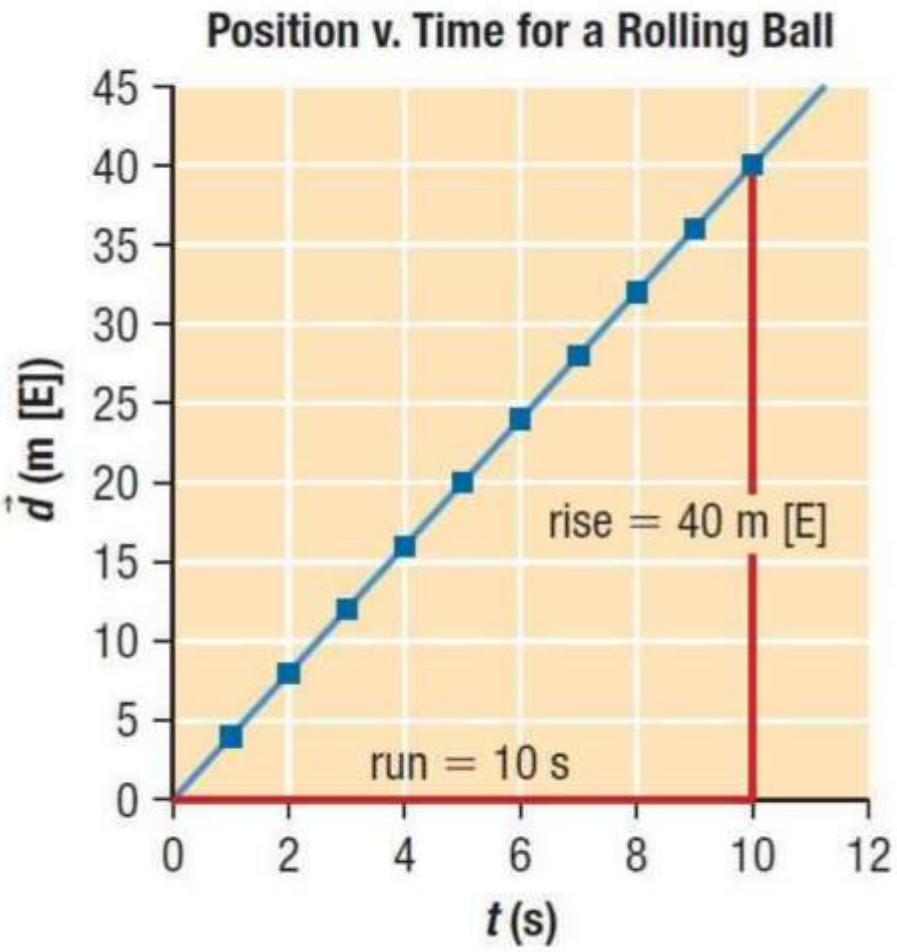
SPH3U
UNIVERSITY PHYSICS

KINEMATICS

- Position-Time Graphs
  (P.16-20)

Position-Time Graphs

*A **position-time graph** is a graph that describes the position of an object over time (position on the y-axis and time on the x-axis). The following diagram shows a position-time graph for the motion of a rolling ball measured by students during an experiment. Notice that the points on the graph form a straight line that moves upward from left to right.*



Position-Time Graphs

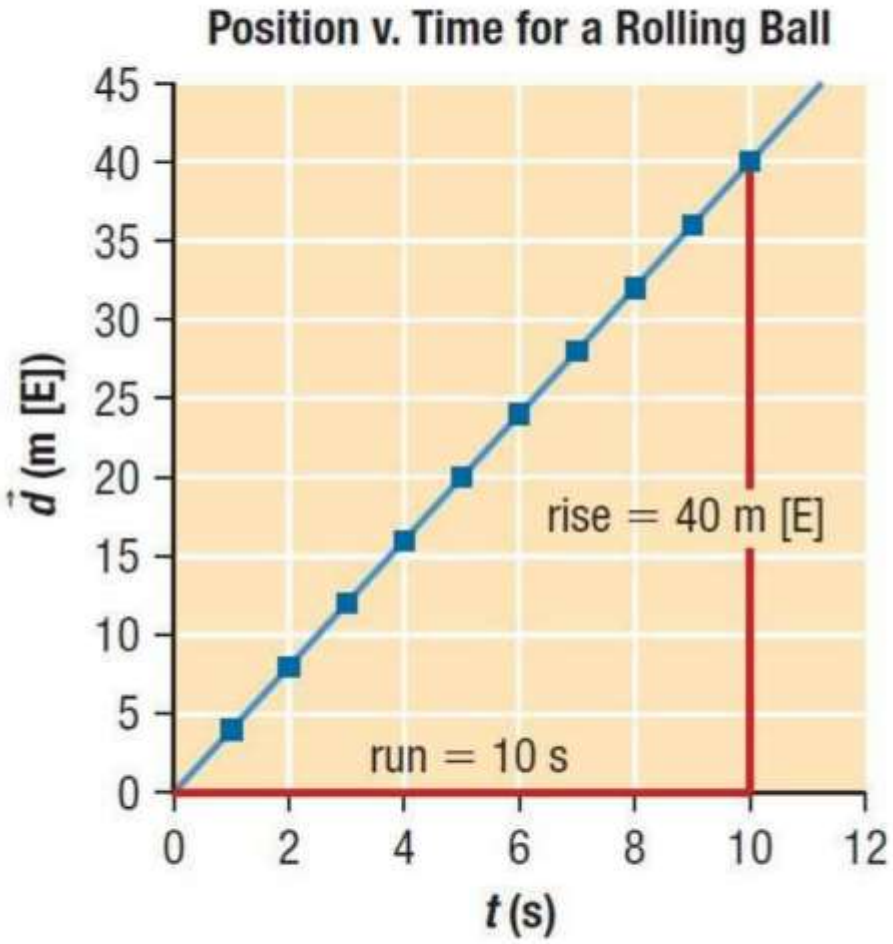
Whenever an object is moving at a constant velocity (i.e., uniform motion), the position-time graph of that motion is a straight line.

NOTE!

