Section 1: Measuring Motion

Preview

Key Ideas

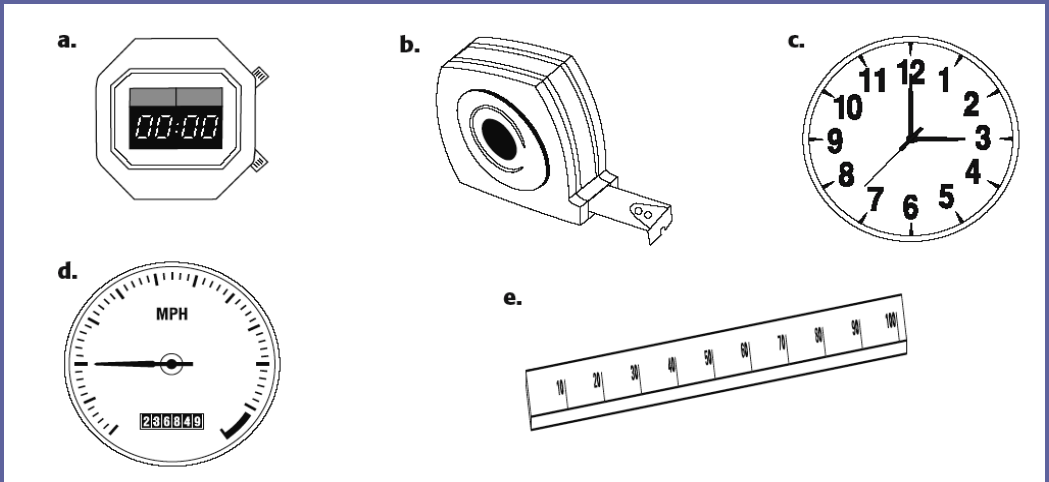
- How is a frame of reference used to describe motion?
- What is the difference between speed and velocity?
- What do you need to know to find the speed of an object?
- How can you study speed by using graphs?

Bellringer

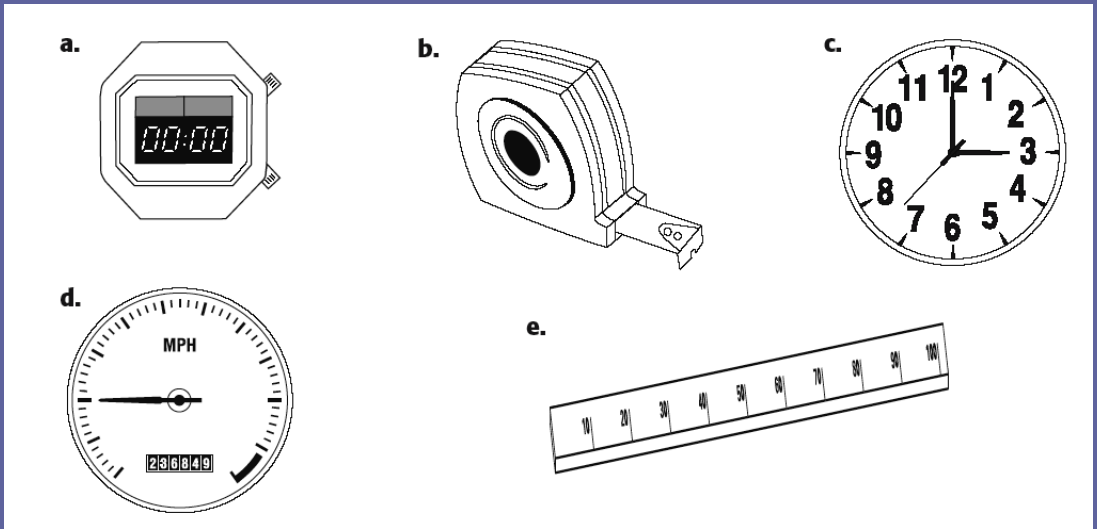
Everybody knows what motion is, but how do you measure it?

