Preview

What do you think?

- Is the book on your instructor's desk in motion?
  - Explain your answer.

Frame of Reference

- Motion
  - a change in position
- Frame of reference
  - A point against which position is measured
- Example: A train traveling between stations
  - It is in motion when measured against the track.
  - It is stationary when measured against a seat.

Frame of Reference

Click below to watch the Visual Concept.

Visual Concept

Displacement (Δx)

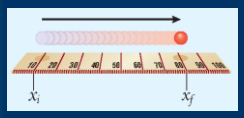
- Straight line distance from the initial position to the final position (change in position)
- Can be positive or negative

DISPLACEMENT

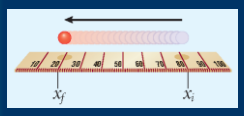
$$\Delta x = x_f - x_i$$

displacement = change in position = final position − initial position

Displacement



- What is the displacement for the objects shown?
- Answer: 9 cm



- Answer: -15 cm

Displacement - Sign Conventions

- Right (or east) ---> +
- Left (or west) ---> –
- Up (or north) ----> +
- Down (or south) ---> –

Average Velocity

- Average velocity is displacement divided by the time interval.

AVERAGE VELOCITY

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

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

- The units can be determined from the equation.
  - SI Units: m/s
  - Other Possible Units: mi/h, km/h, cm/year

Classroom Practice Problems

- A car travels 36 km to the north in 30.0 min. Find the average velocity in km/min and in km/h.
  - Answer: 1.2 km/min to the north or 72 km/h to the north
- A car travels 100.0 km to the east. If the first half of the distance is driven at 50.0 km/h and the second half at a 100.0 km/h, what is the average velocity?
  - Answer: 66.7 km/h to the east

Speed

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

- Speed does not include direction while velocity does.
- Speed uses *distance* rather than *displacement.*
- In a round trip, the average velocity is zero but the average speed is not zero.

Graphing Motion

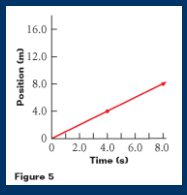


Figure 5

- How would you describe the motion shown by this graph?
  - Answer: Constant speed (straight line)
- What is the slope of this line?
  - Answer: 1 m/s
- What is the average velocity?
  - Answer: 1 m/s

Slope of a Line

$$\text{slope} = \frac{\text{rise}}{\text{run}} = \frac{\text{change in vertical coordinates}}{\text{change in horizontal coordinates}}$$

Average Velocity

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

Graphing Motion

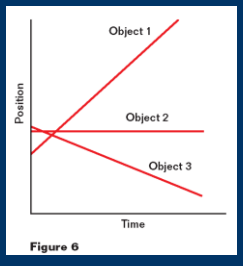


Figure 6

- Describe the motion of each object.
- Answers
  - Object 1: constant velocity to the right or upward
  - Object 2: constant velocity of zero (at rest)
  - Object 3: constant velocity to the left or downward

Instantaneous Velocity

- Velocity at a single instant of time
  - Speedometers in cars measure instantaneous speed.
- Determined by finding the slope at a single point (the slope of the tangent)

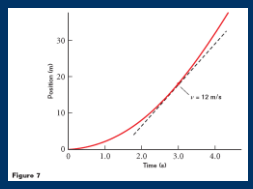


Figure 7

- What is the slope of the tangent line at $t = 3.0$ s?
  - Answer: approximately 12 m/s
- What is the instantaneous velocity at $t = 3.0$ s?
  - Answer: approximately 12 m/s

Now what do you think?

- Is the book on your instructor's desk in motion?
  - How does your answer depend on the frame of reference?
- What are some common terms used to describe the motion of objects?

What do you think?

- Which of the following cars is accelerating?
  - A car shortly after a stoplight turns green
  - A car approaching a red light
  - A car with the cruise control set at 80 km/h
  - A car turning a curve at a constant speed
- Based on your answers, what is *your* definition of acceleration?

Acceleration

AVERAGE ACCELERATION

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

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

- Rate of change in velocity
- What are the units?
  - SI Units: (m/s)/s or m/s^2
  - Other Units: (km/h)/s or (mi/h)/s
- Acceleration = 0 implies a constant velocity (or rest)

Classroom Practice Problem

- Find the acceleration of an amusement park ride that falls from rest to a velocity of 28 m/s downward in 3.0 s.
  - Answer: 9.3 m/s^2 downward

Direction of Acceleration

V_i	a
+	+
+	-
-	-
-	+

*Describe the motion of an object with $\mathbf{v}_i$ and **a** as shown to the left.*

- Moving right as it speeds up
- Moving right as it slows down
- Moving left as it speeds up
- Moving left as it slows down

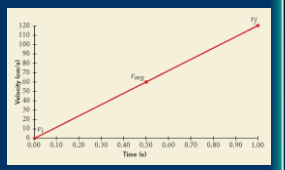
Acceleration

Click below to watch the Visual Concept.

