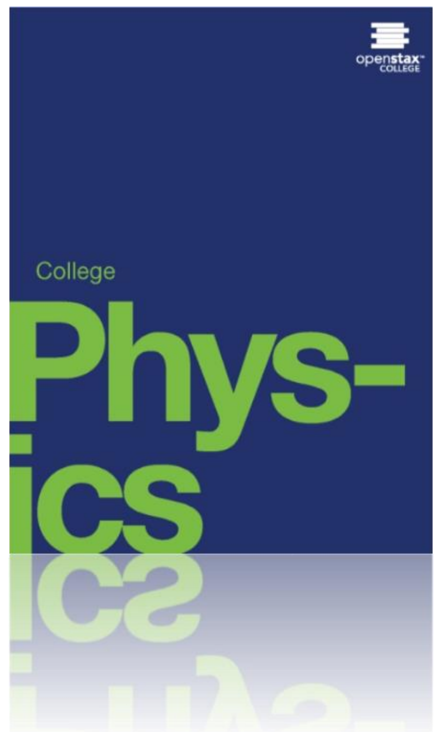
COLLEGE PHYSICS

Chapter 2 KINEMATICS

PowerPoint Image Slideshow



KINEMATICS IN ONE DIMENSION

The motion of an American kestrel through the air can be described by the bird's displacement, speed, velocity, and acceleration. When it flies in a straight line without any change in direction, its motion is said to be one dimensional.

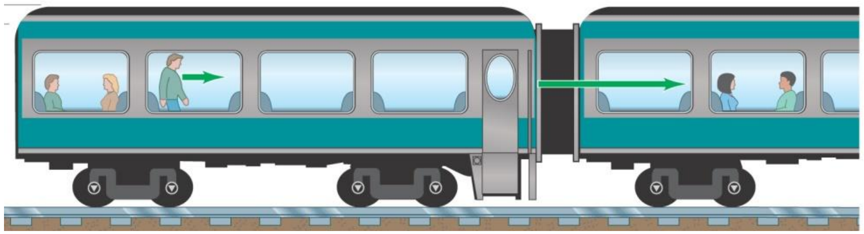
These cyclists in Vietnam can be described by their position relative to buildings and a canal. Their motion can be described by their change in position, or displacement, in the frame of reference.

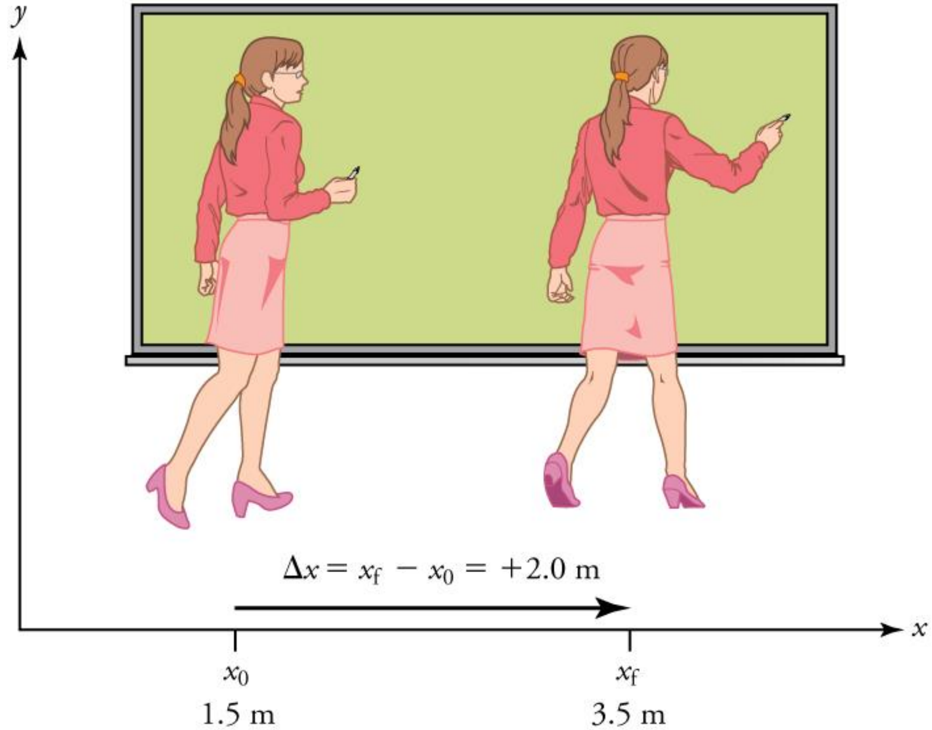
- Reference Frames and Displacement
- Average Velocity
- Instantaneous Velocity
- Acceleration
- Motion at Constant Acceleration
- Solving Problems
- Falling Objects
- Graphical Analysis of Linear Motion

Any measurement of position, distance, or speed must be made with respect to a reference frame.

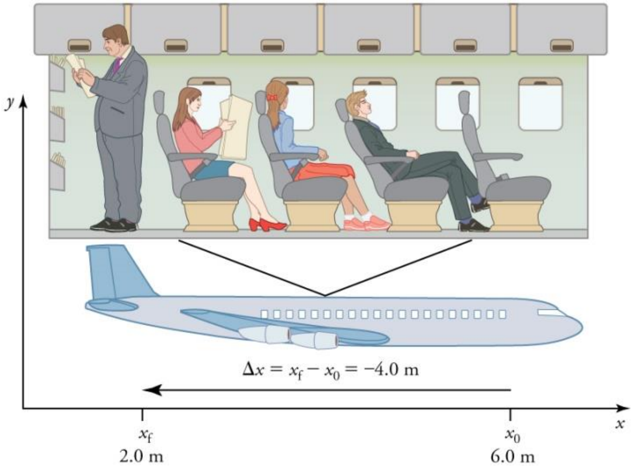
For example, if you are sitting on a train and someone walks down the aisle, their speed with respect to the train is a few miles per hour, at most. Their speed with respect to the ground is much higher.

Reference Frames and Displacement





A professor paces left and right while lecturing. Her position relative to Earth is given by x . The +2.0 m displacement of the professor relative to Earth is represented by an arrow pointing to the right.

