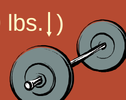
Chapter 2

Intro to Kinematics

VECTORS & SCALARS

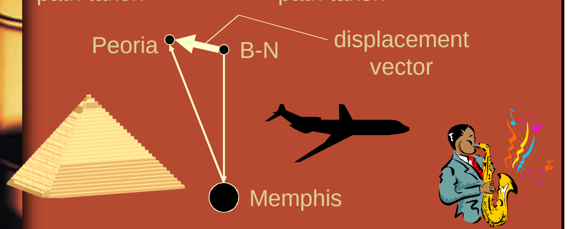
Introductory Concepts

scalar	vector
magnitude, units	magnitude, units, direction
e.g.,	e.g.,
mass (25 kg)	weight (140 lbs. ↓)
temperature (83 K)	force (48 N ⟶)

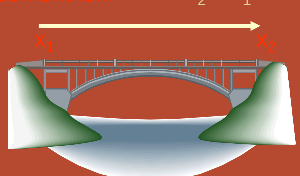


DISPLACEMENT

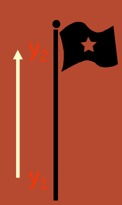
distance (d)	displacement (Δx or Δy)
how far object travels	the difference between the starting and ending points
-- depends on path taken	-- independent of path taken



For position coordinates x_1 and x_2, displacement is... $\Delta x = x_2 - x_1$.

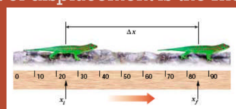


For position coordinates y_1 and y_2, displacement is... $\Delta y = y_2 - y_1$.



Displacement

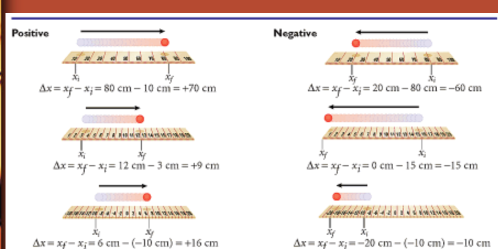
- **Displacement** is a **change in position.**
- Displacement is not always equal to the distance traveled.
- The SI unit of displacement is the **meter, m.**



$$\Delta x = x_f - x_i$$

displacement = final position – initial position

Positive and Negative Displacements



VELOCITY

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.**

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.**

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

Today

- Link
- Kinematic equations
- Sample Problems

ACCELERATION

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.

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:
  - d = displacement
  - v_i = initial velocity
  - v_f = final velocity
  - t = time interval

Equations for Constantly Accelerated Straight-Line Motion

$$\Delta d = v_i * \Delta t + \frac{1}{2} * a * \Delta t^2$$

$$v_f = v_i + a * t$$

$$v_f = \sqrt{(v_i^2 + \frac{1}{2} a d)}$$

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?

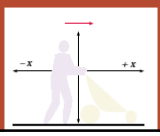
Sample Problem, *continued*

1. Define

Given:
- v_i = 0 m/s
- a = 0.500 m/s²
- d = 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*

Relationship?

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

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

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

Sample Problem, *continued*

3. Calculate

Substitute the values into the equation and solve:

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

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

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.

Problems to try

1. As the shuttle bus comes to a sudden stop to avoid hitting a dog, it accelerates uniformly at -4.1 m/s^2 as it slows from 9.0 m/s to 0.0 m/s. Find the time interval of acceleration for the bus.
2. A car traveling at 7.0 m/s accelerates uniformly at 2.5 m/s^2 to reach a speed of 12.0 m/s. How long does it take for this acceleration to occur?

An automobile with an initial speed of 4.30 m/s accelerates uniformly at the rate of 3.00 m/s^2. Find the final speed and the displacement after 5.00 s.

A car starts from rest and travels for 5.0 s with a constant acceleration of -1.5 m/s^2. What is the final velocity of the car? How far does the car travel in this time interval?

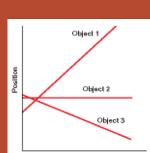
Homework

- Page 59 #1-3
  - Use the problem solving method given
  - Do not solve the problems on pages you have taken notes

GRAPHING KINEMATIC VALUES

Interpreting Velocity Graphically

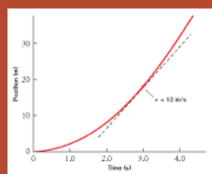
- For any **position-time graph,** we can determine the **average velocity** by drawing a straight line between any two points on the graph.
- If the velocity is **constant**, the graph of position versus time is a **straight line.** The slope indicates the velocity.
  - **Object 1:** positive slope = positive velocity
  - **Object 2:** zero slope= zero velocity
  - **Object 3:** negative slope = negative velocity



Interpreting Velocity Graphically, *continued*

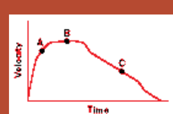
The **instantaneous velocity** is the velocity of an object at some instant or at a specific point in the object's path.

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.



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.**



Graphing summary

- Displacement vs. time
  - Slope
  - Area under the curve
- Velocity vs. time
  - Slope
  - Area under the curve
- Acceleration vs. time
  - Slope
  - Area under the curve

FREELY-FALLING OBJECTS