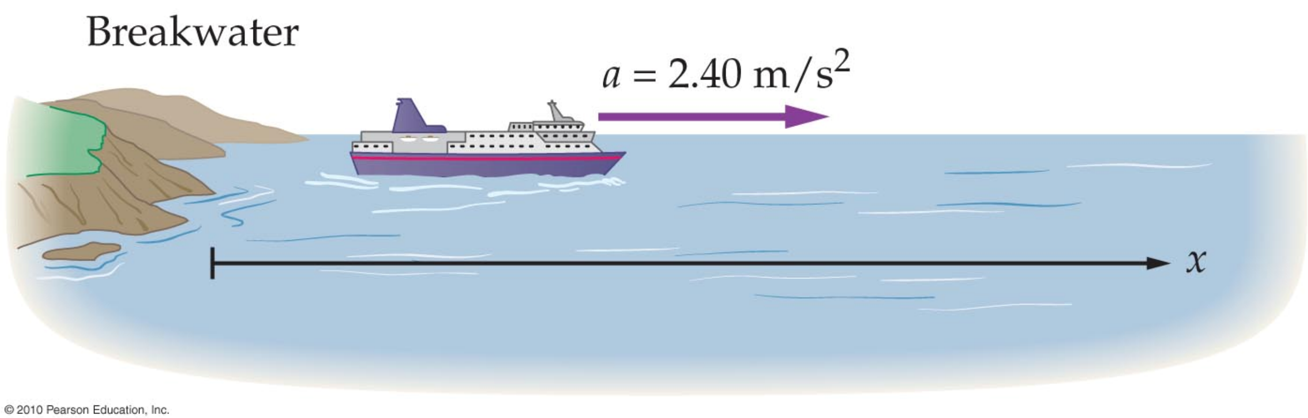
2-5 Motion with Constant Acceleration

The relationship between position and time follows a characteristic curve.



EXAMPLE 2–5 FULL SPEED AHEAD

A boat moves slowly inside a marina (so as not to leave a wake) with a constant speed of 1.50 m/s. As soon as it passes the breakwater, leaving the marina, it throttles up and accelerates at 2.40 m/s^2. (a) How fast is the boat moving after accelerating for 5.00 s? (b) How far has the boat traveled in this time?