Recall that the ***slope*** *(m) of a line describes its steepness.*

$$slope = \frac{rise}{run}$$

$$m = \frac{\Delta \vec{d}\ (m)}{\Delta t\ (s)}$$

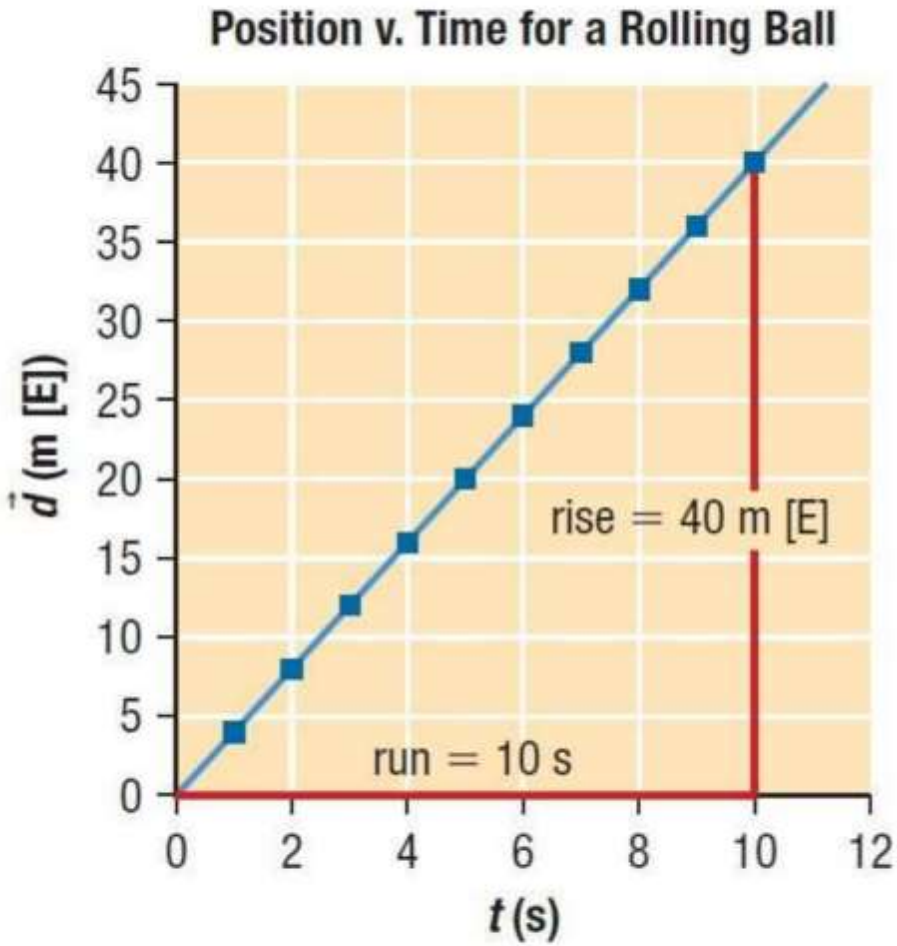


Position-Time Graphs

PRACTICE

1. What is the slope of this line?

m = 4.0 m/s[E]