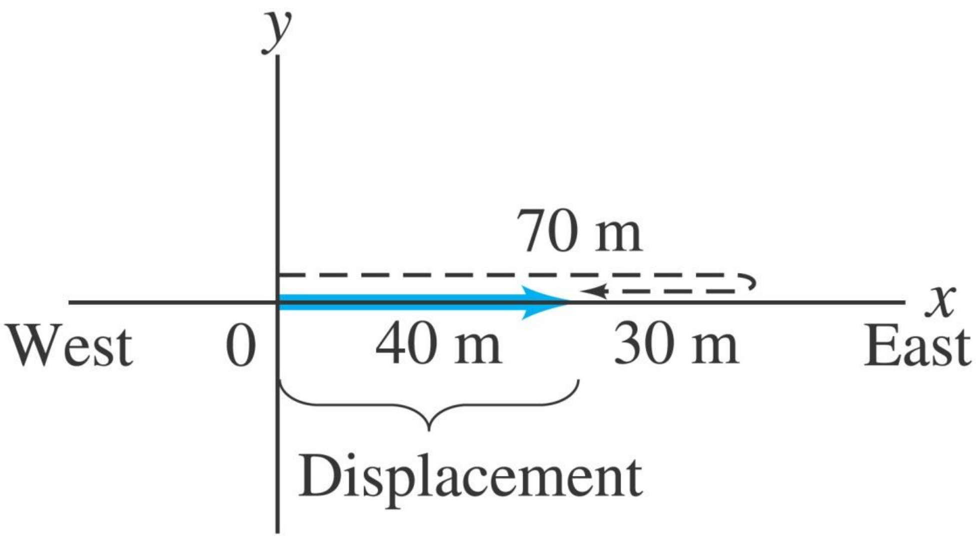


There is a distinction between distance and displacement.

Displacement (blue line) is how far the object is from its starting point, regardless of how it got there.

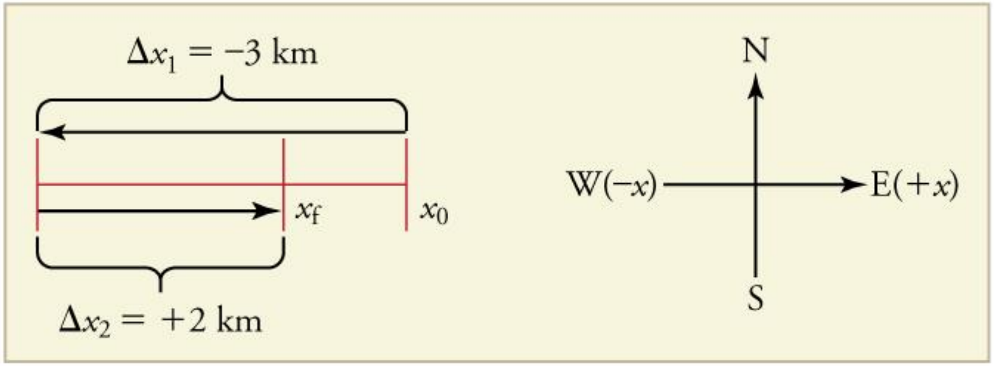
Distance traveled (dashed line) is measured along the actual path.

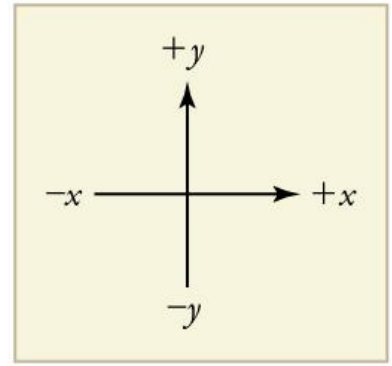
A passenger moves from his seat to the back of the plane. His location relative to the airplane is given by x . The −4.0-m displacement of the passenger relative to the plane is represented by an arrow toward the rear of the plane. Notice that the arrow representing his displacement is twice as long as the arrow representing the displacement of the professor.

