Preview

- Objectives
- One Dimensional Motion
- Displacement
- Average Velocity
- Velocity and Speed
- Interpreting Velocity Graphically

Objectives

- **Describe** motion in terms of frame of reference, displacement, time, and velocity.
- **Calculate** the displacement of an object traveling at a known velocity for a specific time interval.
- **Construct** and **interpret** graphs of position versus time.

One Dimensional Motion

- To simplify the concept of motion, we will first consider motion that takes place in **one direction.**
- One example is the motion of a commuter train on a straight track.
- To measure motion, you must choose a **frame of reference.** A frame of reference is a system for specifying the precise location of objects in space and time.

End of Slide

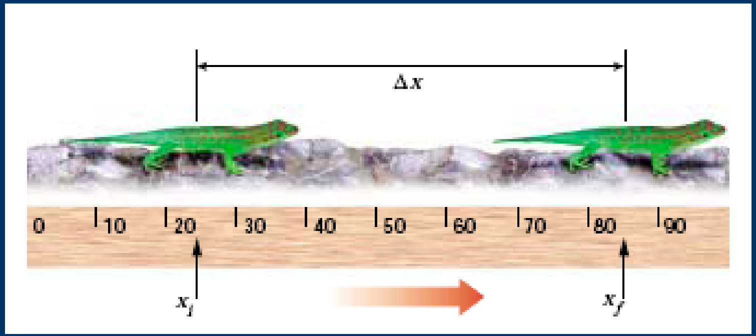
Frame of Reference

Click below to watch the Visual Concept.

Visual Concept

Displacement

- **Displacement** is a **change in position.**
- Displacement is not always equal to the distance traveled.
- The SI unit of displacement is the **meter, m.**



$$\Delta x = x_f - x_i$$

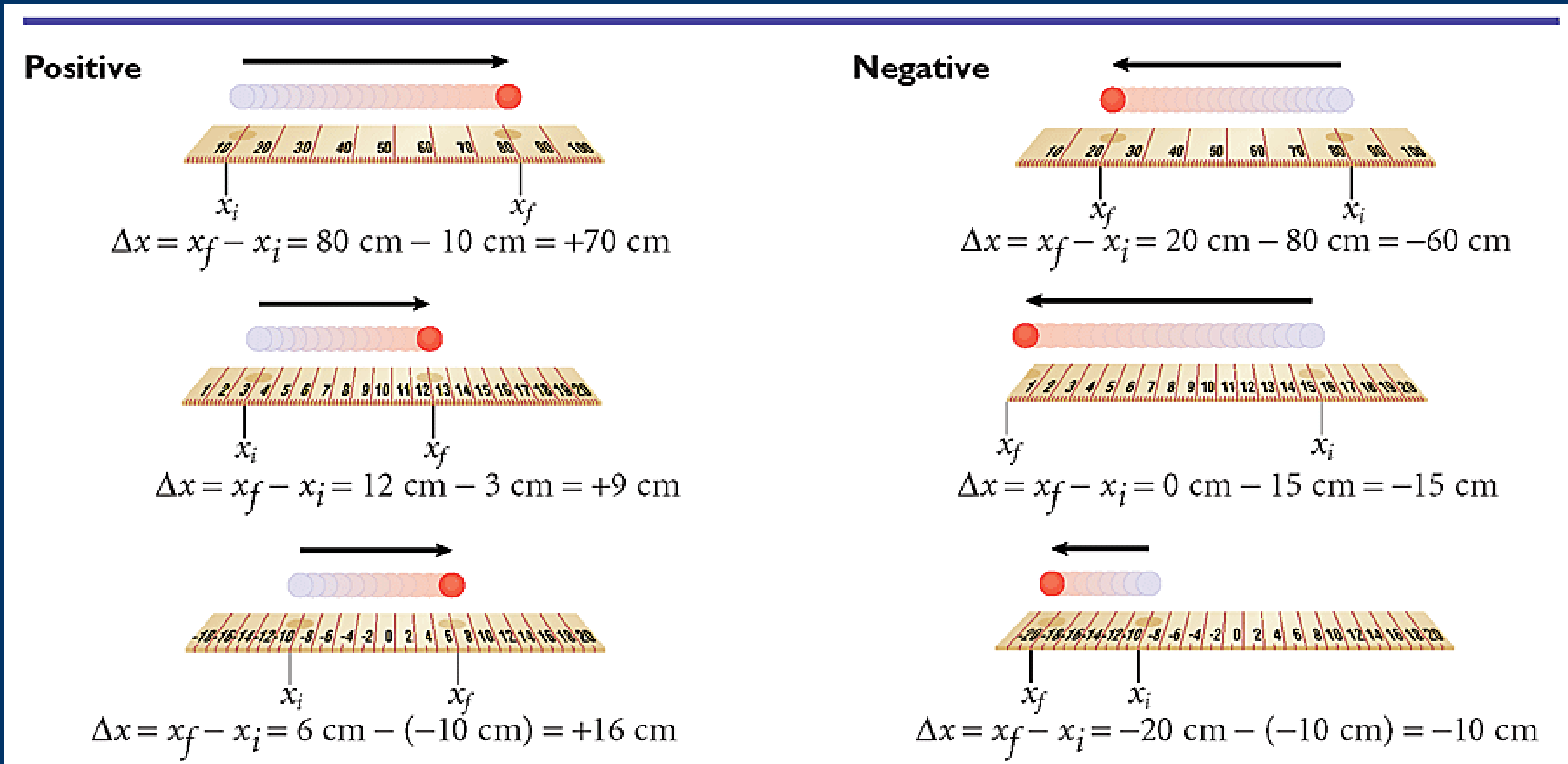
displacement = final position – initial position