Note: show PDF file next

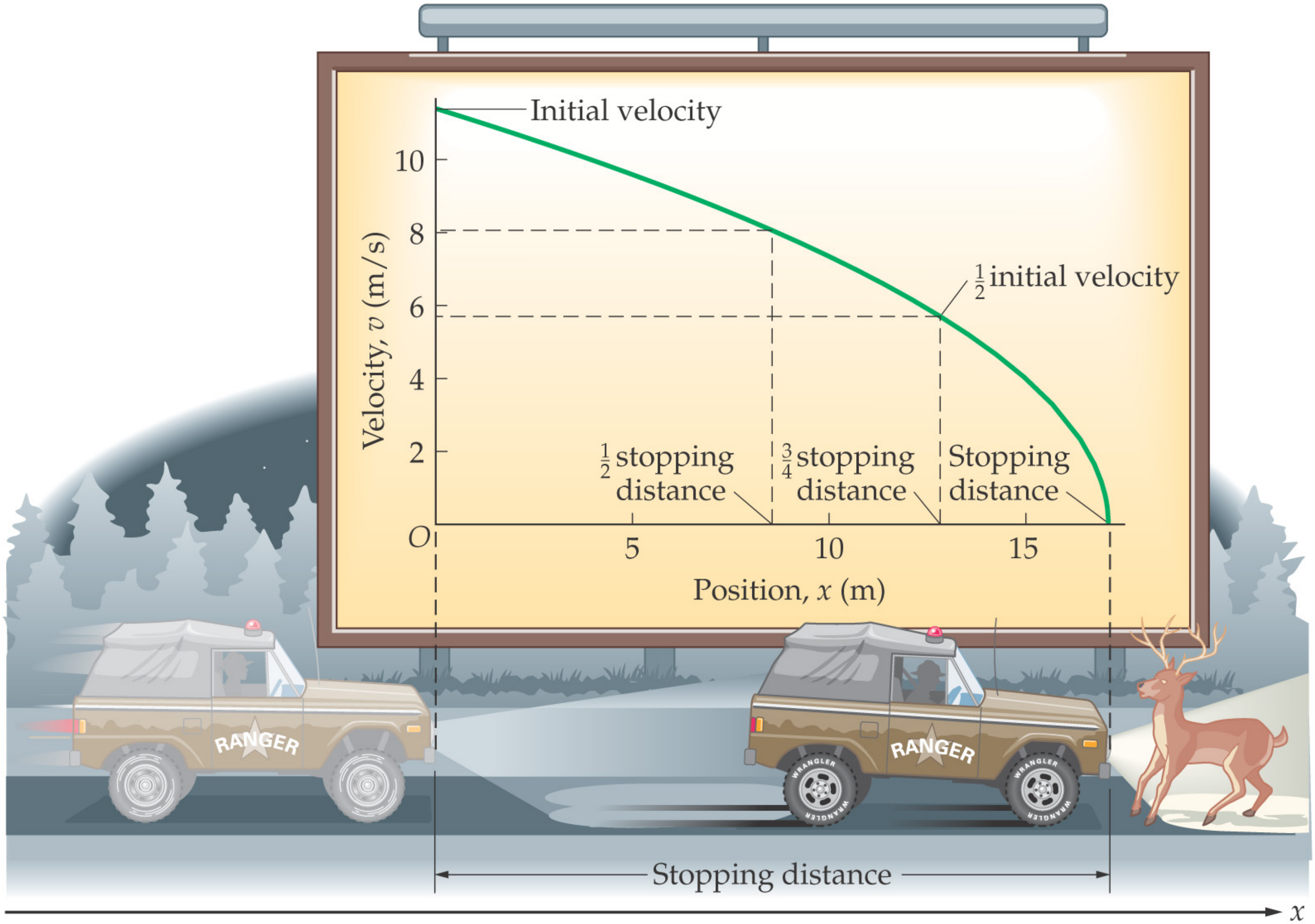
2-5 Motion with Constant Acceleration

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	$x = x_0 + v_0 t + \frac{1}{2}at^2$	2–11
velocity, position, acceleration	$v^2 = v_0^2 + 2a(x - x_0) = v_0^2 + 2a\Delta x$	2–12

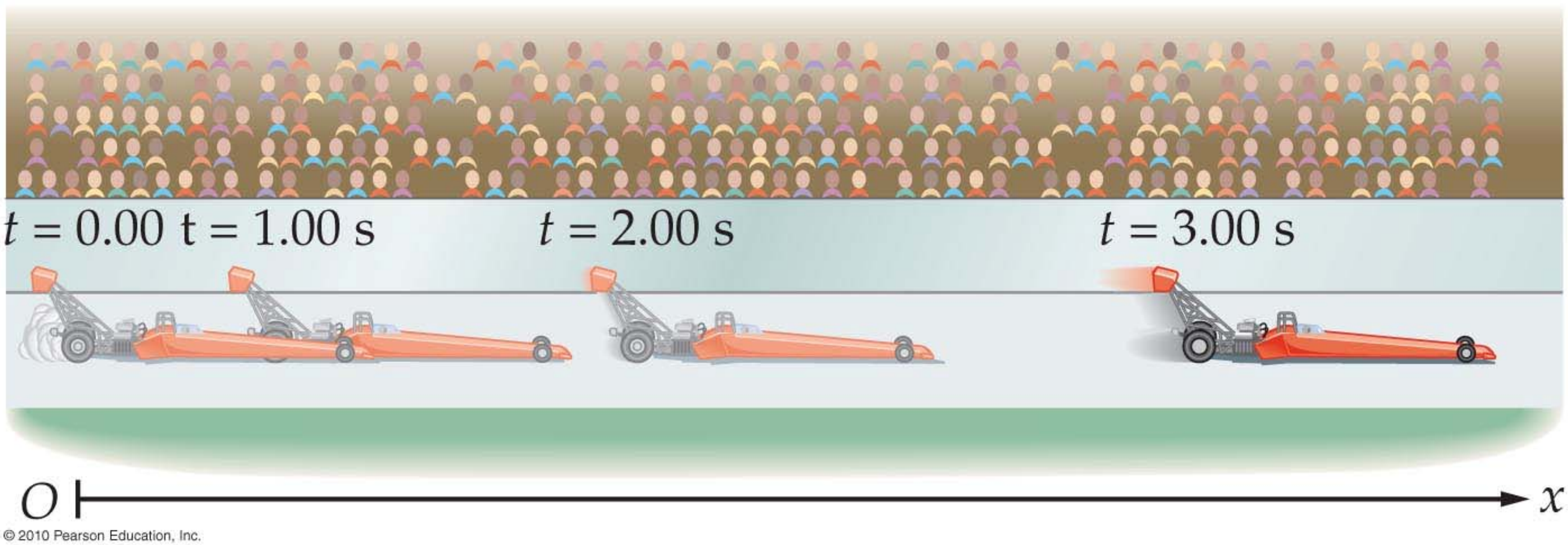
2-6 Applications of the Equations of Motion

Hit the Brakes!



