Motion Basics

- How objects move through space and time
- Position: location in a coordinate system
- Displacement: change in position

  $\Delta x = x_f - x_i$
- Velocity: *rate of change* in position

  $\mathbf{v} = \Delta x / \Delta t$
- Displacement & velocity are **vector** quantities: include a direction!

Vector Basics

- Vectors are drawn as arrows in diagrams
- A vector quantity is written either in bold or with a small arrow over the top: **v** or $\vec{v}$
- Ways to express vectors depend on the *coordinate system*
  - Magnitude and angle: angle measured *counterclockwise* from x-axis
  - Components: along x- & y-axes
  - SOH CAH TOA: Use it, know it, it is your best friend for decomposing vectors!

Example: A person runs northwest (exactly halfway between due north and due west) at a speed of 2 m/s

1. Define coordinate system and origin
2. Magnitude/angle version
3. Components version

A bird flies 3.0 m due west and then 2.0 m due north. What is the magnitude of the bird's displacement?

A. 2.0 m
B. 3.0 m
C. 3.6 m
D. 5.0 m
E. 6.0 m

Displacement Isn't Distance

- The displacement of an object is not the same as the distance it travels
  - Example: Throw a ball straight up and then catch it at the same point you released it
    - The distance is twice the height
    - The displacement is zero

Distance & Displacement Lecture-Tutorial

- Work with a partner or two
- Read directions and answer all questions carefully. Take time to understand it now!
- Come to a consensus answer you all agree on before moving on to the next question.
- If you get stuck, ask another group for help.
- If you get really stuck, raise your hand and I will come around.

Speed

- The **average speed** of an object is defined as the total distance traveled divided by the total time elapsed

$$\text{Average speed} = \frac{\text{total distance}}{\text{total time}}$$

$$v = \frac{d}{t}$$

  - Speed is a scalar quantity

Velocity

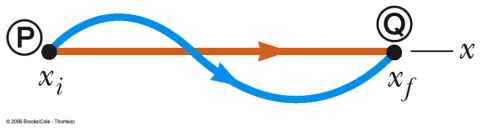
- It takes time for an object to undergo a displacement
- The **average velocity** is rate at which the displacement occurs

$$v_{avg} = \frac{\Delta x}{\Delta t}$$

Velocity continued

- Direction will be the same as the direction of the displacement (time interval is always positive)
  - + or - is sufficient
- Units of velocity are m/s

Speed vs. Velocity



- Cars on both paths have the same displacement in the same time interval
- The car on the blue path will have a greater average speed since the distance it traveled is larger

Uniform Velocity

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

Acceleration

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

$$\vec{a} = \frac{\Delta v}{\Delta t}$$

- Units are m/s²

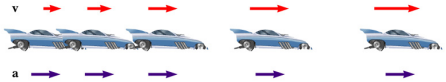
Average Acceleration

- Vector quantity
- 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 in the opposite directions, the speed is decreasing

Relationship Between Acceleration and Velocity

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

Relationship Between Velocity and Acceleration



- 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)
- Positive velocity and positive acceleration

Relationship Between Velocity and Acceleration

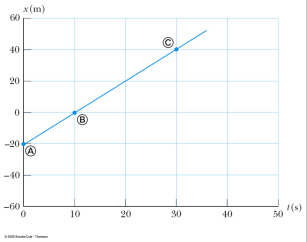
- Acceleration and velocity are in opposite directions
- Acceleration is uniform (blue arrows maintain the same length)
- Velocity is decreasing (red arrows are getting shorter)
- Velocity is positive and acceleration is negative

Graphical Interpretation of Velocity

- Velocity can be determined from a position-time graph
- Average velocity equals the slope of the line joining the initial and final positions
- An object moving with a constant velocity will have a graph that is a straight line

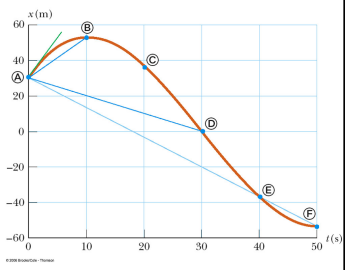
Average Velocity, Constant

- The straight (not curved) line indicates constant velocity
- The slope of the line is the value of the average velocity



Average Velocity, Non-Constant

- This motion is non-constant velocity
- The average velocity is the slope of the blue line joining two points



Instantaneous Velocity on a Graph

- The slope of the line tangent to the position-vs.-time graph is defined to be the instantaneous velocity at that time
  - The instantaneous speed is defined as the magnitude of the instantaneous velocity

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

Motion Graphs Lecture-Tutorial

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