- One way is to measure distance, or how far something goes during a motion.
- Another is to measure time, or how long a motion takes to occur.
- A third way is to measure speed, or how fast something is moving.

Each of the devices shown below can be used to measure some aspect of motion.



Bellringer, *continued*



1. For each of the devices above, indicate whether it measures distance, time, or speed.
2. For each of the devices above, indicate which of the following units are possible for a measurement: meters (m), seconds (s), or meters per second (m/s).

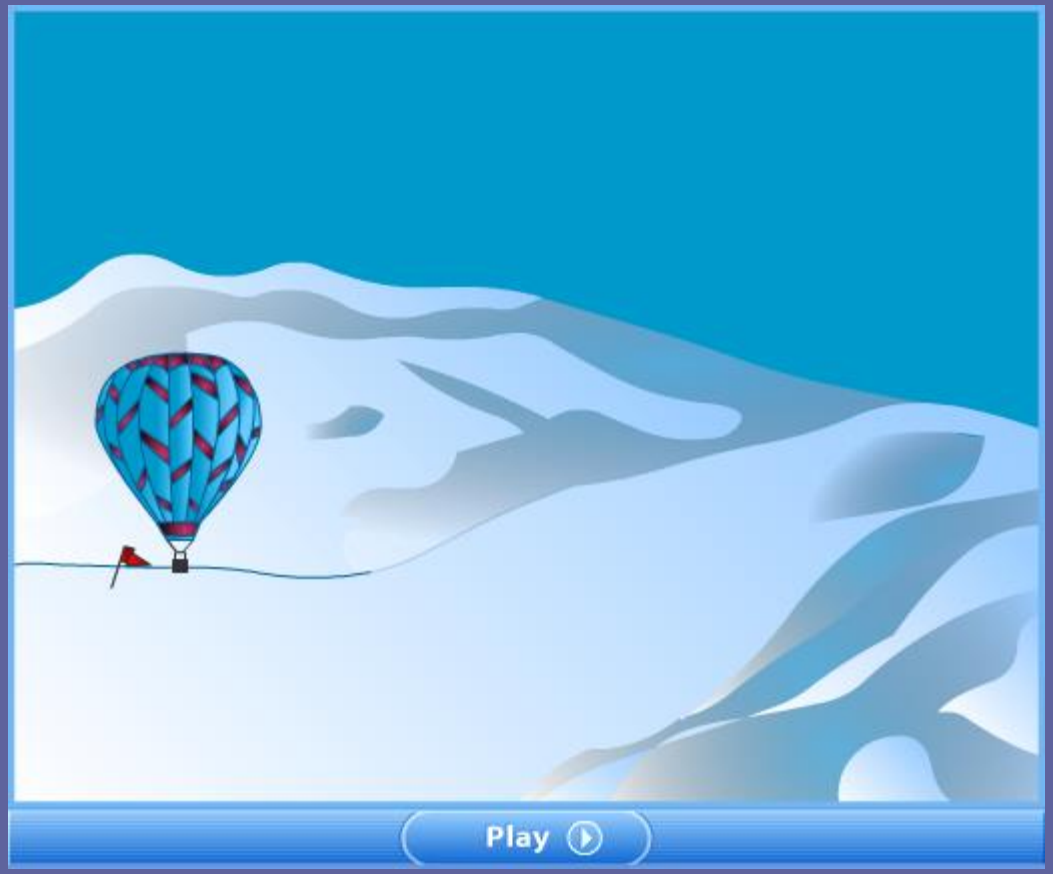
Observing Motion

〉 How is a frame of reference used to describe motion?

〉 When an object changes position with respect to a frame of reference, the object is in motion.