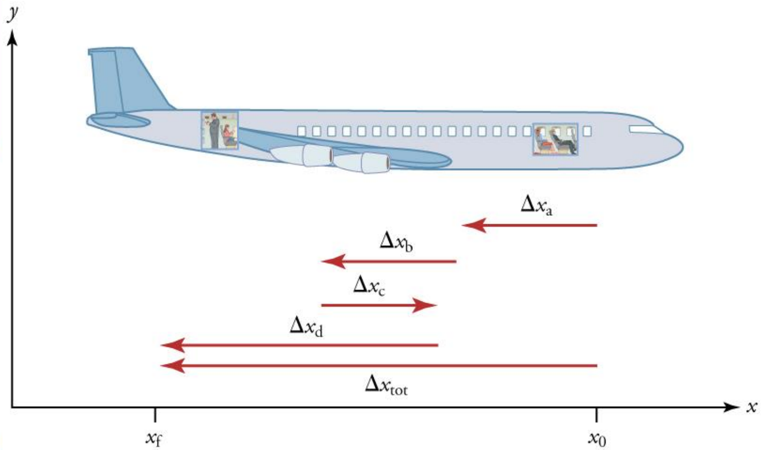


Displacement

$$\Delta x = x_2 - x_1$$

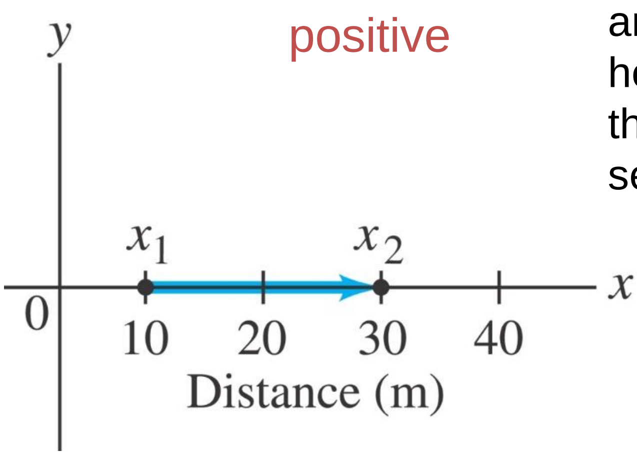




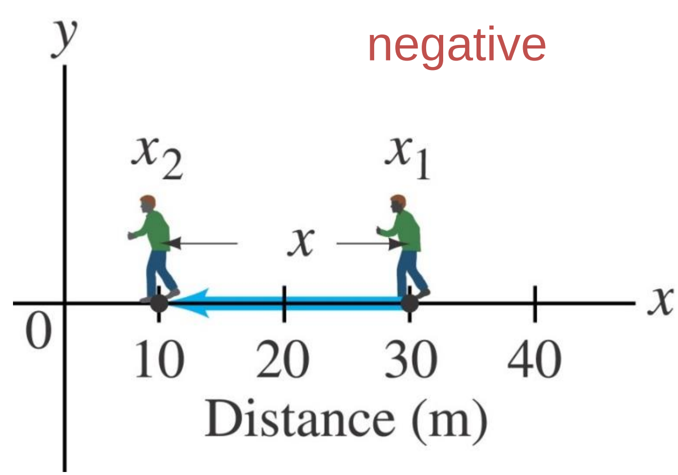


A more detailed record of an airplane passenger heading toward the back of the plane, showing smaller segments of his trip.

positive



negative



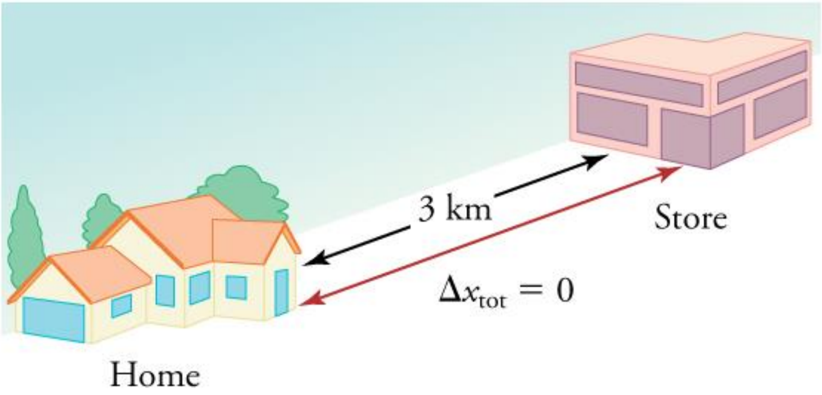
Velocity

Speed: how far an object travels in a given time interval

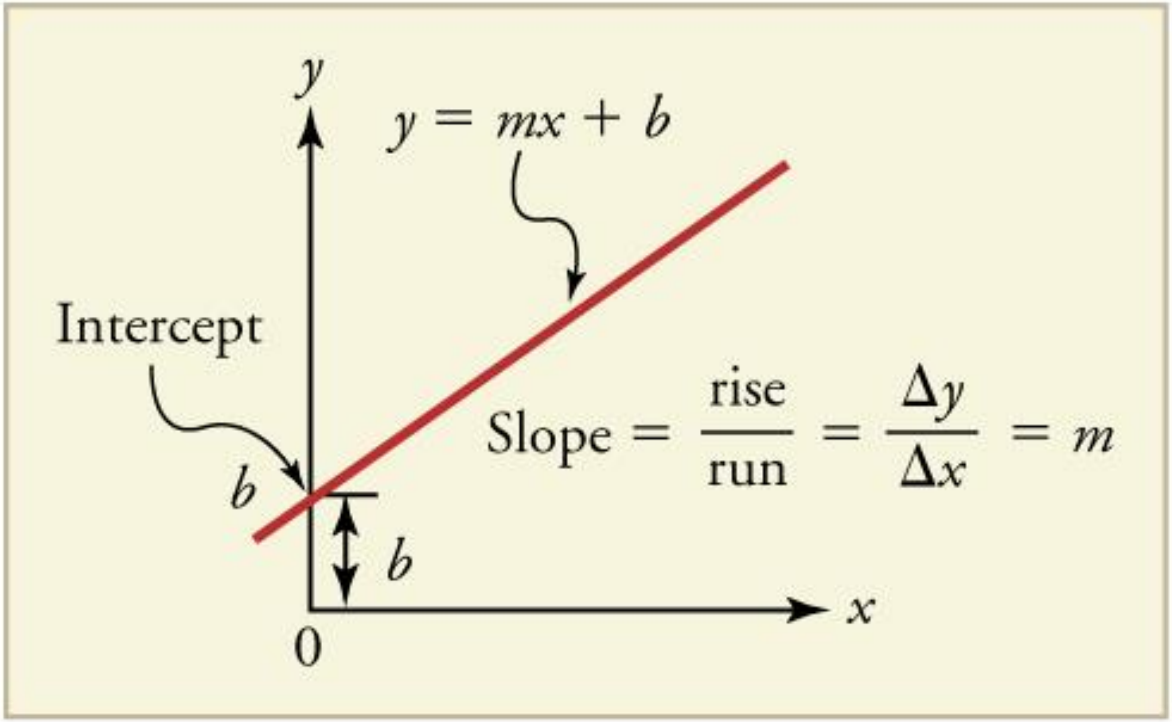
$$\text{average speed} = \frac{\text{distance traveled}}{\text{time elapsed}}$$

Velocity includes directional information:

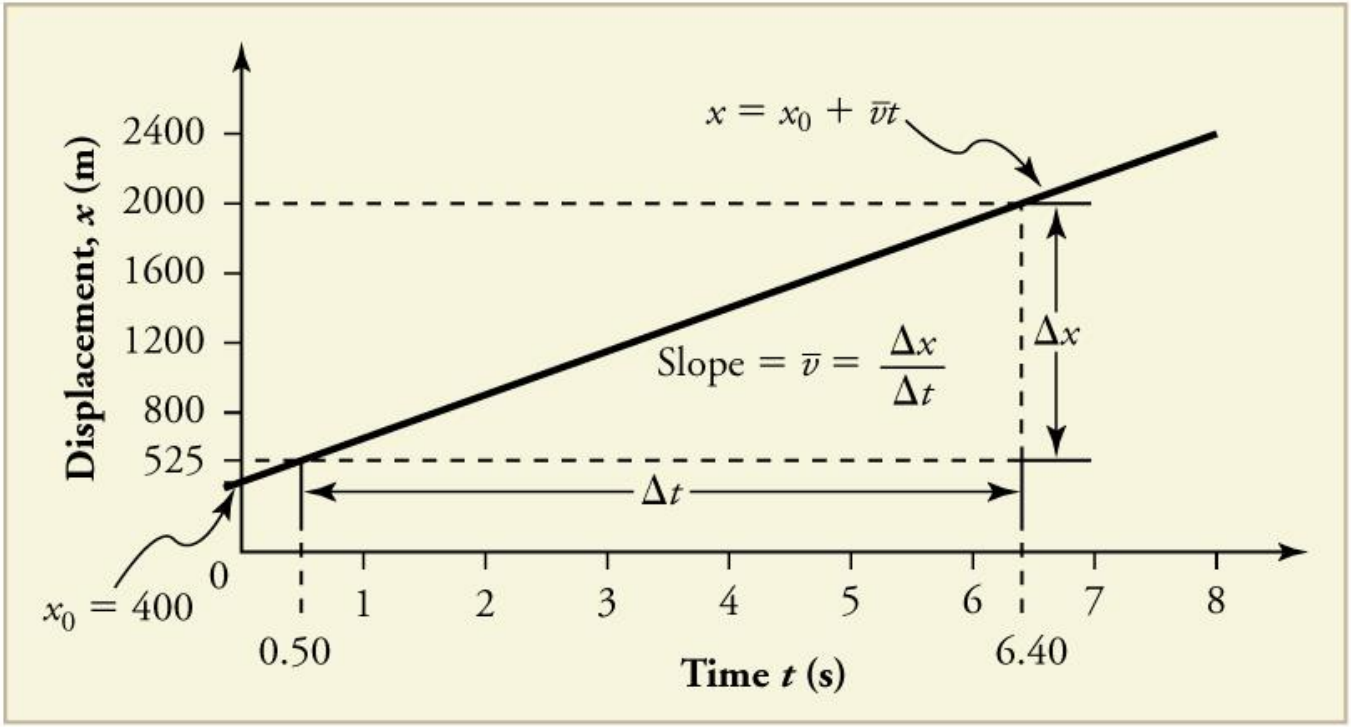
$$\text{average velocity} = \frac{\text{displacement}}{\text{time elapsed}}$$



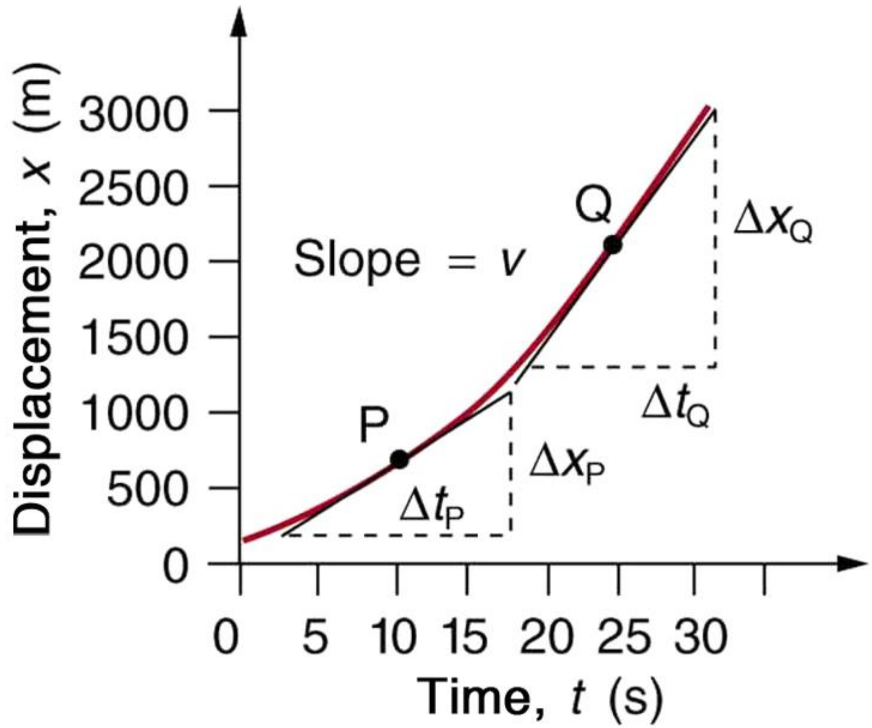
During a 30-minute round trip to the store, the total distance traveled is 6 km. The average speed is 12 km/h. The displacement for the round trip is zero, since there was no net change in position. Thus the average velocity is zero.



A straight-line graph. The equation for a straight line is $y = mx + b$.



Graph of displacement versus time for a jet-powered car on the Bonneville Salt Flats.



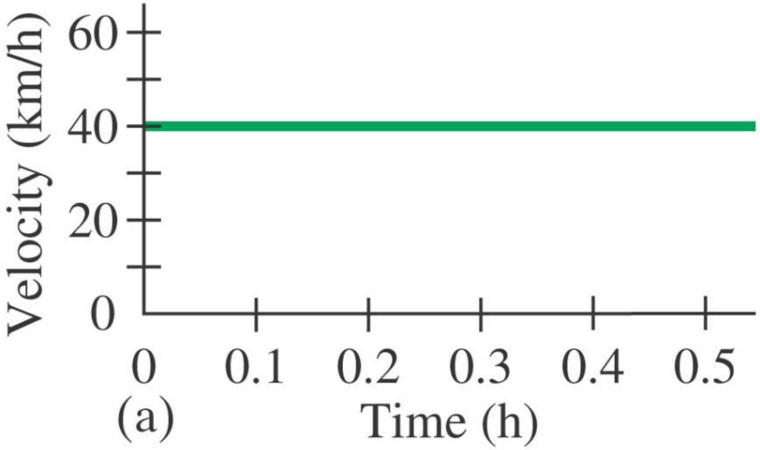
t (s)	x (m)
0	200
5	338
10	600
15	988
20	1500
25	2138
30	2900

The slope of an x vs. t graph is velocity. This is shown at two points. Instantaneous velocity at any point is the slope of the tangent at that point.

