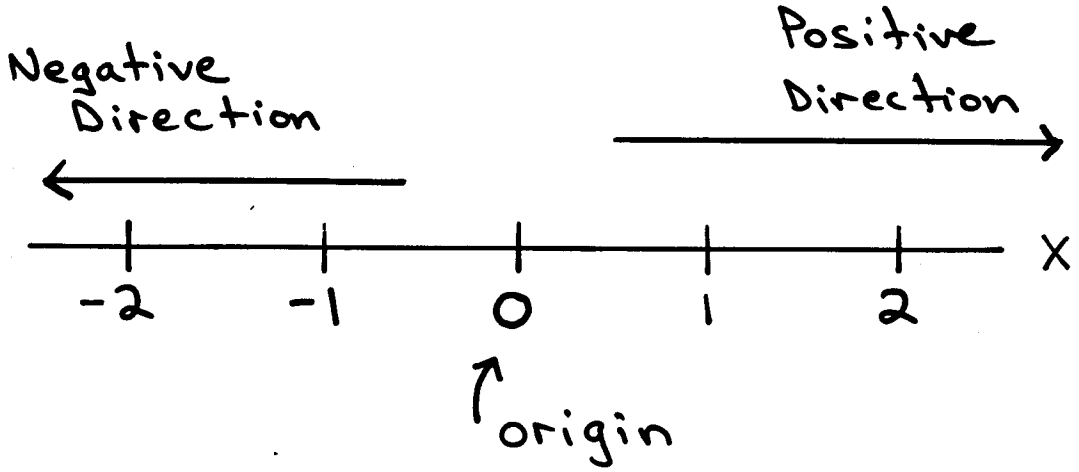
Chapter 2

Motion in One Dimension

Kinematics is the branch of physics concerned with describing the motion of an object

In order to study the motion of an object, certain physical quantities such as displacement, velocity, and acceleration need to be defined.



The displacement of an object is defined as its change in position.

Displacement is the difference between an object's final position (x_f) and its initial position (x_i).

$$\Delta X = X_f - X_i$$

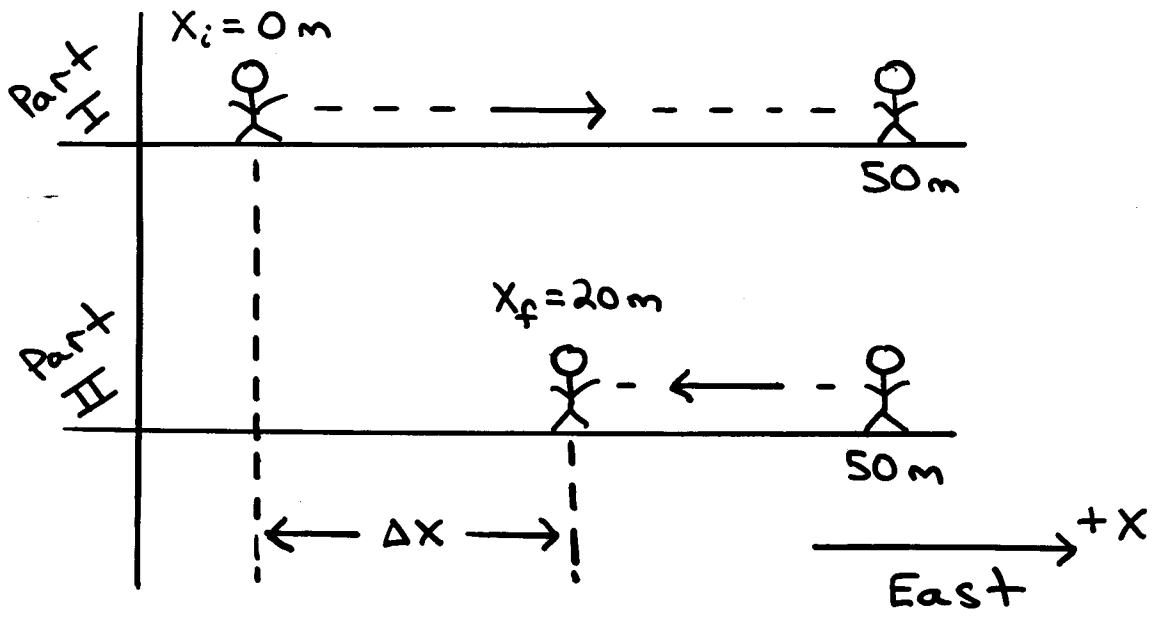
The displacement is described by a distance and a direction. Hence it is called a vector quantity.