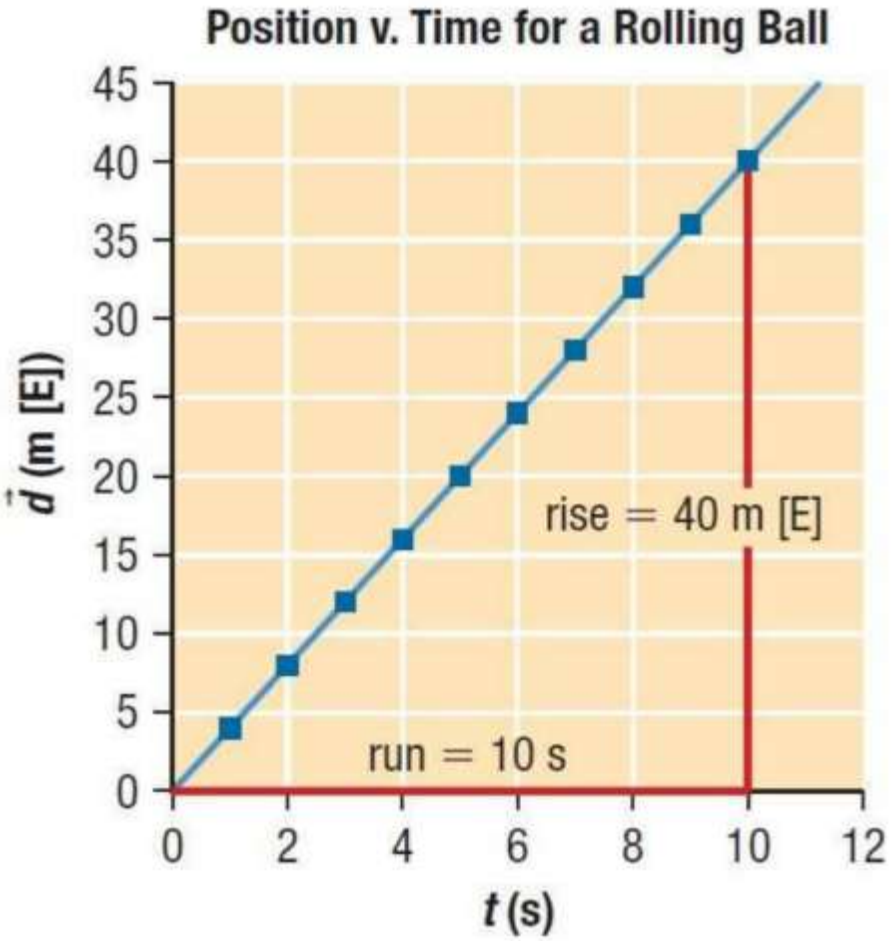


Position-Time Graphs

PRACTICE

2. What does the slope of the straight line on a position-time graph represent?

slope = velocity



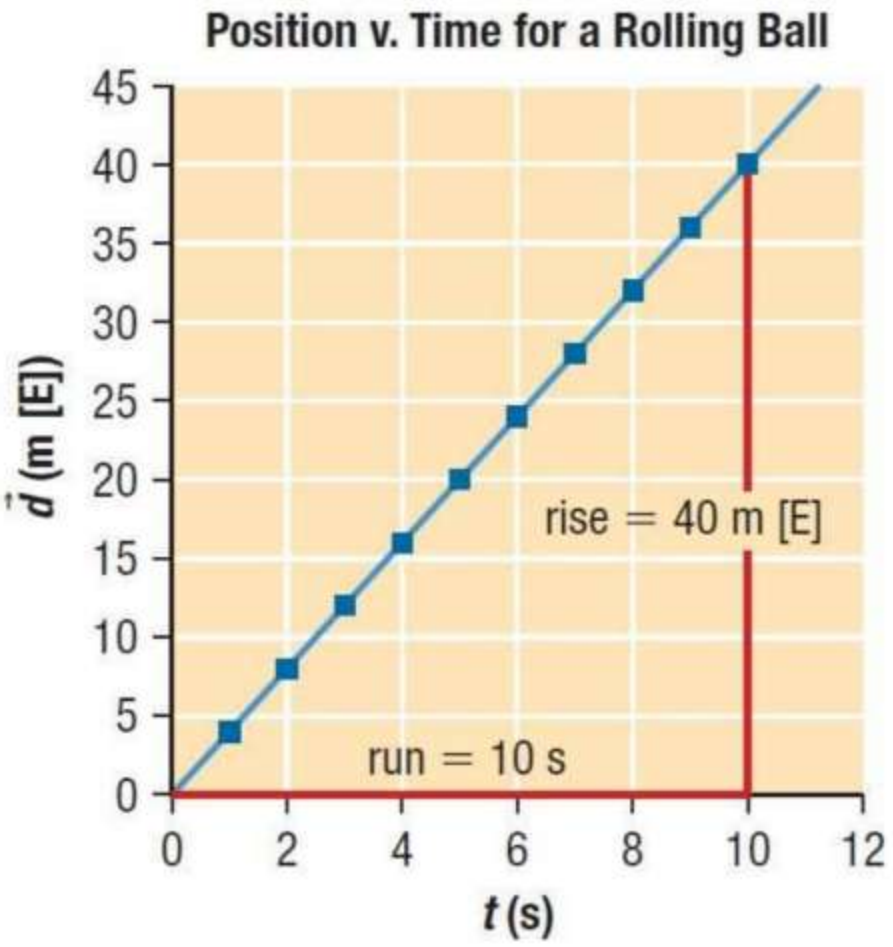
Position-Time Graphs

For an object moving at a constant velocity, so that its position-time graph is a straight line, the key relationship is:

The slope of a position-time graph gives the velocity of the object.

NOTE!

The steeper the slope, the greater is its velocity.



Position-Time Graphs

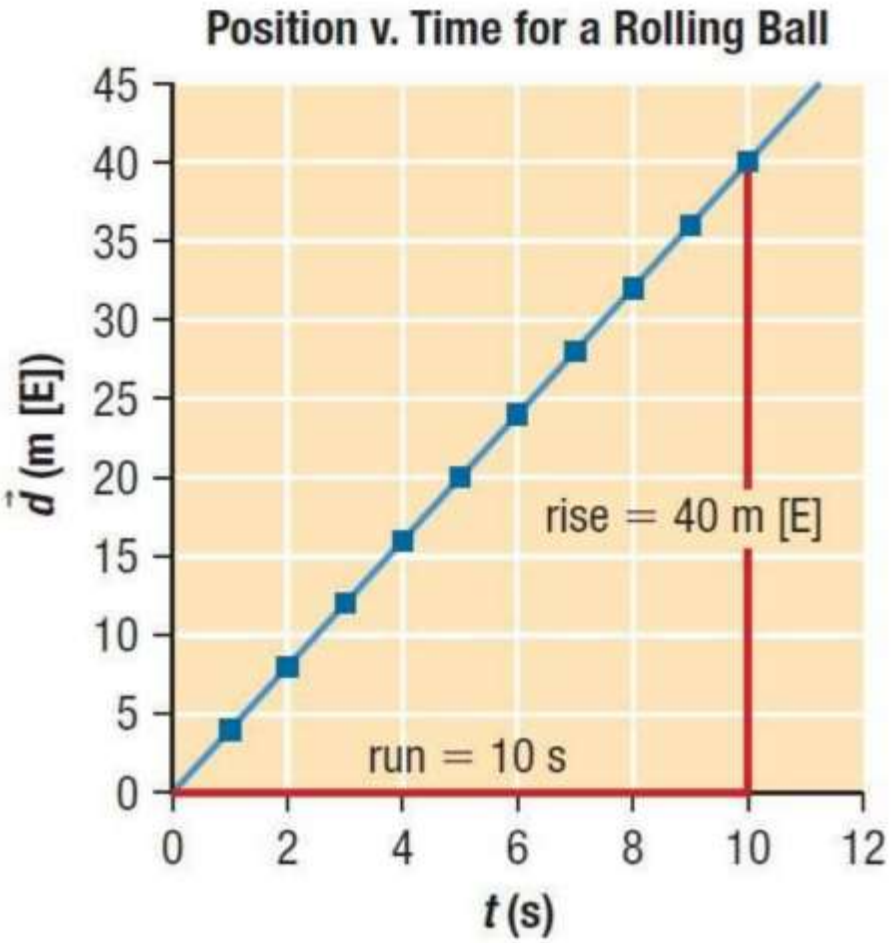
PRACTICE

3. Prove that the slope of a position-time graph gives the (average) velocity of the object.

$$slope = \frac{rise}{run}$$

$$m = \frac{\Delta \vec{d}}{\Delta t}$$

$$\vec{v}_{avg} = \frac{\Delta \vec{d}}{\Delta t}$$



Activity #1: Analyzing Position-Time Graphs

Recall that **uniform motion** is motion at a constant speed in a straight line. It is the simplest type of motion that an object can undergo, except for being at rest.

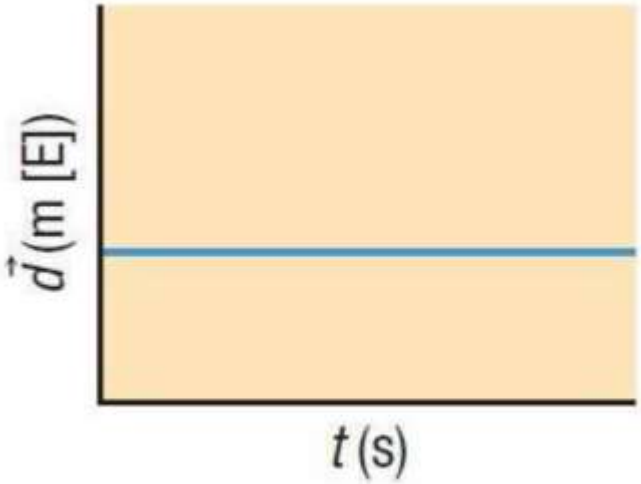
INSTRUCTIONS

A. Analyze the following position-time graphs to determine the motion being depicted in each.

Activity #1: Analyzing Position-Time Graphs

GRAPH A

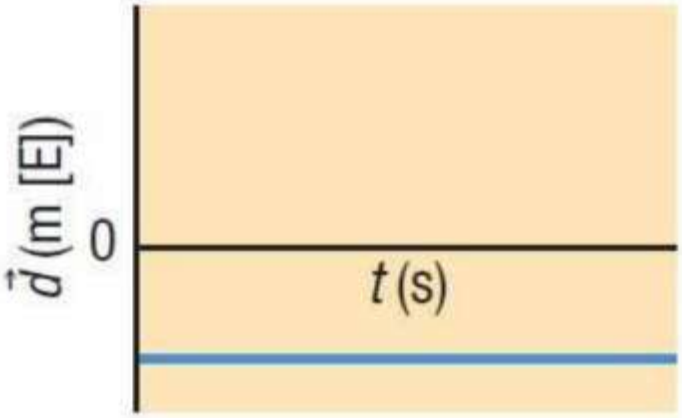
- the graph is a horizontal straight line with a slope of zero
- the object has a velocity of zero
- the object is at rest at a location east of 'home' (the reference position)