Displacement

Click below to watch the Visual Concept.

Visual Concept

Positive and Negative Displacements



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Preview
Main

Average Velocity

- **Average velocity** is the total **displacement** divided by the **time interval** during which the displacement occurred.

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

$$\text{average velocity} = \frac{\text{change in position}}{\text{change in time}} = \frac{\text{displacement}}{\text{time interval}}$$

- In SI, the unit of velocity is **meters per second,** abbreviated as **m/s.**

End of Slide

Average Velocity

Click below to watch the Visual Concept.

Visual Concept

Velocity and Speed

- **Velocity** describes motion with both a **direction** and a **numerical value** (a magnitude).
- **Speed** has no direction, only magnitude.
- **Average speed** is equal to the total **distance traveled** divided by the **time interval.**

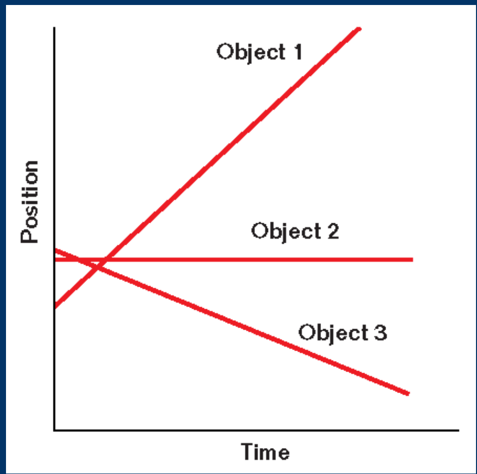
$$\text{average speed} = \frac{\text{distance traveled}}{\text{time of travel}}$$

End of Slide

Interpreting Velocity Graphically

- For any **position-time graph,** we can determine the **average velocity** by drawing a straight line between any two points on the graph.

- If the velocity is **constant**, the graph of position versus time is a **straight line.** The slope indicates the velocity.