Visual Concept

Graphing Velocity

- The slope (rise/run) of a velocity/time graph is the acceleration.
  - Rise is change in *v*
  - Run is change in *t*
- This graph shows a constant acceleration.
- Average speed is the midpoint.



$$v_{avg} = \frac{v_i + v_f}{2}$$

Graph of v vs. t for a train

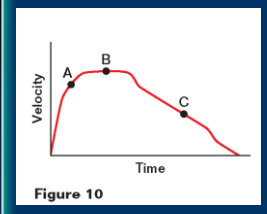


Figure 10

- Describe the motion at points A, B, and C.
- Answers
  - A: accelerating (increasing velocity/slope) to the right
  - B: constant velocity to the right
  - C: negative acceleration (decreasing velocity/slope) and still moving to the right

Useful Equations

1. $v_{avg} = \frac{\Delta x}{\Delta t}$
2. $a_{avg} = \frac{\Delta v}{\Delta t}$ $\quad v_f = v_i + a\Delta t$
3. $v_{avg} = \frac{v_i + v_f}{2}$
4. $\Delta x = v_i \Delta t + \frac{1}{2} a \Delta t^2$
5. $v_f^2 = v_i^2 + 2a\Delta x$

Classroom Practice Problems

- A bicyclist accelerates from 5.0 m/s to 16 m/s in 8.0 s. Assuming uniform acceleration, what distance does the bicyclist travel during this time interval?
  - Answer: 84 m
- An aircraft has a landing speed of 83.9 m/s. The landing area of an aircraft carrier is 195 m long. What is the minimum uniform acceleration required for safe landing?
  - Answer: -18.0 m/s^2

Now what do you think?

- Which of the following cars is accelerating?
  - A car shortly after a stoplight turns green
  - A car approaching a red light
  - A car with the cruise control set at 80 km/h
  - A car turning a curve at a constant speed
- Based on your answers, what is the definition of acceleration?
  - How is acceleration calculated?
  - What are the SI units for acceleration?

What do you think?

- Observe a metal ball being dropped from rest.
  - Describe the motion in words.
  - Sketch a velocity-time graph for this motion.
- Observe the same ball being tossed vertically upward and returning to the starting point.
  - Describe the motion in words.
  - Sketch a velocity-time graph for this motion.

Free Fall

- Assumes no air resistance
- Acceleration is constant for the entire fall
- Acceleration due to gravity ($\mathbf{a}_g$ or $\mathbf{g}$)
  - Has a value of -9.81 m/s^2
    - Negative for downward
  - Roughly equivalent to -22 (mi/h)/s

Free Fall

- For a ball tossed upward, make predictions for the sign of the velocity and acceleration to complete the chart.

	Velocity (+, -, or zero)	Acceleration (+, -, or zero)
When halfway up	+	-
When at the peak	zero	-
When halfway down	-	-

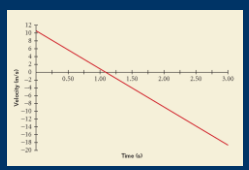
Free Fall

Click below to watch the Visual Concept.

Visual Concept

Graphing Free Fall

- Based on your present understanding of free fall, sketch a velocity-time graph for a ball that is tossed upward (assuming no air resistance).
  - Is it a straight line?
  - If so, what is the slope?
- Compare your predictions to the graph to the right.



Velocity and Acceleration of an Object at its High Point

Click below to watch the Visual Concept.

Visual Concept

Classroom Practice Problem

A ball is thrown straight up into the air at an initial velocity of 25.0 m/s upward. Create a table showing the ball's position, velocity and acceleration each second for the first 5 s.

t (s)	y (m)	v (m/s)	a (m/s^2)
1.00	20.1	+15.2	-9.81
2.00	30.4	+5.4	-9.81
3.00	30.9	-4.4	-9.81
4.00	21.6	-14.2	-9.81
5.00	2.50	-24.0	-9.81

Now what do you think?

Review the descriptions and graphs you created at the beginning of the presentation.

- Do you want to make any modifications?
- For the second graph, circle the point representing the highest point of the toss.