A vector is a physical quantity that requires the specification of both direction and magnitude
Ex: displacement, velocity, acceleration

A scalar is a quantity that has magnitude and no direction.
Ex: distance, speed, mass

Example: A person walks 50m due east. He then turns around and walks back (due west) a distance of 30 m.

(a) What is his overall displacement?
(b) What is the total distance covered?



Answer

(a) 20m due east
(b) 80m

The average velocity, $\overline{V}$, is defined as the displacement, Δx, divided by the time interval during which the displacement occurred

$$\overline{V} = \frac{\Delta X}{\Delta t} = \frac{X_f - X_i}{t_f - t_i}$$

SI units $[V] = \frac{m}{s}$

The average velocity is also defined as the slope of the straight line joining the initial and final points on a position vs. time graph

$$\text{Slope} = \frac{\text{change in the vertical axis}}{\text{change in the horizontal axis}}$$

Note: The average velocity gives no detail of the motion between the initial and final points.

The velocity of a particle at any instant of time is called the instantaneous velocity, defined as

$$v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t}$$

The instantaneous velocity can be positive, negative, or zero. It is a vector quantity.

The instantaneous velocity (velocity) is the slope of the tangent line at a particular point in time.

The instantaneous speed of an object is defined as the magnitude of the instantaneous velocity. It is a scalar quantity and can never be negative

Example

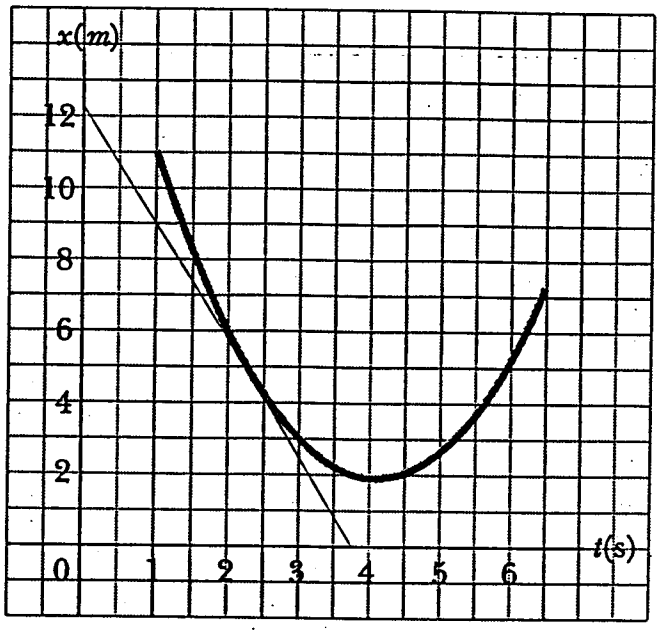


Fig P2.9
R. Serway
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Position vs. Time Graph

(a) Find the average velocity in the time interval $t_i = 1.5\,s$ and $t_f = 4.0\,s$.

(b) Find the instantaneous velocity at $t = 2.0\,s$. (Hint: measure the slope of the tangent line).

(c) At what value of t is the instantaneous velocity zero?

Answers: (a) $\bar{v} = -2.4\,\frac{m}{s}$
(b) $v = -3.27\,\frac{m}{s}$
(c) $t = 4\,s$

When the velocity of a particle changes with time, the particle is said to be accelerating.

The average acceleration is the change in velocity divided by the time interval during which this change occurs

$$\bar{a} = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{t_f - t_i}$$

SI units $[a] = m/s^2$

When the object's velocity and acceleration are in the same direction, the speed of the object increases with time.

When the object's velocity and acceleration are in opposite directions, the speed of the object decreases with time.

The acceleration of a particle at any instant of time is called the instantaneous acceleration, defined as

$$a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t}$$

The instantaneous acceleration (acceleration) is the slope of the tangent line in a velocity vs. time graph at a particular instant in time.