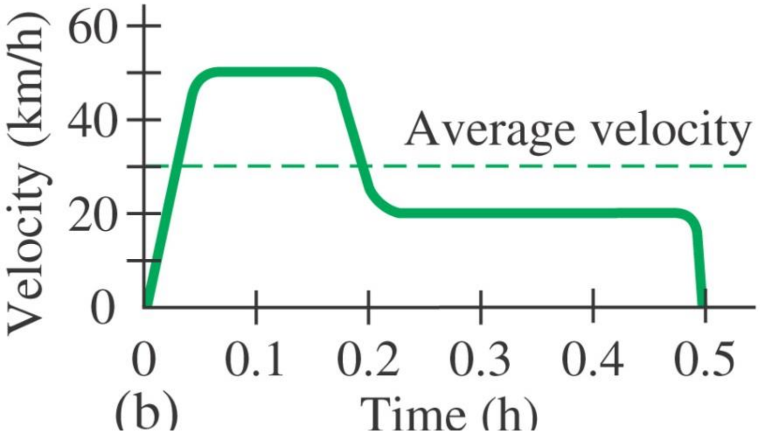
Instantaneous Velocity

The instantaneous velocity is the average velocity, in the limit as the time interval becomes infinitesimally short.

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



(a)



(b)

These graphs show (a) constant velocity and (b) varying velocity.

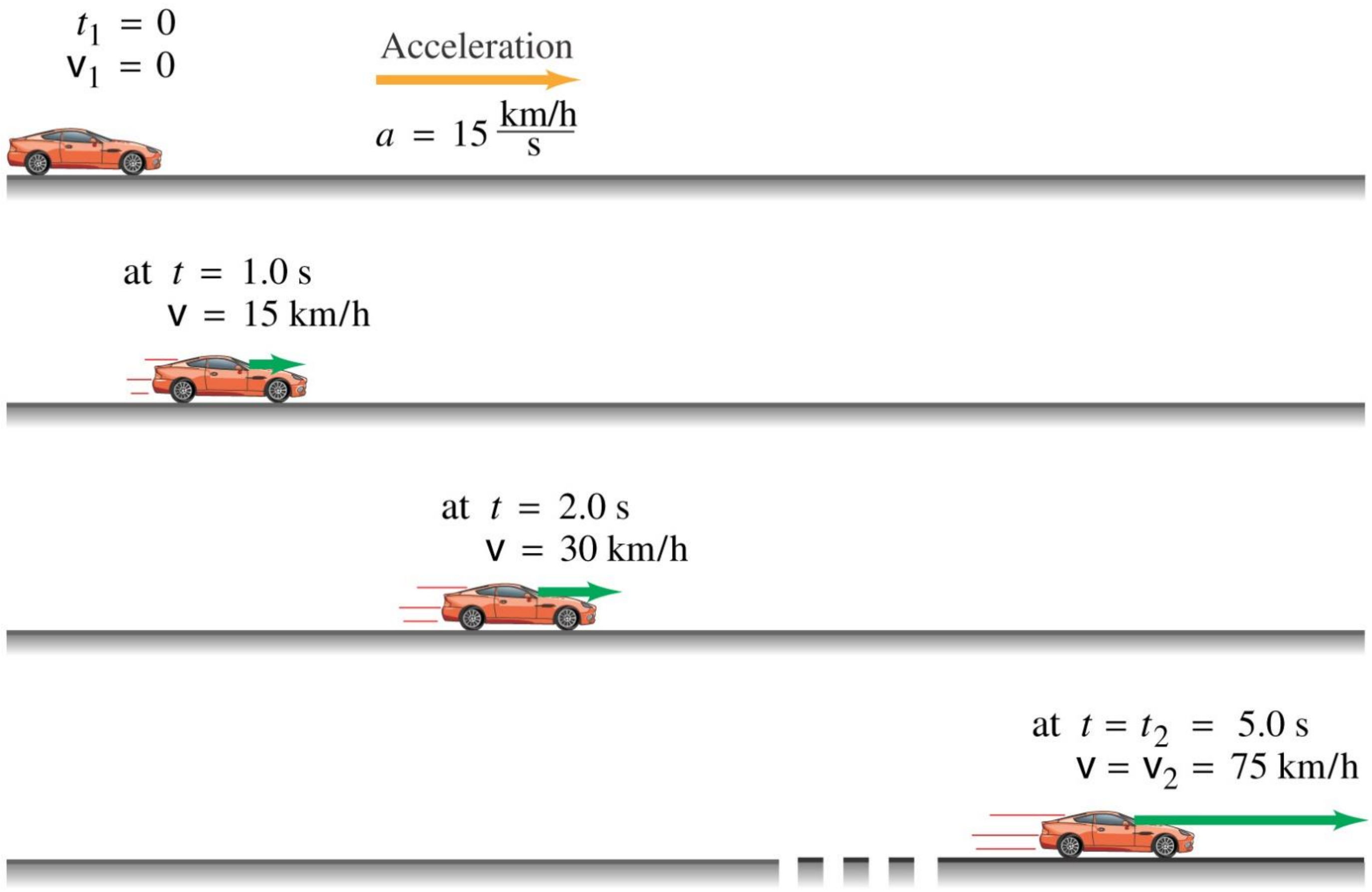
A plane decelerates, or slows down, as it comes in for landing in St. Maarten. Its acceleration is opposite in direction to its velocity.

A subway train in Sao Paulo, Brazil, decelerates as it comes into a station. It is accelerating in a direction opposite to its direction of motion.

Acceleration

Acceleration is the rate of change of velocity.

$$\text{average acceleration} = \frac{\text{change of velocity}}{\text{time elapsed}}$$



Acceleration

There is a difference between negative acceleration and deceleration:

Negative acceleration is acceleration in the negative direction as defined by the coordinate system.