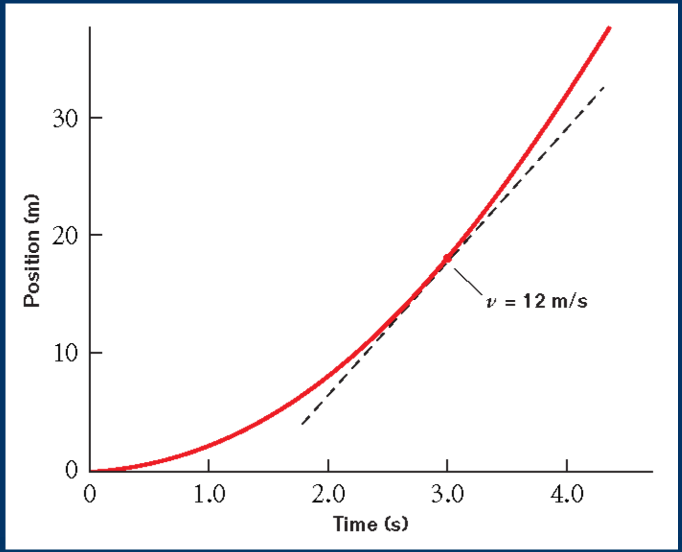


  - **Object 1:** positive slope = positive velocity
  - **Object 2:** zero slope= zero velocity
  - **Object 3:** negative slope = negative velocity

Interpreting Velocity Graphically, *continued*

The **instantaneous velocity** is the velocity of an object at some instant or at a specific point in the object's path.

The instantaneous velocity at a given time can be determined by measuring the slope of the line that is tangent to that point on the position-versus-time graph.



Sign Conventions for Velocity

Click below to watch the Visual Concept.

Visual Concept

Preview

- Objectives
- Changes in Velocity
- Motion with Constant Acceleration
- Sample Problem

Objectives

- **Describe** motion in terms of changing velocity.
- **Compare** graphical representations of accelerated and nonaccelerated motions.
- **Apply** kinematic equations to **calculate** distance, time, or velocity under conditions of constant acceleration.

End of Slide

Changes in Velocity

- **Acceleration** is the rate at which velocity changes over time.

$$a_{avg} = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{t_f - t_i}$$

$$\text{average acceleration} = \frac{\text{change in velocity}}{\text{time required for change}}$$

- An object accelerates if its **speed, direction, or both** change.
- Acceleration has direction and magnitude. Thus, acceleration is a **vector** quantity.

End of Slide

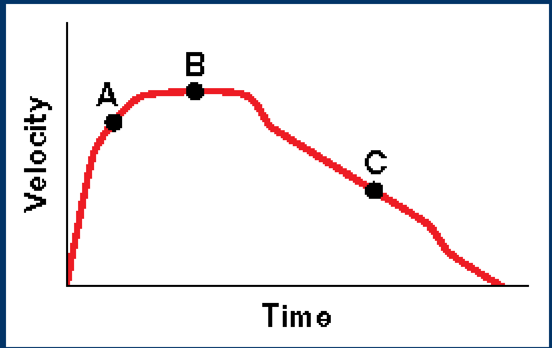
Acceleration

Click below to watch the Visual Concept.

Visual Concept

Changes in Velocity, *continued*

- Consider a train moving to the right, so that the displacement and the velocity are positive.
- The slope of the velocity-time graph is the average acceleration.
  - When the velocity in the positive direction is increasing, the **acceleration is positive**, as at **A.**
  - When the velocity is constant, there is **no acceleration**, as at **B.**
  - When the velocity in the positive direction is decreasing, the **acceleration is negative,** as at **C.**



Graphical Representations of Acceleration

Click below to watch the Visual Concept.