EXAMPLE 2–6 PUT THE PEDAL TO THE METAL

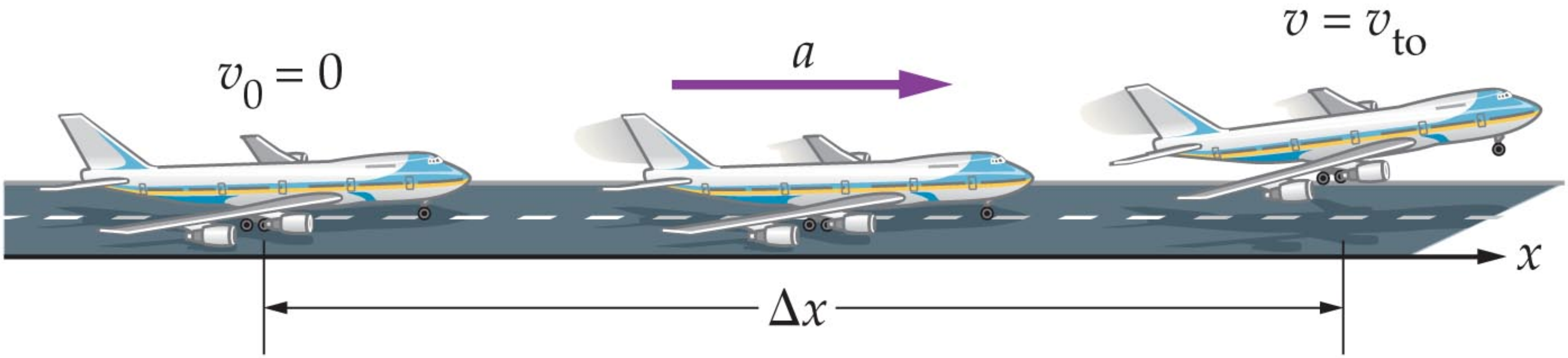
A drag racer starts from rest and accelerates at 7.40 m/s^2. How far has it traveled in **(a)** 1.00 s, **(b)** 2.00 s, **(c)** 3.00 s?



EXAMPLE 2–7 TAKEOFF DISTANCE FOR AN AIRLINER

REAL-WORLD PHYSICS

Jets at JFK International Airport accelerate from rest at one end of a runway, and must attain takeoff speed before reaching the other end of the runway. **(a)** Plane A has acceleration a and takeoff speed v_{to}. What is the minimum length of runway, Δx_A, required for this plane? Give a symbolic answer. **(b)** Plane B has the same acceleration as plane A, but requires twice the takeoff speed. Find Δx_B and compare with Δx_A. **(c)** Find the minimum runway length for plane A if $a = 2.20\ m/s^2$ and $v_{to} = 95.0\ m/s$. (These values are typical for a 747 jetliner.)