Deceleration occurs when the acceleration is opposite in direction to the velocity.

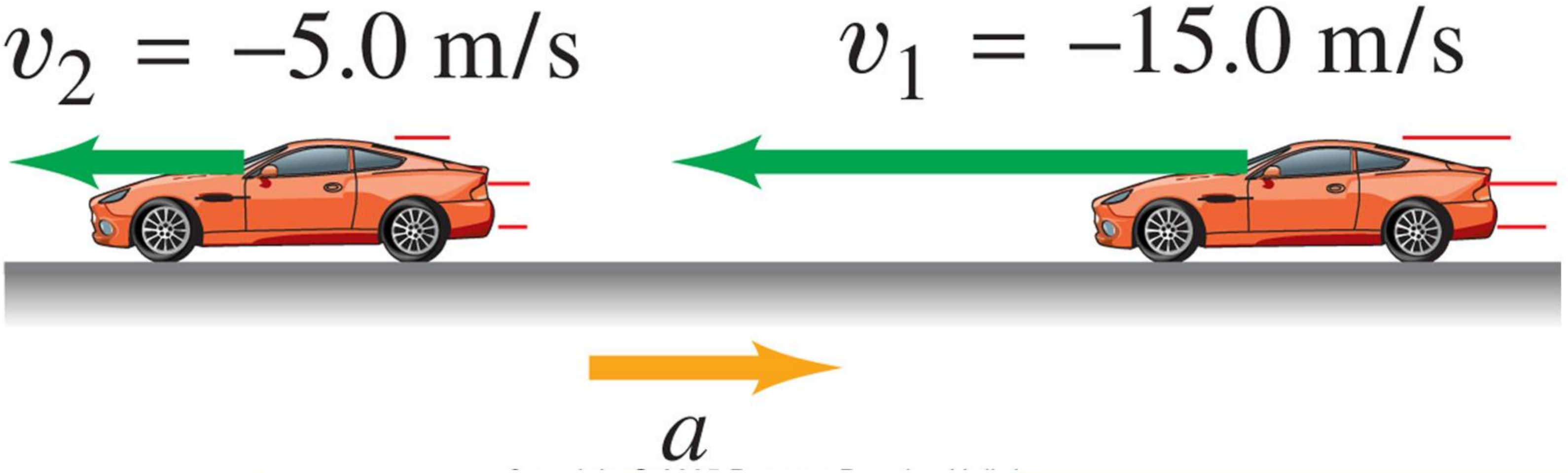


FIGURE 2.29

The airplane lands with an initial velocity of 70.0 m/s and slows to a final velocity of 10.0 m/s before heading for the terminal. Note that the acceleration is negative because its direction is opposite to its velocity, which is positive.

a) This car is speeding up as it moves toward the right. It therefore has positive acceleration in our coordinate system.

b) This car is slowing down as it moves toward the right. Therefore, it has negative acceleration in our coordinate system, because its acceleration is toward the left. The car is also decelerating: the direction of its acceleration is opposite to its direction of motion.

c) This car is moving toward the left, but slowing down over time. Therefore, its acceleration is positive in our coordinate system because it is toward the right. However, the car is decelerating because its acceleration is opposite to its motion.

d) This car is speeding up as it moves toward the left. It has negative acceleration because it is accelerating toward the left. However, because its acceleration is in the same direction as its motion, it is speeding up (not decelerating).