Activity #1: Analyzing Position-Time Graphs

GRAPH B

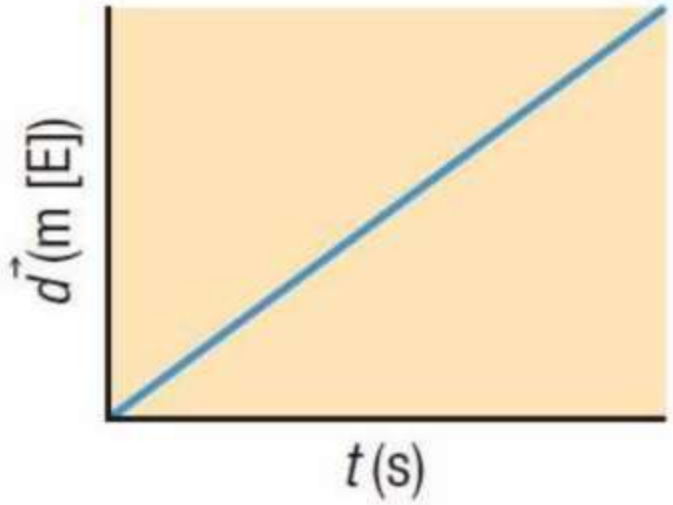
- the graph is a horizontal straight line with a slope of zero
- the object has a velocity of zero
- the object is at rest at a location west of 'home'



Activity #1: Analyzing Position-Time Graphs

GRAPH C

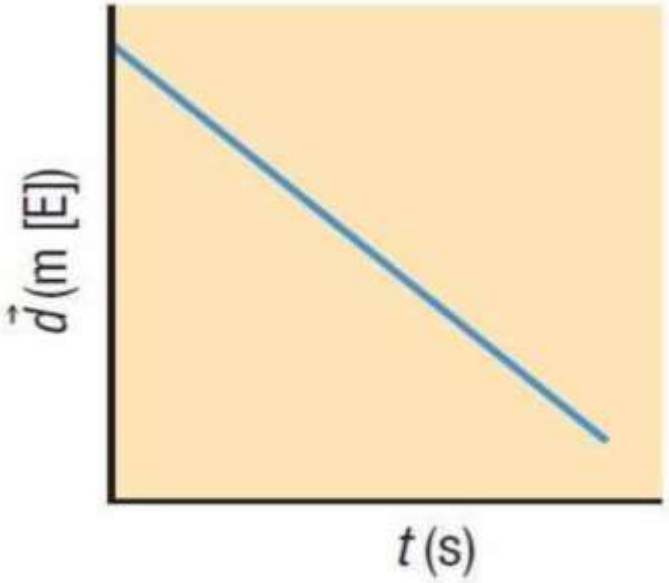
- the graph is a straight line with a positive slope
- the object has a constant positive velocity
- the y-axis & positive slope indicates that the object is moving east away from 'home' at a constant speed



Activity #1: Analyzing Position-Time Graphs

GRAPH D

- the graph is a straight line with a negative slope
- the object has a constant negative velocity
- the y-axis & negative slope indicates the object is moving west back towards 'home' at a constant speed



Activity #1: Analyzing Position-Time Graphs

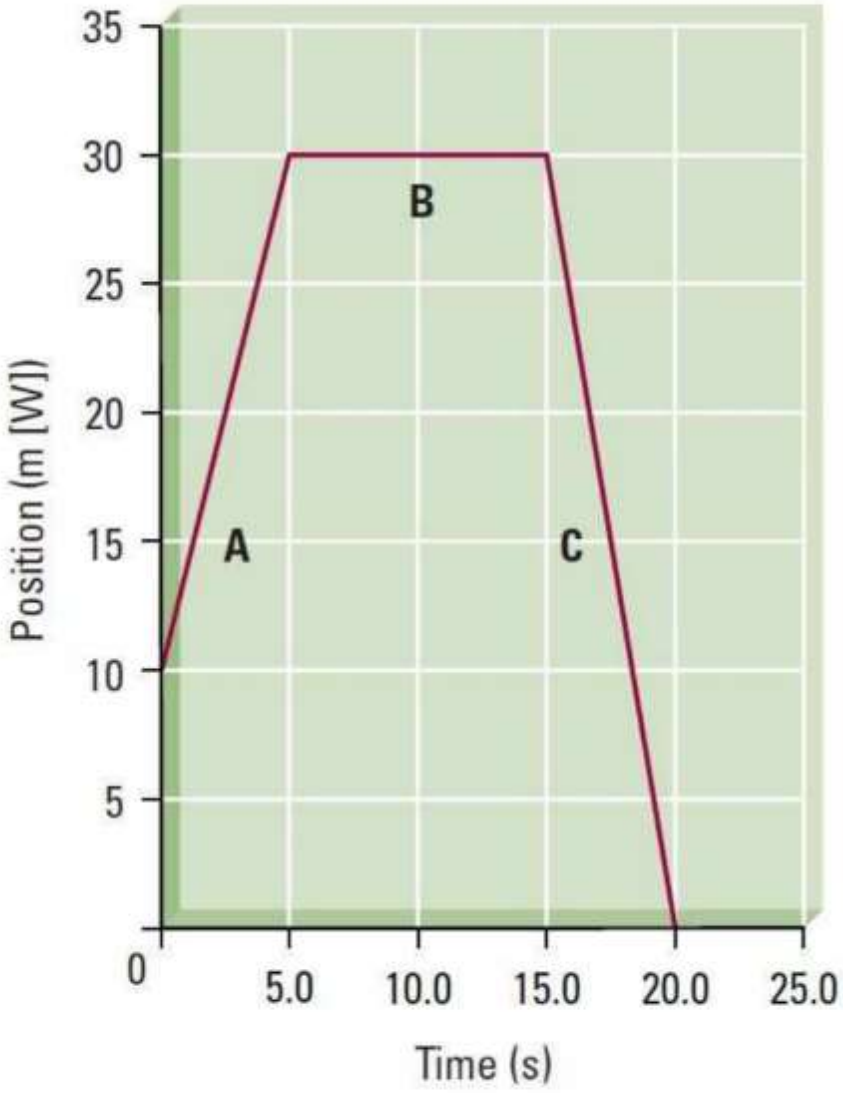
QUESTIONS

1. What type of graphs (linear or non-linear) were shown?
2. What type of motion (uniform or non-uniform) was exhibited?

1. linear
2. uniform

Complex Position-Time Graphs

Sometimes the motion of an object is complex and so the position-time graph for the object is not a single straight line but several.