2-7 Freely Falling Objects

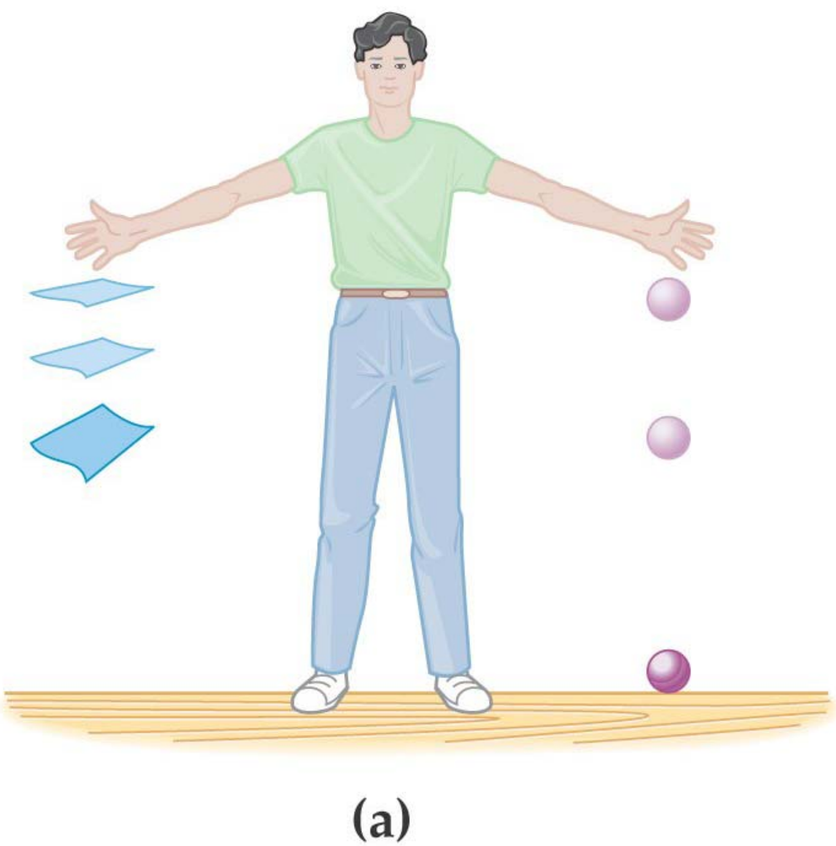
Free fall is the motion of an object subject only to the influence of gravity. The acceleration due to gravity is a constant, *g*.

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

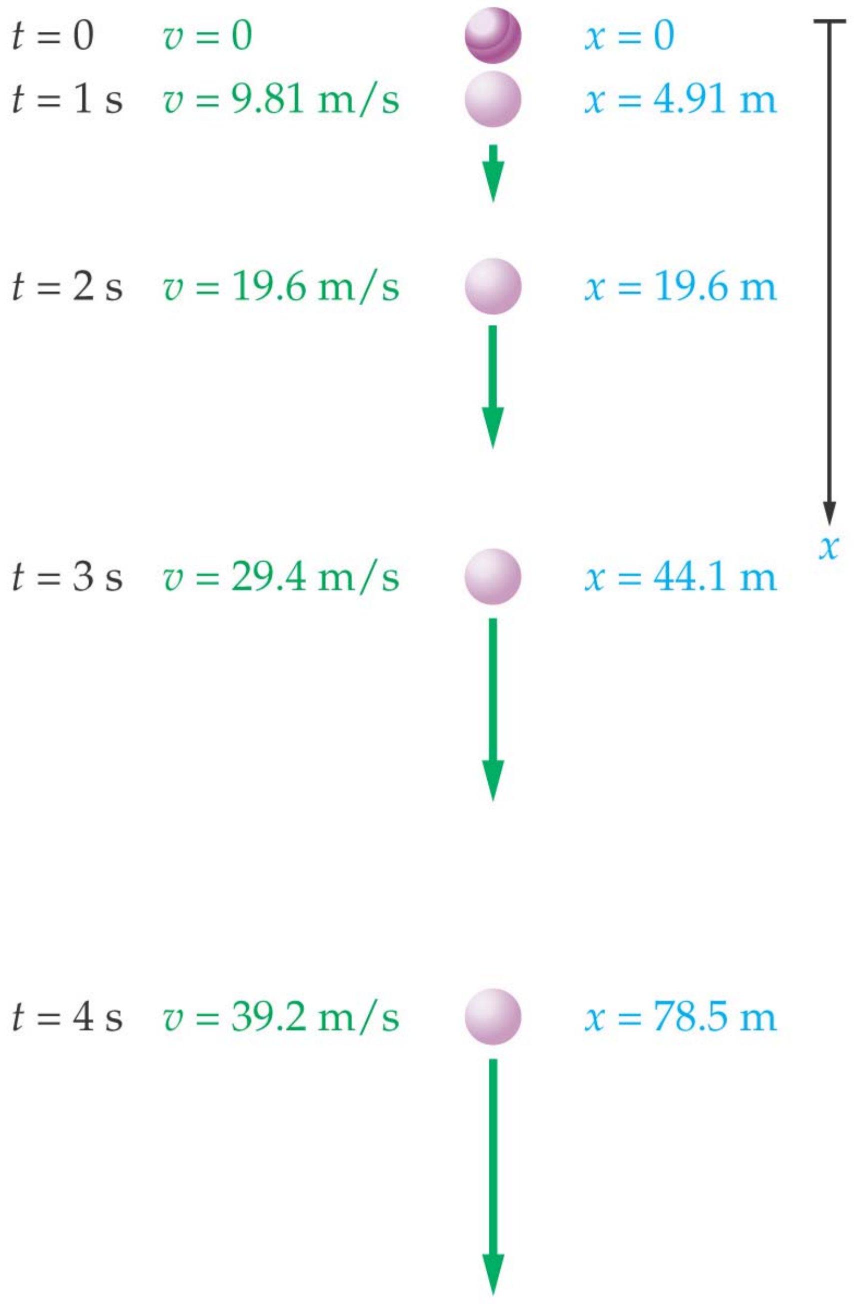
2-7 Freely Falling Objects

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



2-7 Freely Falling Objects

Free fall from rest:



Question 2.8b Acceleration II

When throwing a ball straight up, which of the following is true about its velocity *v* and its acceleration *a* at the highest point in its path?

a) both $v = 0$ and $a = 0$

b) $v \neq 0$, but $a = 0$

c) $v = 0$, but $a \neq 0$

d) both $v \neq 0$ and $a \neq 0$

e) not really sure

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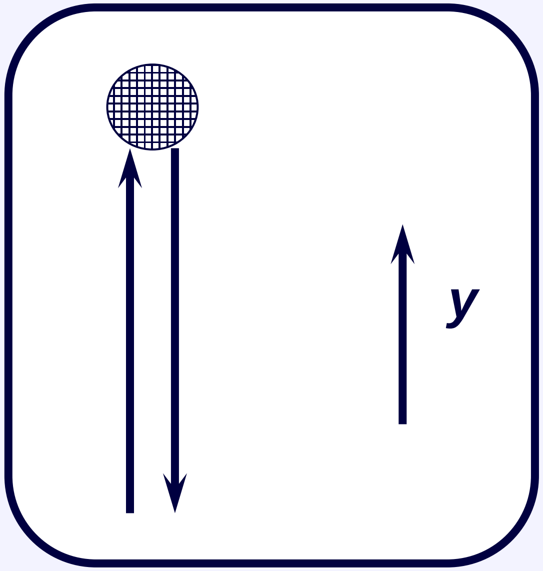
At the top, clearly $v = 0$ because the ball has momentarily stopped. But the velocity of the ball is changing, so its acceleration is definitely not zero! Otherwise it would remain at rest!!



Follow-up: …and the value of *a* is…?

Question 2.9a Free Fall I

You throw a ball straight up into the air. After it leaves your hand, at what point in its flight does it have the maximum value of acceleration?

a) its acceleration is constant everywhere

b) at the top of its trajectory

c) halfway to the top of its trajectory

d) just after it leaves your hand

e) just before it returns to your hand on the way down

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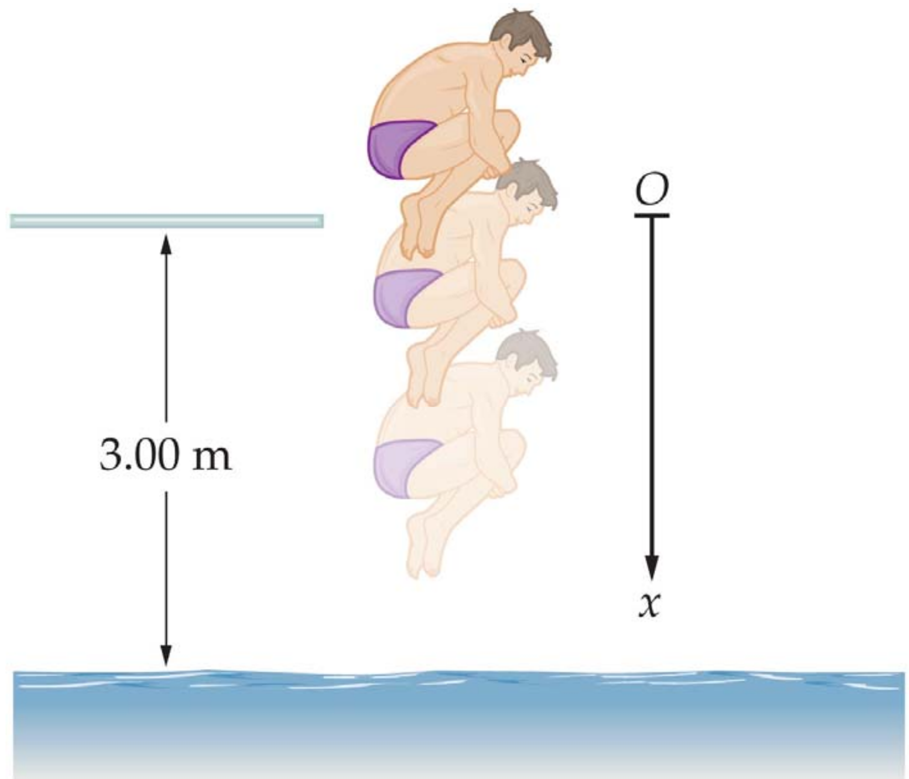
The ball is in free fall once it is released. Therefore, it is entirely under the influence of gravity, and the only acceleration it experiences is *g*, which is constant at all points.