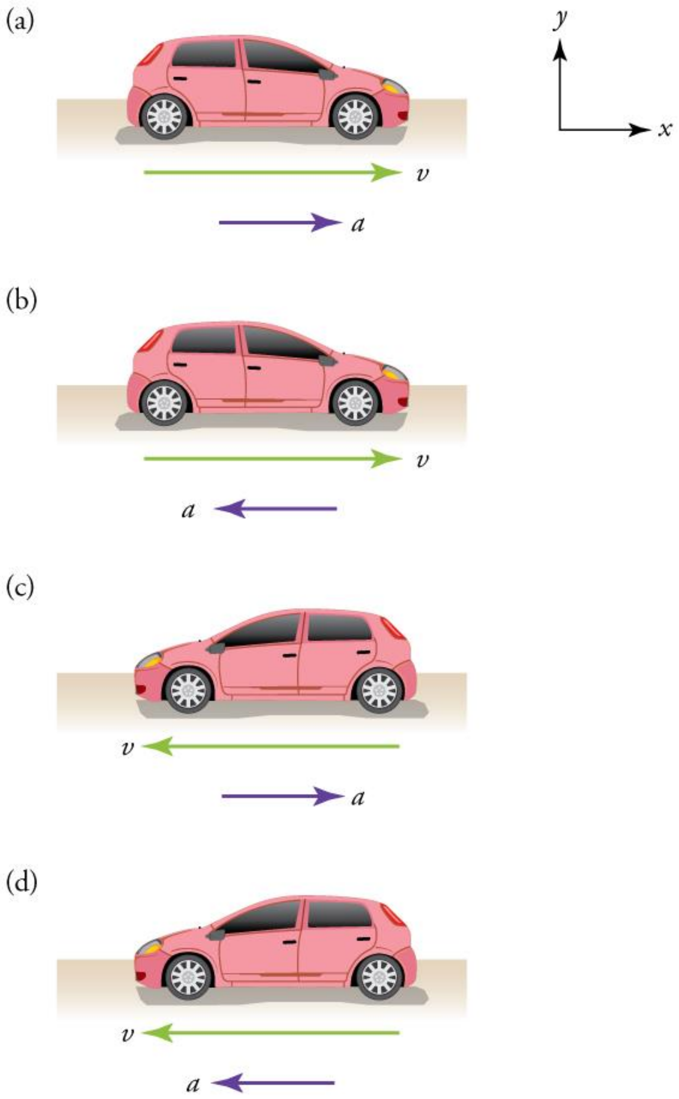
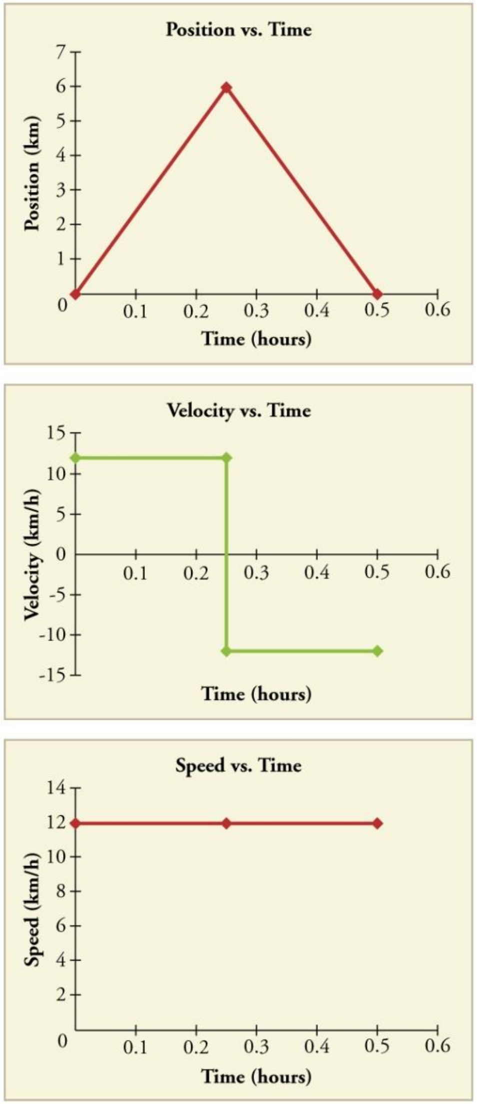
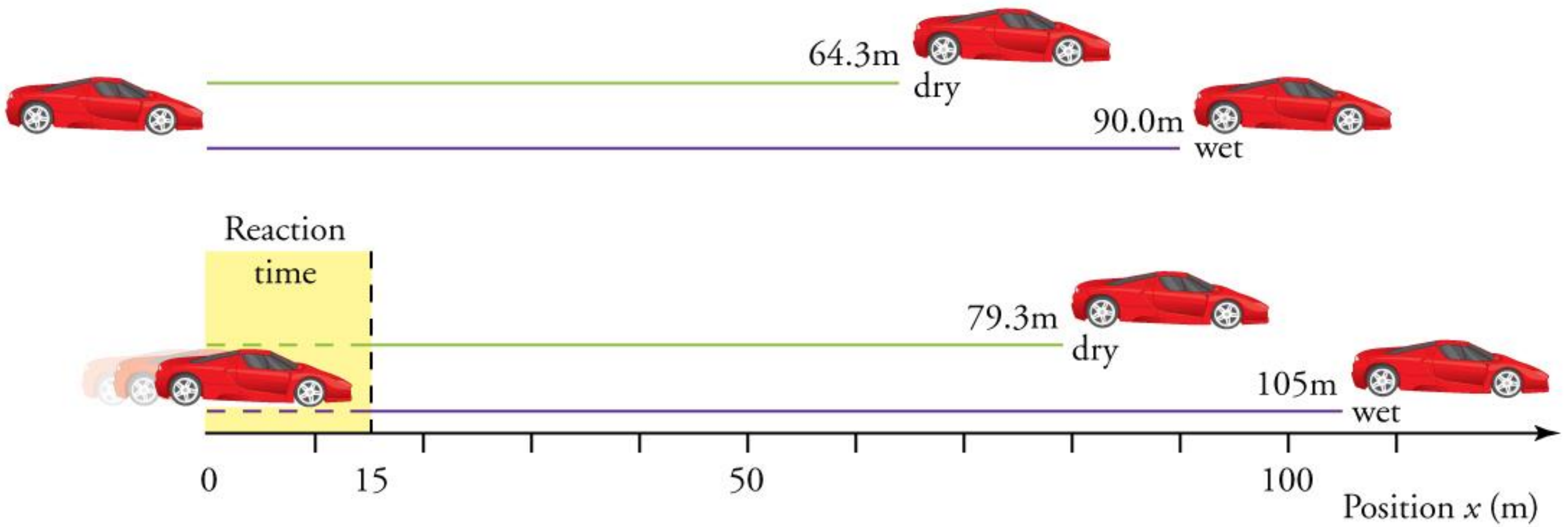


FIGURE 2.11



Position vs. time, velocity vs. time, and speed vs. time on a trip. Note that the velocity for the return trip is negative.



The distance necessary to stop a car varies greatly, depending on road conditions and driver reaction time. Shown here are the braking distances for dry and wet pavement, as calculated in this example, for a car initially traveling at 30.0 m/s. Also shown are the total distances traveled from the point where the driver first sees a light turn red, assuming a 0.500 s reaction time.