PRACTICE

4. Describe the motion of the object in segments A, B, and C of the graph shown.

A - moves from a position 10 m[W] to a position 30 m[W] in a time of 5.0 s

B - remains at a position 30 m[W] for 10 s

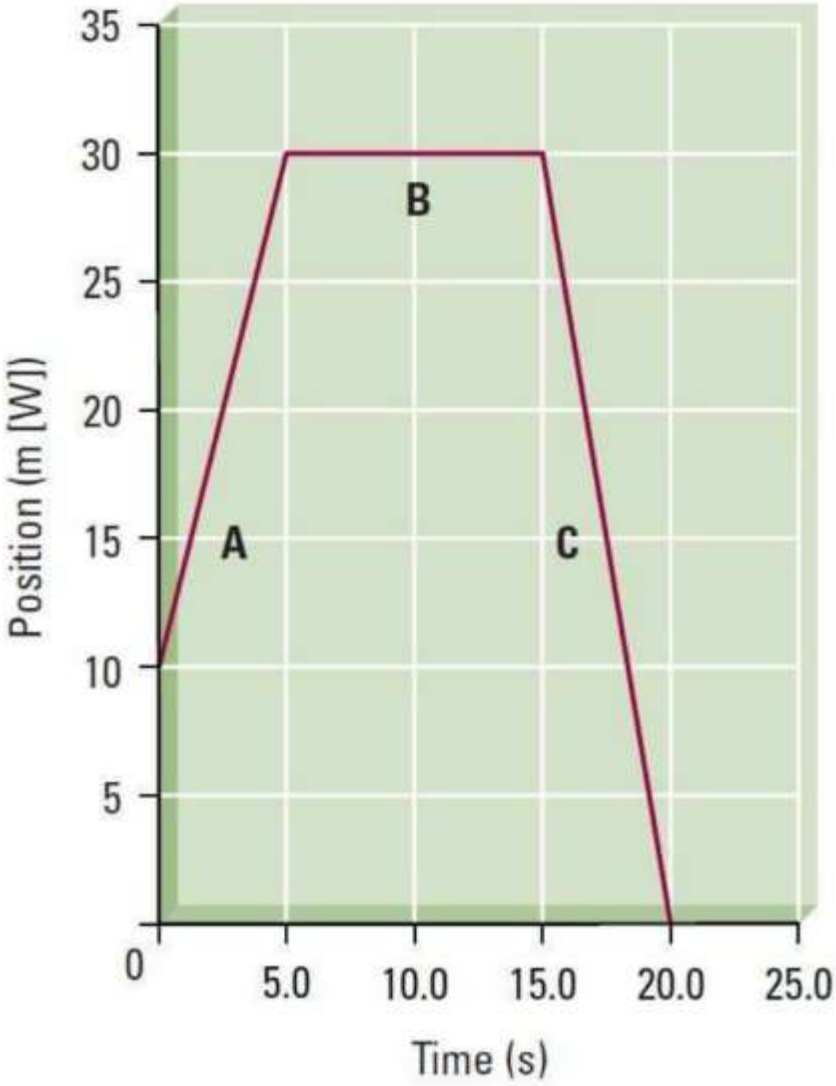
C - moves from a position 30 m[W] to home in a time of 5.0 s

Complex Position-Time Graphs

PRACTICE

5. (a) For each segment determine the displacement and average velocity.

(a)	Δd	v_{avg}
A	20 m[W]	4.0 m/s[W]
B	0	0
C	-30 m[W]	-6.0 m/s[W]
	30 m[E]	6.0 m/s[E]

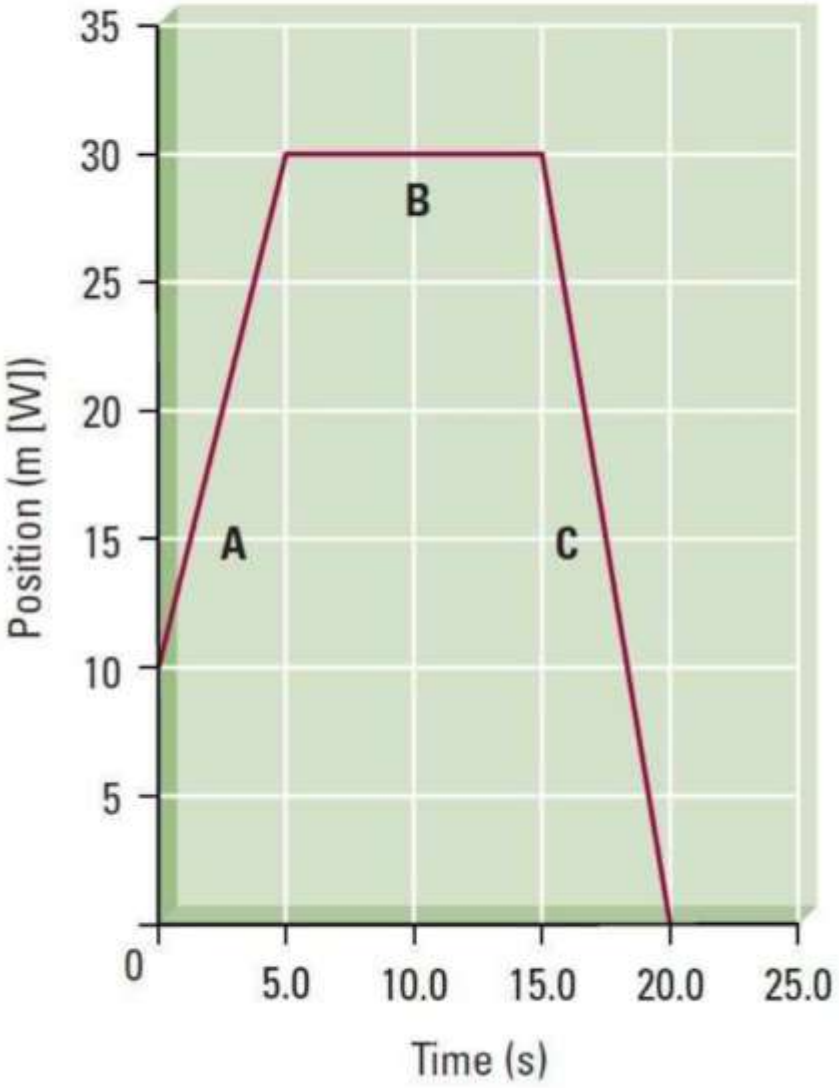


Complex Position-Time Graphs

PRACTICE

5. (b) How would the distances and speeds compare?

(b) The distances and speeds would be the same as the displacements and the velocities (minus the direction).