EXAMPLE 2–10 DO THE CANNONBALL!

A person steps off the end of a 3.00-m-high diving board and drops to the water below. **(a)** How long does it take for the person to reach the water? **(b)** What is the person's speed on entering the water?



Question 2.10a Up in the Air I

You throw a ball upward with an initial speed of 10 m/s. Assuming that there is no air resistance, what is its speed when it returns to you?

a) more than 10 m/s

b) 10 m/s

c) less than 10 m/s

d) zero

e) need more information

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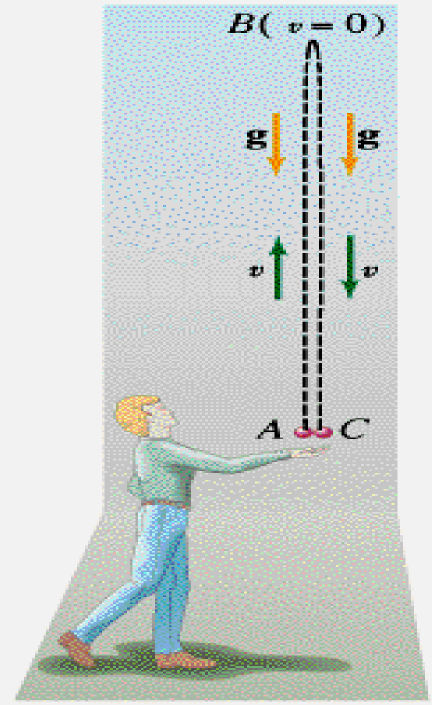
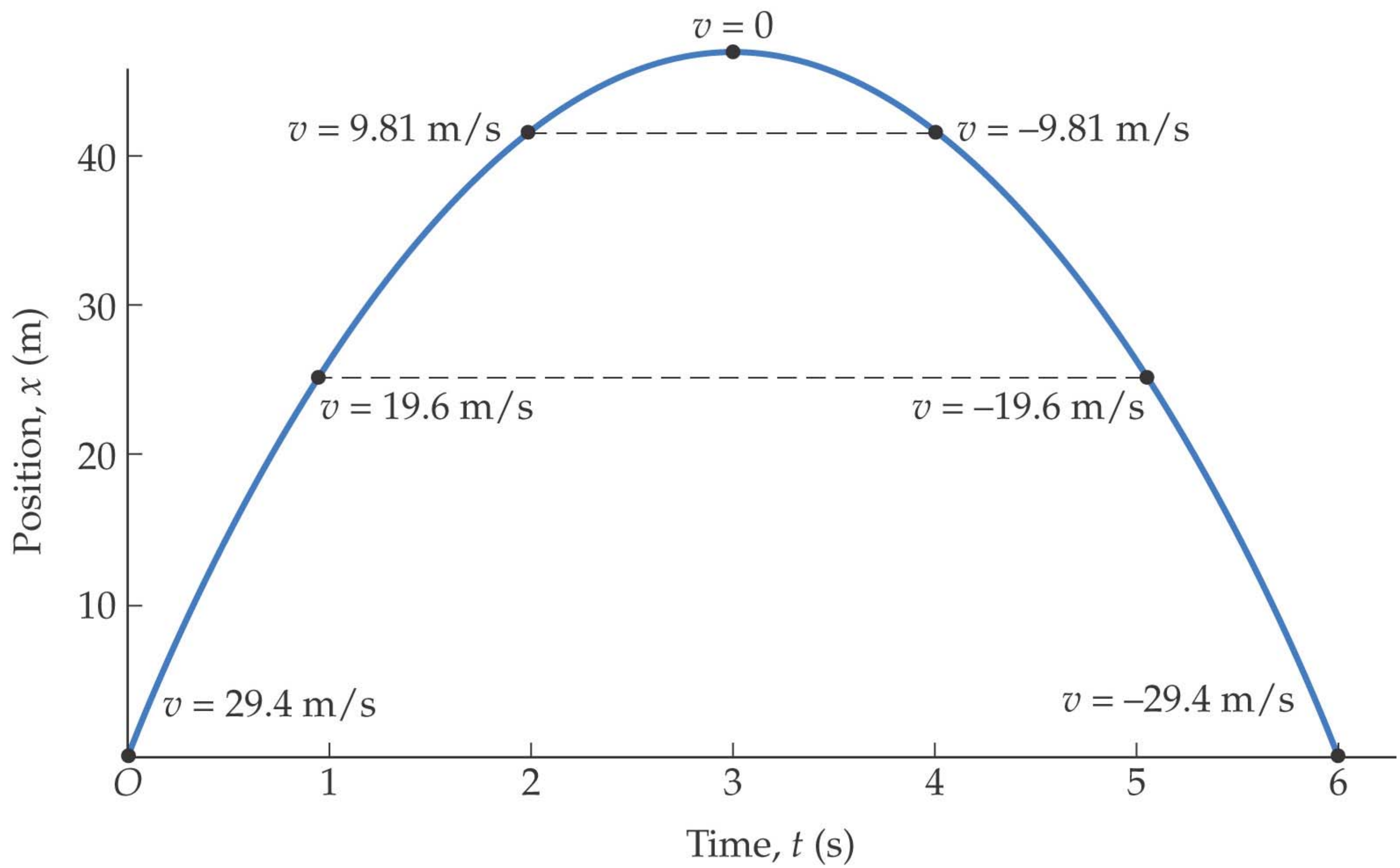
e) need more information