- **motion:** an object's change in position relative to a reference point
- **frame of reference:** a system for specifying the precise location of objects in space and time

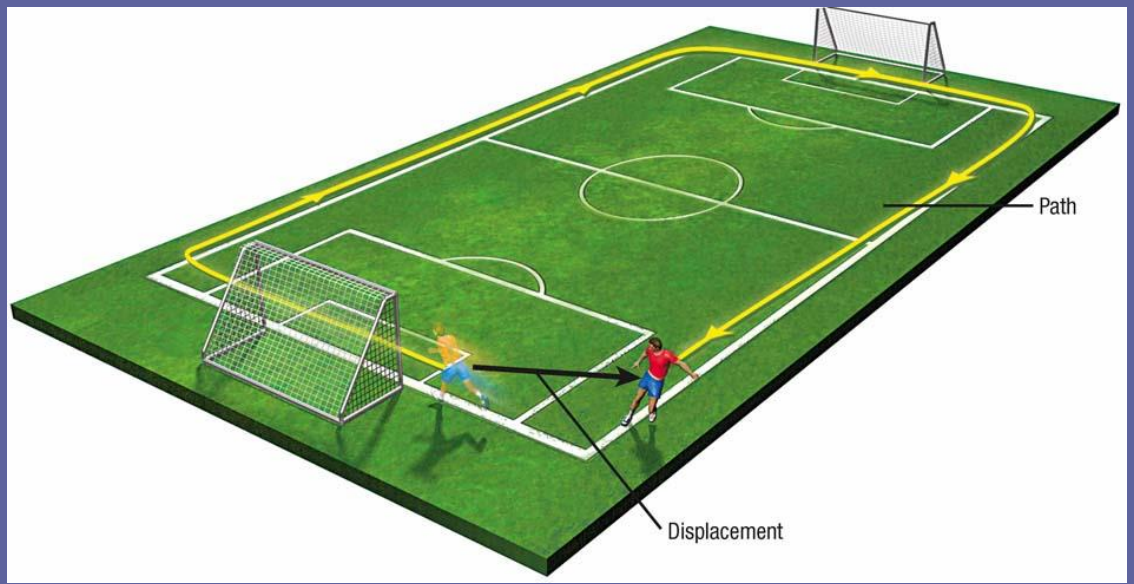
Visual Concept: Motion



Observing Motion, *continued*

- Distance measures the path taken.
- Displacement is the change of an object's position.
  - **displacement:** the change in position of an object
  - always includes direction