Visual Concept

Velocity and Acceleration

v_i	a	Motion
+	+	speeding up
−	−	speeding up
+	−	slowing down
−	+	slowing down
− or +	0	constant velocity
0	− or +	speeding up from rest
0	0	remaining at rest

Motion with Constant Acceleration

- When velocity changes by the same amount during each time interval, **acceleration is constant.**
- The relationships between **displacement, time, velocity,** and **constant acceleration** are expressed by the equations shown on the next slide. These equations apply to any object moving with constant acceleration.
- These equations use the following symbols:

Δx = displacement

v_i = initial velocity

v_f = final velocity

Δt = time interval

End of Slide

Equations for Constantly Accelerated Straight-Line Motion

Form to use when accelerating object has an initial velocity	Form to use when accelerating object starts from rest
$\Delta x = \frac{1}{2}(v_i + v_f)\Delta t$	$\Delta x = \frac{1}{2}v_f\Delta t$
$v_f = v_i + a\Delta t$	$v_f = a\Delta t$
$\Delta x = v_i\Delta t + \frac{1}{2}a(\Delta t)^2$	$\Delta x = \frac{1}{2}a(\Delta t)^2$
$v_f^2 = v_i^2 + 2a\Delta x$	$v_f^2 = 2a\Delta x$

Sample Problem

Final Velocity After Any Displacement

A person pushing a stroller starts from rest, uniformly accelerating at a rate of 0.500 m/s². What is the velocity of the stroller after it has traveled 4.75 m?

End of Slide

Sample Problem, *continued*

1. Define

Given:

v_i = 0 m/s

a = 0.500 m/s^2

Δx = 4.75 m

Unknown:

v_f = ?

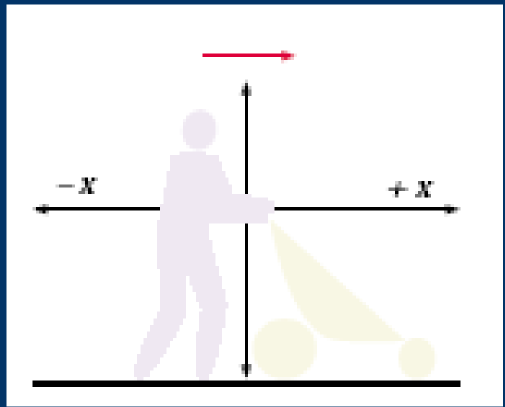


Diagram: Choose a coordinate system. The most convenient one has an origin at the initial location of the stroller, as shown above. The positive direction is to the right.

Sample Problem, *continued*

2. Plan

Choose an equation or situation: Because the initial velocity, acceleration, and displacement are known, the final velocity can be found using the following equation:

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

Rearrange the equation to isolate the unknown: Take the square root of both sides to isolate v_f .

$$v_f = \pm\sqrt{v_i^2 + 2a\Delta x}$$

End of Slide

Sample Problem, *continued*

3. Calculate

Substitute the values into the equation and solve:

$$v_f = \pm\sqrt{(0 \text{ m/s})^2 + 2(0.500 \text{ m/s}^2)(4.75 \text{ m})}$$

$$\boxed{v_f = +2.18 \text{ m/s}}$$

Tip: *Think about the physical situation to determine whether to keep the positive or negative answer from the square root. In this case, the stroller starts from rest and ends with a speed of 2.18 m/s. An object that is speeding up and has a positive acceleration must have a positive velocity. So, the final velocity must be positive.*

4. Evaluate

The stroller's velocity after accelerating for 4.75 m is 2.18 m/s to the right.

Preview

- Objectives
- Free Fall
- Free-Fall Acceleration
- Sample Problem

Objectives

- **Relate** the motion of a freely falling body to motion with constant acceleration.
- **Calculate** displacement, velocity, and time at various points in the motion of a freely falling object.
- **Compare** the motions of different objects in free fall.

Free Fall

Click below to watch the Visual Concept.

Visual Concept

Free Fall

- **Free fall** is the motion of a body when only the force due to gravity is acting on the body.
- The acceleration on an object in free fall is called the **acceleration due to gravity,** or **free-fall acceleration.**
- Free-fall acceleration is denoted with the symbols a_g (generally) or g (on Earth's surface).