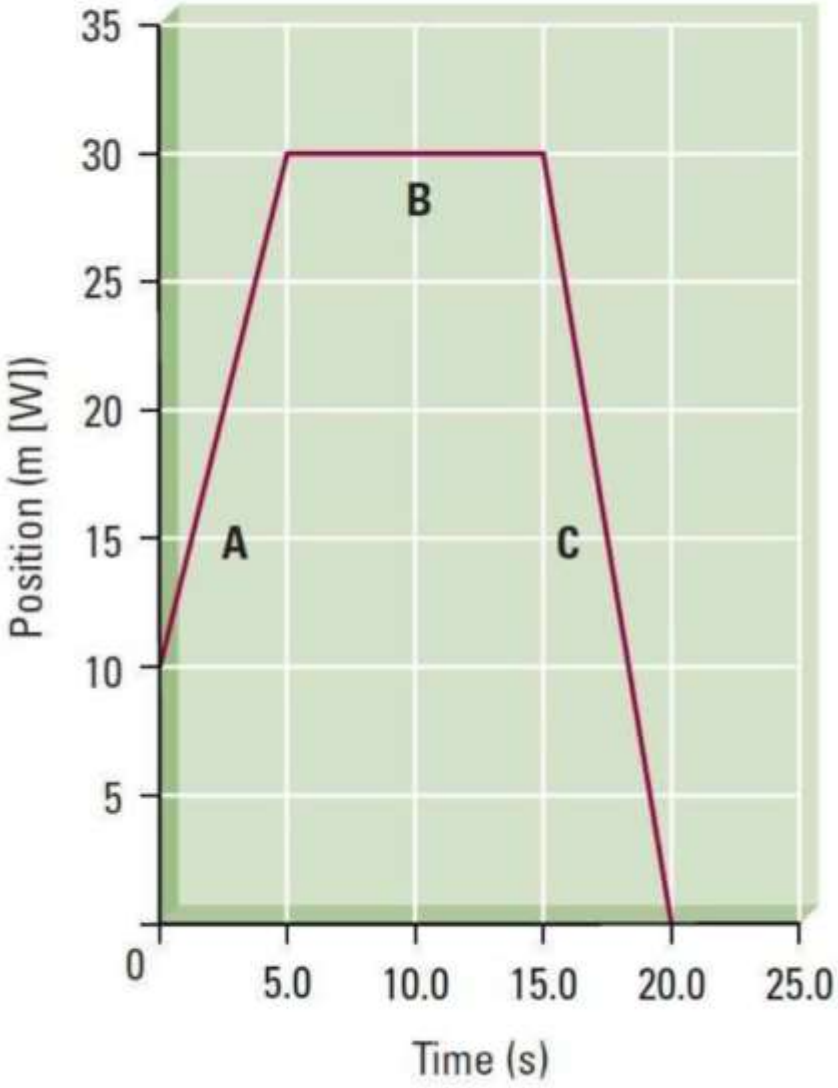
Complex Position-Time Graphs

PRACTICE

6. For the entire trip, what is:
   (a) the total distance and the total displacement?
   (b) the average speed and the average velocity?

(a) $d_T = 50$ m
$\Delta d_T = 10$ m[E]

(b) $v_{avg} = 2.5$ m/s
$v_{avg} = 0.5$ m/s[E]



Activity #2: Analyzing Position-Time Graphs

While it is true that objects sometimes move at a constant velocity in everyday life, usually the velocities we observe are not constant. **Non-uniform motion** is motion that involves a change in speed and/or direction. This type of motion is also known as **accelerated motion**.

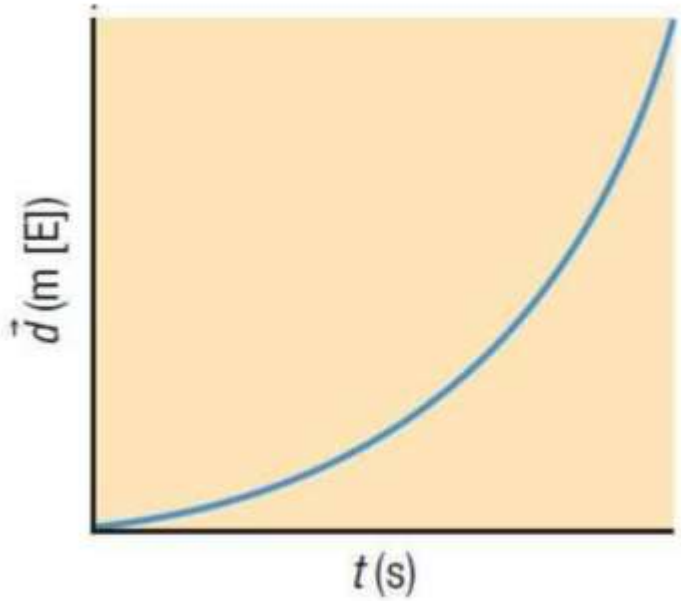
INSTRUCTIONS

A. Analyze the following position-time graphs to determine the motion being depicted in each.

Activity #2: Analyzing Position-Time Graphs

GRAPH E

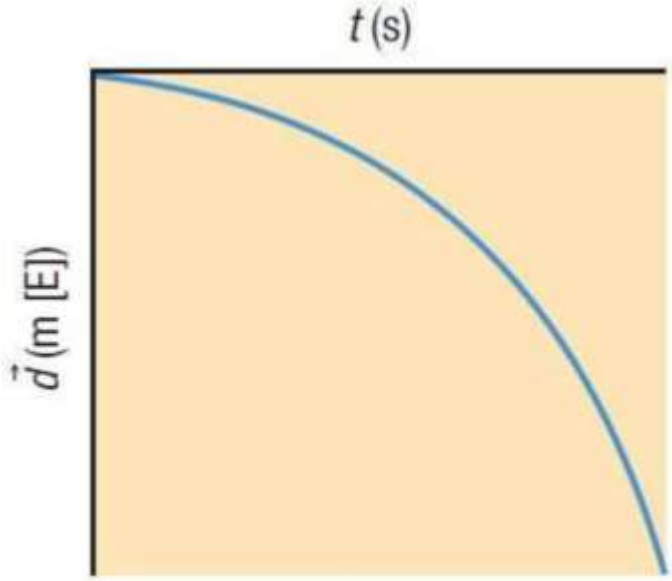
- the graph is a curve & so the velocity is not constant
- the slope is positive & increases as time increases
- the y-axis & positive slope indicates the object is moving east
- the object is speeding up as it moves east away from 'home'