- In the diagram:
  - yellow line = distance
  - black arrow = displacement



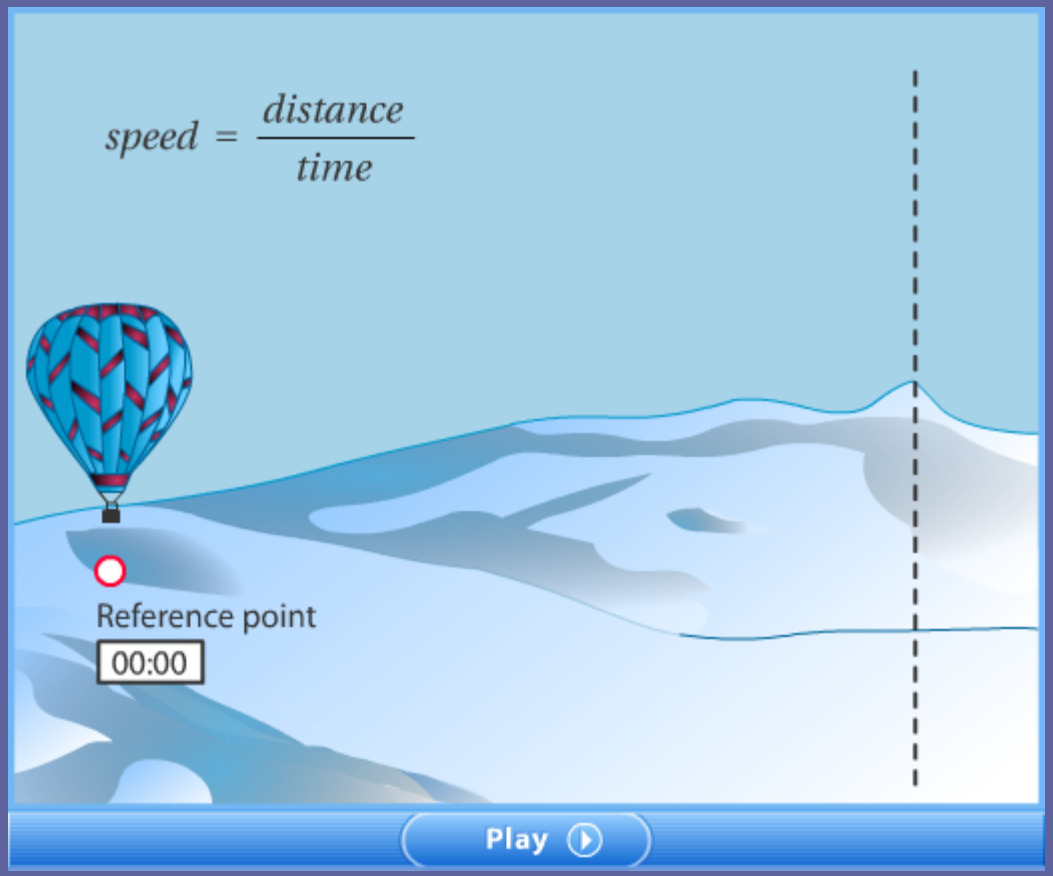
Speed and Velocity

〉 What is the difference between speed and velocity?

〉 Speed tells us how fast an object moves, and velocity tells us both the speed and the direction that the object moves.

- **speed**: the distance traveled divided by the time interval during which the motion occurred
- **velocity:** the speed of an object in a particular direction