End of Slide

Free-Fall Acceleration

Click below to watch the Visual Concept.

Visual Concept

Free-Fall Acceleration

- Free-fall acceleration is the same for all objects, regardless of mass.
- This book will use the value **g = 9.81 m/s^2.**
- Free-fall acceleration on Earth's surface is –9.81 m/s^2 at **all points** in the object's motion.
- Consider a ball thrown up into the air.
  – **Moving upward:** velocity is decreasing, acceleration is –9.81 m/s^2
  – **Top of path:** velocity is zero, acceleration is –9.81 m/s^2
  – **Moving downward:** velocity is increasing, acceleration is –9.81 m/s^2

End of Slide

Velocity and Acceleration of an Object in Free Fall

Click below to watch the Visual Concept.

Visual Concept

Sample Problem

Falling Object

Jason hits a volleyball so that it moves with an initial velocity of 6.0 m/s straight upward. If the volleyball starts from 2.0 m above the floor, how long will it be in the air before it strikes the floor?

End Of Slide

Sample Problem, *continued*

1. Define

Given:

v_i = +6.0 m/s

$a = -g$ = –9.81 m/s^2

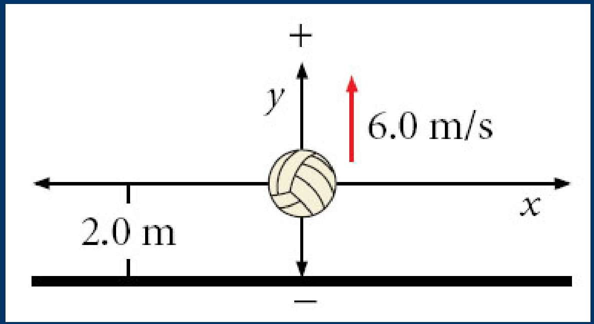
Δy = –2.0 m

Unknown:

Δt = ?

Diagram:

Place the origin at the Starting point of the ball (y_i = 0 at t_i = 0).



Sample Problem, *continued*

2. Plan

Choose an equation or situation:

Both Δt and v_f are unknown. Therefore, first solve for v_f using the equation that does not require time. Then, the equation for v_f that does involve time can be used to solve for Δt.

$$v_f^2 = v_i^2 + 2a\Delta y \qquad v_f = v_i + a\Delta t$$

Rearrange the equation to isolate the unknown:

Take the square root of the first equation to isolate v_f. The second equation must be rearranged to solve for Δt.

$$v_f = \pm\sqrt{v_i^2 + 2a\Delta y} \qquad \Delta t = \frac{v_f - v_i}{a}$$

End of Slide

Sample Problem, *continued*

3. Calculate

Substitute the values into the equation and solve:

First find the velocity of the ball at the moment that it hits the floor.

$$v_f = \pm\sqrt{v_i^2 + 2a\Delta y} = \pm\sqrt{(6.0\ \text{m/s})^2 + 2(-9.81\ \text{m/s}^2)(-2.0\ \text{m})}$$

$$v_f = \pm\sqrt{36\ \text{m}^2/\text{s}^2 + 39\ \text{m}^2/\text{s}^2} = \pm\sqrt{75\ \text{m}^2/\text{s}^2} = -8.7\ \text{m/s}$$

Tip: *When you take the square root to find v_f , select the negative answer because the ball will be moving toward the floor, in the negative direction.*

End of Slide

Sample Problem, *continued*

Next, use this value of v_f in the second equation to solve for Δt.

$$\Delta t = \frac{v_f - v_i}{a} = \frac{-8.7\ \text{m/s} - 6.0\ \text{m/s}}{-9.81\ \text{m/s}^2} = \frac{-14.7\ \text{m/s}}{-9.81\ \text{m/s}^2}$$

$$\boxed{\Delta t = 1.50\ \text{s}}$$

4. Evaluate

The solution, 1.50 s, is a reasonable amount of time for the ball to be in the air.

End of Slide