The ball is slowing down on the way up due to gravity. Eventually it stops. Then it accelerates downward due to gravity (again). Because $a = g$ on the way up and on the way down, the ball reaches the same speed when it gets back to you as it had when it left.



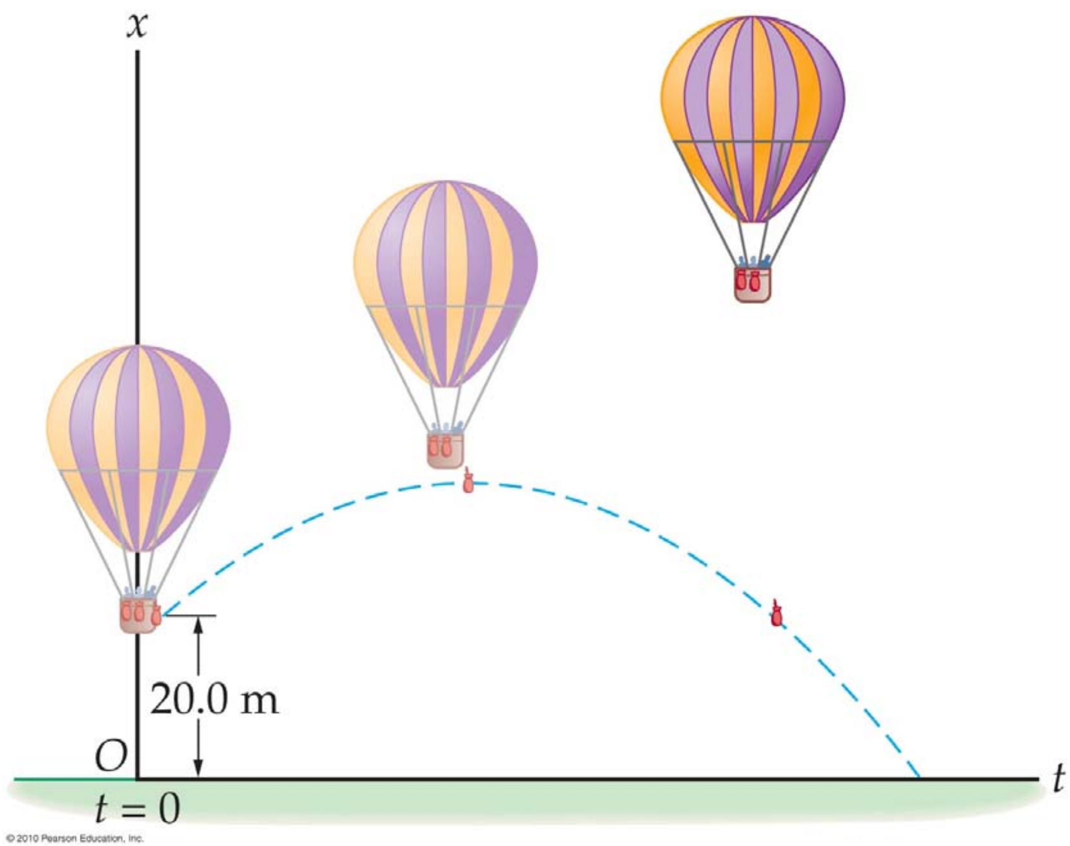
2-7 Freely Falling Objects

Trajectory of a projectile:



EXAMPLE 2–12 LOOK OUT BELOW! A SANDBAG IN FREE FALL

A hot-air balloon is rising straight upward with a constant speed of 6.5 m/s. When the basket of the balloon is 20.0 m above the ground, a bag of sand tied to the basket comes loose. **(a)** How long is the bag of sand in the air before it hits the ground? **(b)** What is the greatest height of the bag of sand during its fall to the ground?



Question 2.10b Up in the Air II

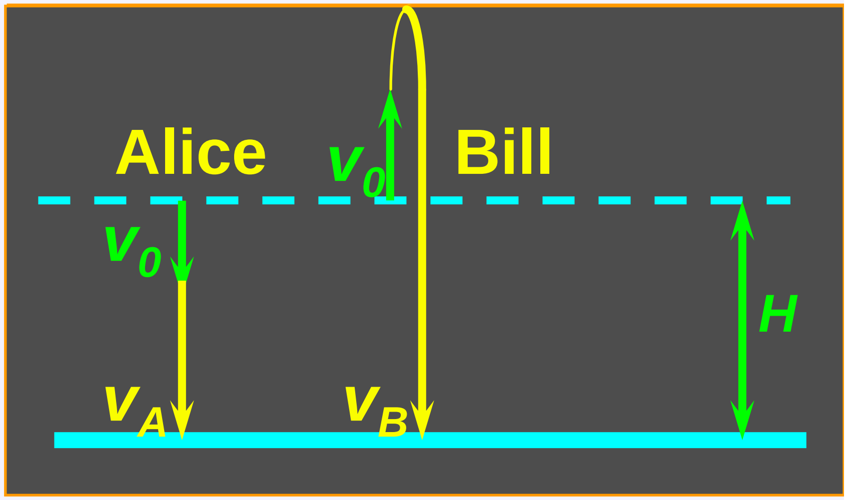
Alice and Bill are at the top of a cliff of height *H*. Both throw a ball with initial speed v_0, Alice straight down and Bill straight up. The speeds of the balls when they hit the ground are v_A and v_B. If there is no air resistance, which is true?

a) $v_A < v_B$

b) $v_A = v_B$

c) $v_A > v_B$

d) impossible to tell



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c) $v_A > v_B$

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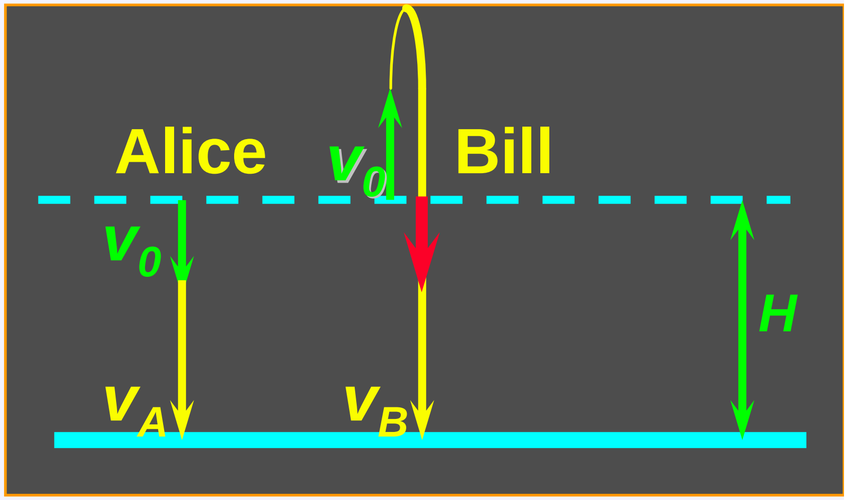
Bill's ball goes up and comes back down to Bill's level. At that point, it is moving downward with v_0, the same as Alice's ball. Thus, it will hit the ground with the same speed as Alice's ball.



Follow-up: what happens if there is air resistance?

Summary

- **Constant acceleration: equations of motion relate position, velocity, acceleration, and time**
- **Freely falling objects: constant acceleration**

$$g = 9.81 \text{ m/s}^2$$