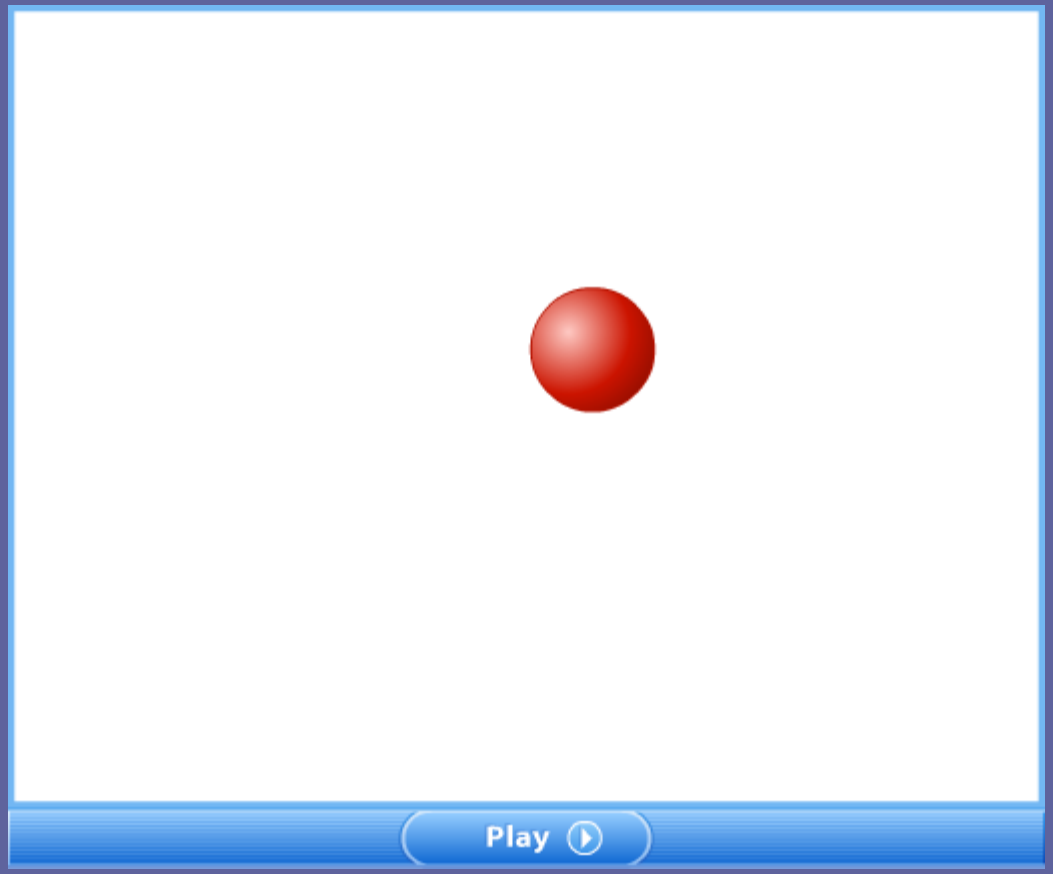
Visual Concept: Speed



Speed and Velocity, *continued*

- Velocity is described relative to a reference point.
  - Direction is described as positive or negative along the line of motion.
  - By convention, up and right are usually positive, and left and down are negative.
- Combined velocities determine the resultant velocity.

Visual Concept: Speed and Velocity



Visual Concept: Velocity

Calculating Speed

- What do you need to know to find the speed of an object?

- To calculate speed, you must measure two quantities: the distance traveled and the time it took to travel that distance.

Calculating Speed, *continued*

- Average speed is calculated as distance divided by time.

$$\text{speed} = \frac{\text{distance}}{\text{time}}, \text{ or } v = \frac{d}{t}$$

- SI unit for speed: meters per second (m/s)
- *constant speed*: equal distances in equal amounts of time
- *instantaneous speed:* the speed at a given time

Math Skills

Velocity

Metal stakes are sometimes placed in glaciers to help measure a glacier's movement. For several days in 1936, Alaska's Black Rapids glacier surged as swiftly as 89 meters per day down the valley. Find the glacier's velocity in m/s. Remember to include direction.

1. List the given and the unknown values.

Given: *time*, t = 1 day

distance, d = 89 m down the valley

Unknown: *velocity*, v = ? (m/s and direction)

Math Skills, *continued*

2a. Perform any necessary conversions.

To find the velocity in meters per second, the value for time must be in seconds.

$$t = 1 \text{ day} = 24 \text{ h} \times \frac{60 \text{ min}}{1 \text{ h}} \times \frac{60 \text{ s}}{1 \text{ min}}$$

$$t = 86\,400 \text{ s} = 8.64 \times 10^4 \text{ s}$$

Math Skills, *continued*

2b. Write the equation for speed.

$$\text{speed} = \frac{\text{distance}}{\text{time}}, \text{ or } v = \frac{d}{t}$$

3. Insert the known values into the equation, and solve.

$$v = \frac{d}{t} = \frac{89 \text{ m}}{8.64 \times 10^4 \text{ s}}$$ (For velocity, include direction.)