Activity #2: Analyzing Position-Time Graphs

GRAPH F

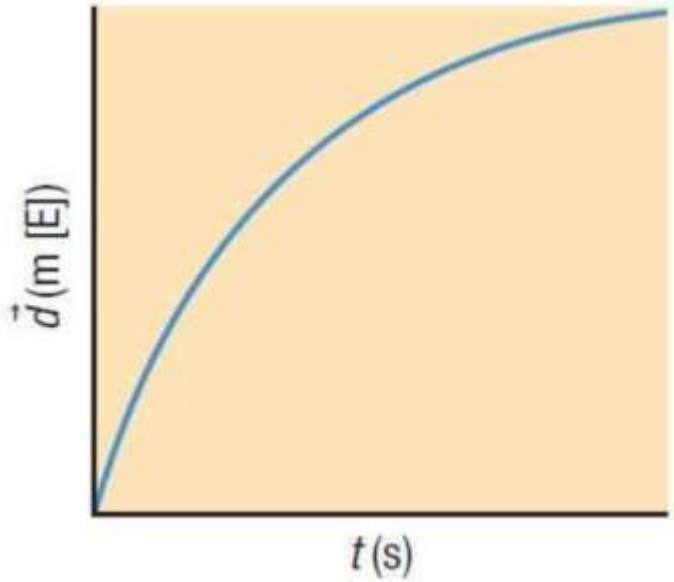
- the graph is a curve & so the velocity is not constant
- the slope is negative & increases as time increases
- the y-axis & negative slope indicates the object is moving west
- the object is speeding up as it moves west away from 'home'



Activity #2: Analyzing Position-Time Graphs

GRAPH G

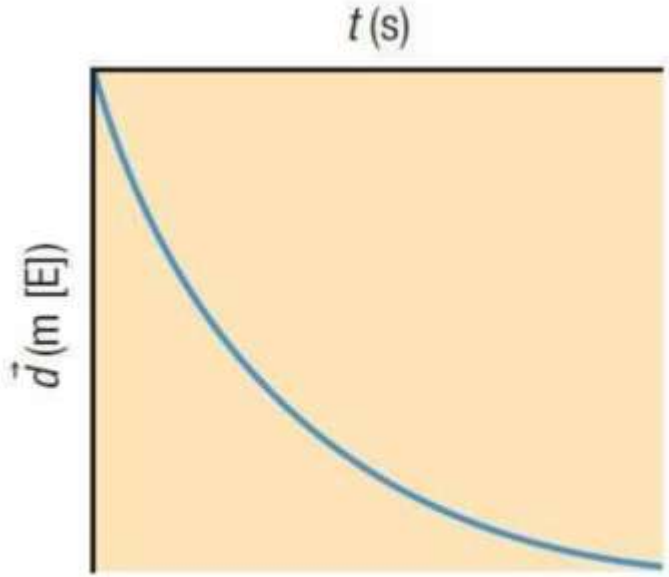
- the graph is a curve & so the velocity is not constant
- the slope is positive & decreases as time increases
- the y-axis & positive slope indicates the object is moving east
- the object is slowing down as it moves east away from 'home'



Activity #2: Analyzing Position-Time Graphs

GRAPH H

- the graph is a curve & so the velocity is not constant
- the slope is negative & decreases as time increases
- the y-axis & negative slope indicates the object is moving west
- the object is slowing down as it moves west away from 'home'



Activity #2: Analyzing Position-Time Graphs

QUESTIONS

1. What type of graphs (linear or non-linear) were shown?
2. What type of motion (uniform or non-uniform) was exhibited?

1. non-linear
2. non-uniform

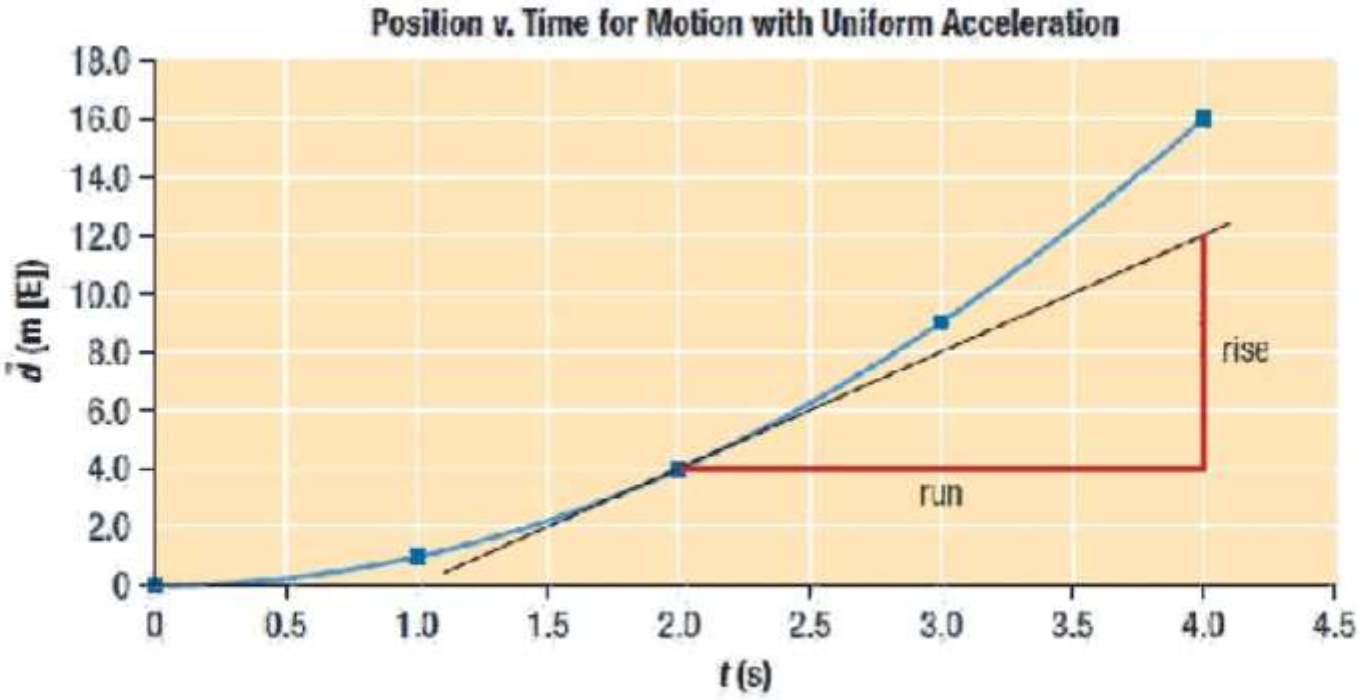
Position-Time Graphs

POSITION-TIME GRAPH (d-t)

- graph that describes the position (y-axis) of an object wrt time (x-axis)
- slope = velocity of object
- the steeper the slope, the greater the velocity
- linear shape (straight line)
  - uniform motion (velocity is constant)
  - acceleration = 0
- non-linear shape (curved line)
  - non-uniform motion (velocity is not constant)
  - acceleration ≠ 0