$$v = 1.0 \times 10^{-3} \text{ m/s down the valley}$$

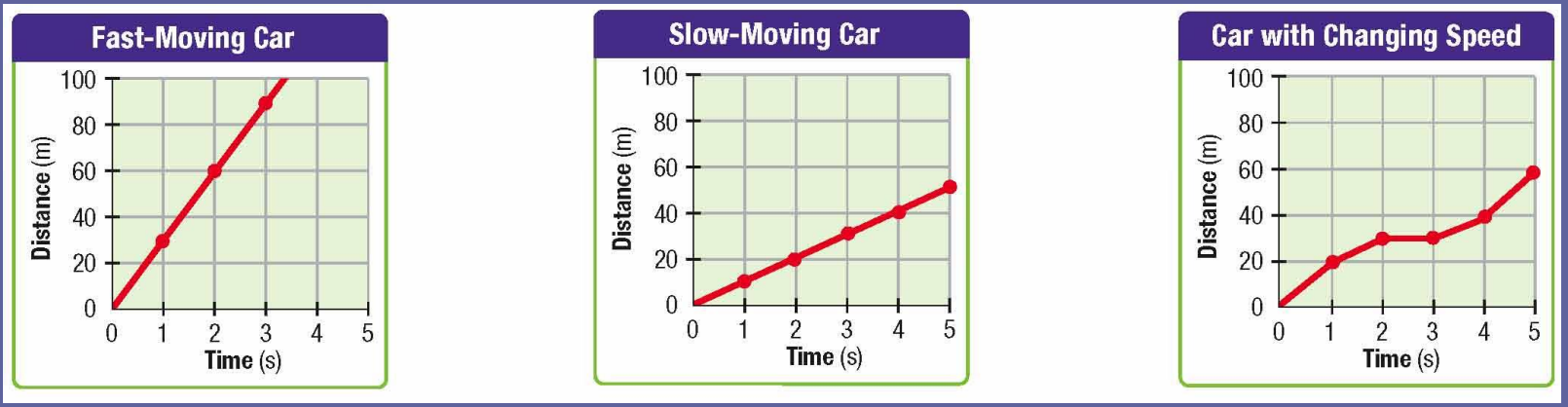
Graphing Motion

- How can you study speed by using graphs?

- You can plot a graph showing distance on the vertical axis and time on the horizontal axis.

Graphing Motion, *continued*

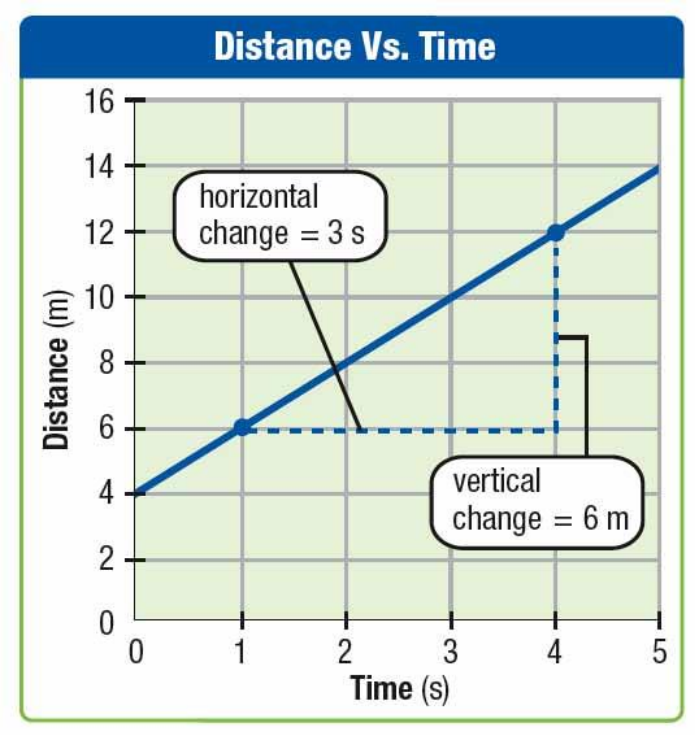
- Motion can be studied using a distance vs. time graph.
  - time (*x*-axis) = independent variable
  - distance (*y*-axis) = dependent variable
- The slope of a distance vs. time graph equals speed.



Graphing Skills

Calculating Slope

The slope of a straight line equals the vertical change divided by the horizontal change. Determine the slope of the blue line shown in the distance vs. time graph.



Graphing Skills, *continued*

1. **Choose two points that you will use to calculate the slope.**

   Point 1: $t = 1$ s and $d = 6$ m

   Point 2: $t = 4$ s and $d = 12$ m

2. **Calculate the vertical change and the horizontal change.**

   vertical change = 12 m – 6 m = 6 m

   horizontal change = 4 s – 1 s = 3 s

3. **Divide the vertical change by the horizontal change.**

   slope = 6 m /3 s = 2 m/s