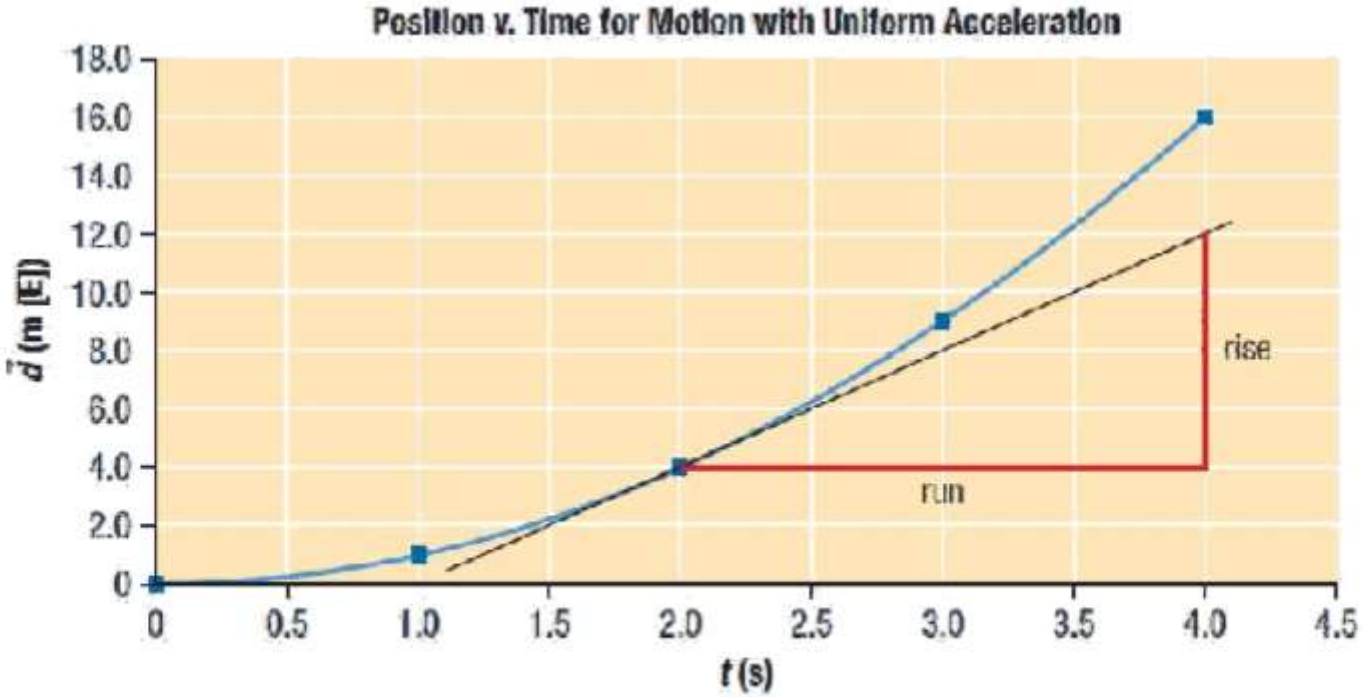
Instantaneous Velocity

*The **instantaneous velocity**, or $\vec{v}_{inst}$, is the velocity of an object at a specific instant in time. For uniform motion, the instantaneous and average velocities are the same. However, for non-uniform motion this is typically not true.*



Instantaneous Velocity

To determine the instantaneous velocity from a position-time graph for an object that is accelerating we must calculate the slope of the tangent of the line at that point. A ***tangent*** *is a straight line that contacts a curve at a single point without intersecting the line.*

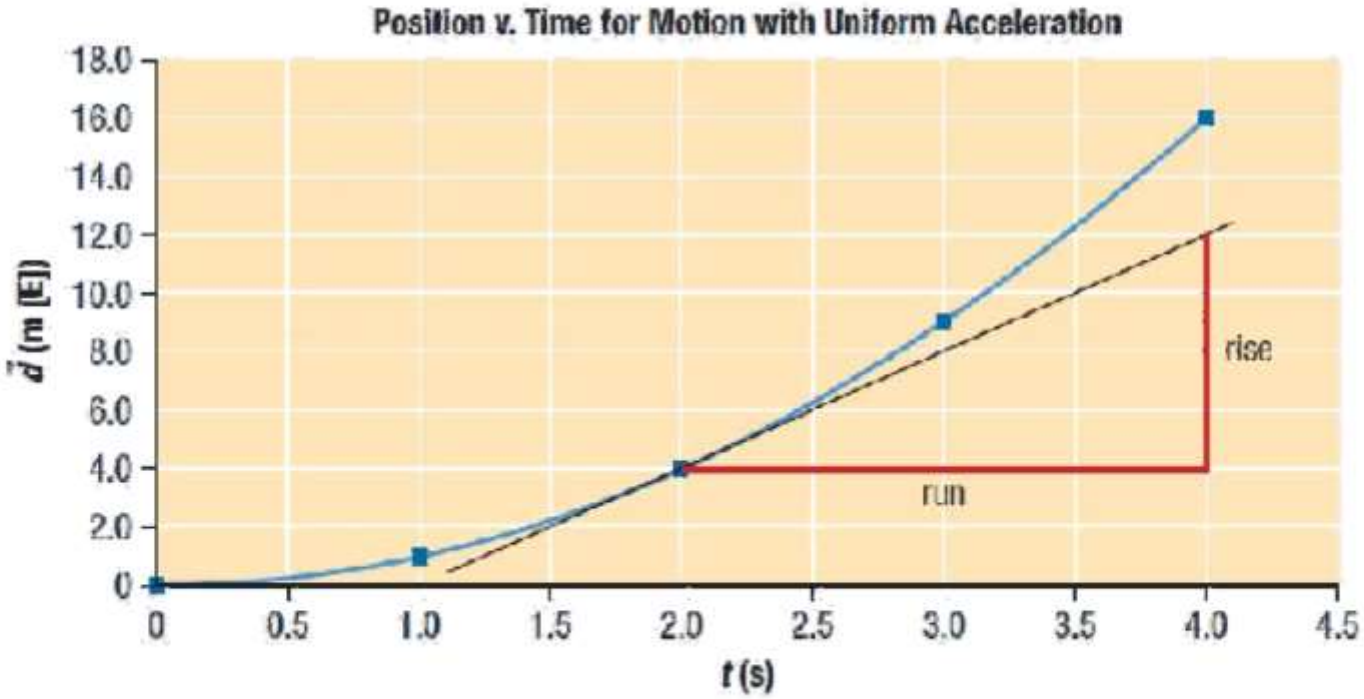


Instantaneous Velocity

PRACTICE

7. What is the instantaneous velocity of the object at t = 2.0 s?

$v_{instantaneous}$ = 4.0 m/s[E]



Instantaneous Velocity

INSTANTANEOUS VELOCITY ($\vec{v}_{inst}$)

- velocity at a specific instant in time
- is equal to the slope of the tangent to the position-time graph at that instant in time

NOTE!

For motion with non-uniform velocity, average and instantaneous velocities are not necessarily equal.