FIGURE 2.52

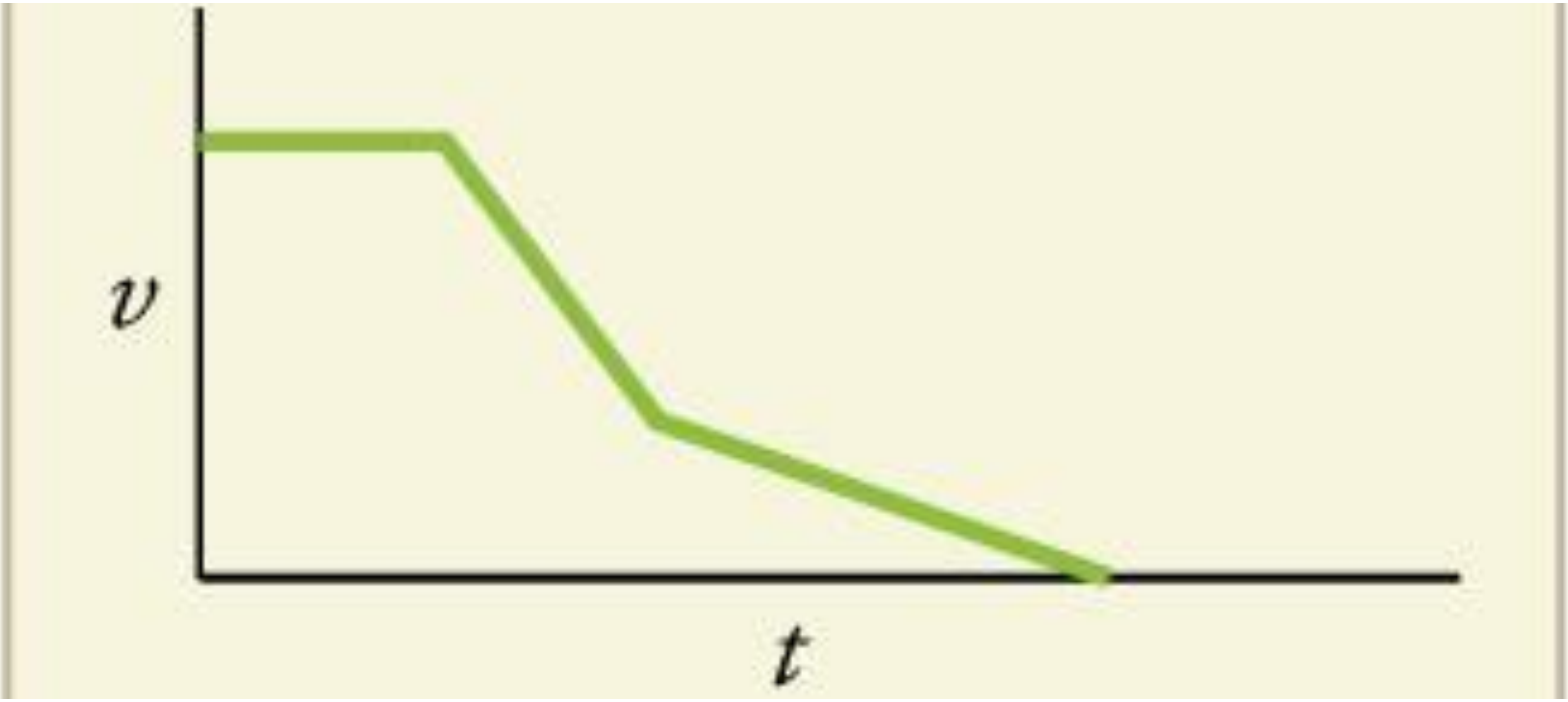
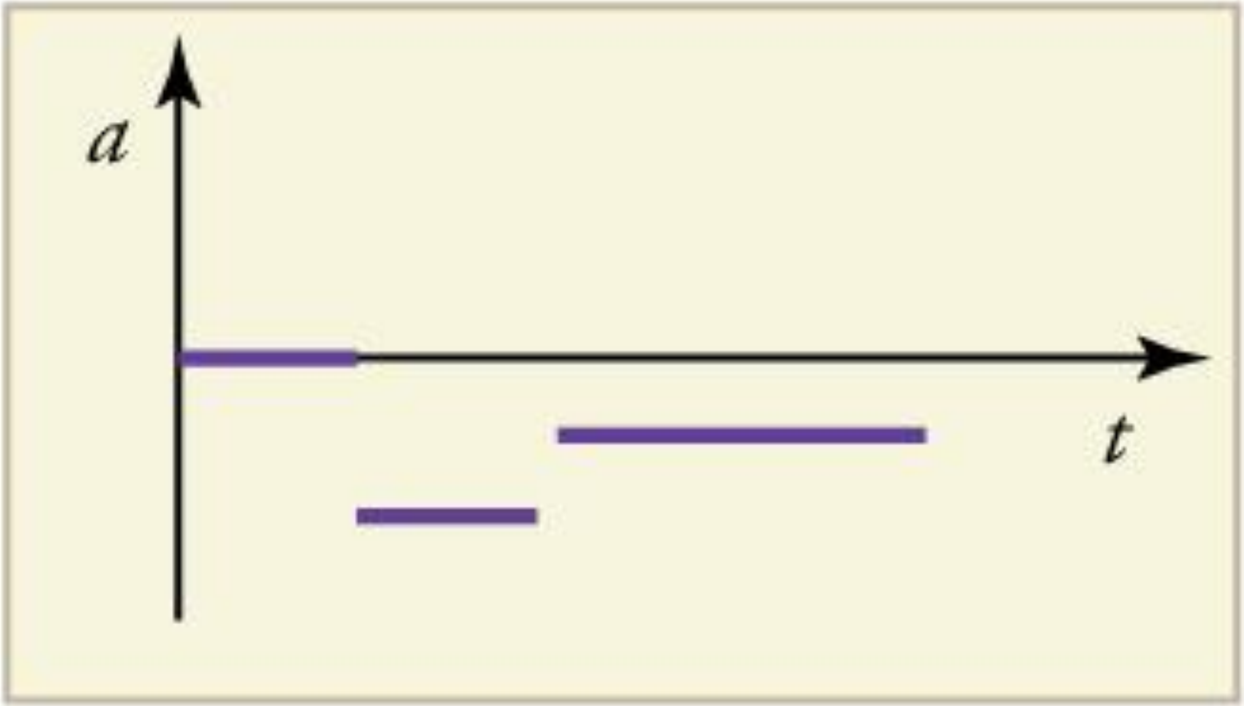


FIGURE 2.53



Acceleration

The instantaneous acceleration is the average acceleration, in the limit as the time interval becomes infinitesimally short.

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

Motion at Constant Acceleration

The average velocity of an object during a time interval *t* is

$$\bar{v} = \frac{x - x_0}{t - t_0} = \frac{x - x_0}{t}$$

The acceleration, assumed constant, is

$$a = \frac{v - v_0}{t}$$

Motion at Constant Acceleration

In addition, as the velocity is increasing at a constant rate, we know that

$$\bar{v} = \frac{v_0 + v}{2}$$

Combining these last three equations, we find:

$$x = x_0 + v_0 t + \tfrac{1}{2} a t^2$$

Motion at Constant Acceleration

We can also combine these equations so as to eliminate *t*:

$$v^2 = v_0^2 + 2a(x - x_0)$$

We now have all the equations we need to solve constant-acceleration problems.

$$v = v_0 + at$$

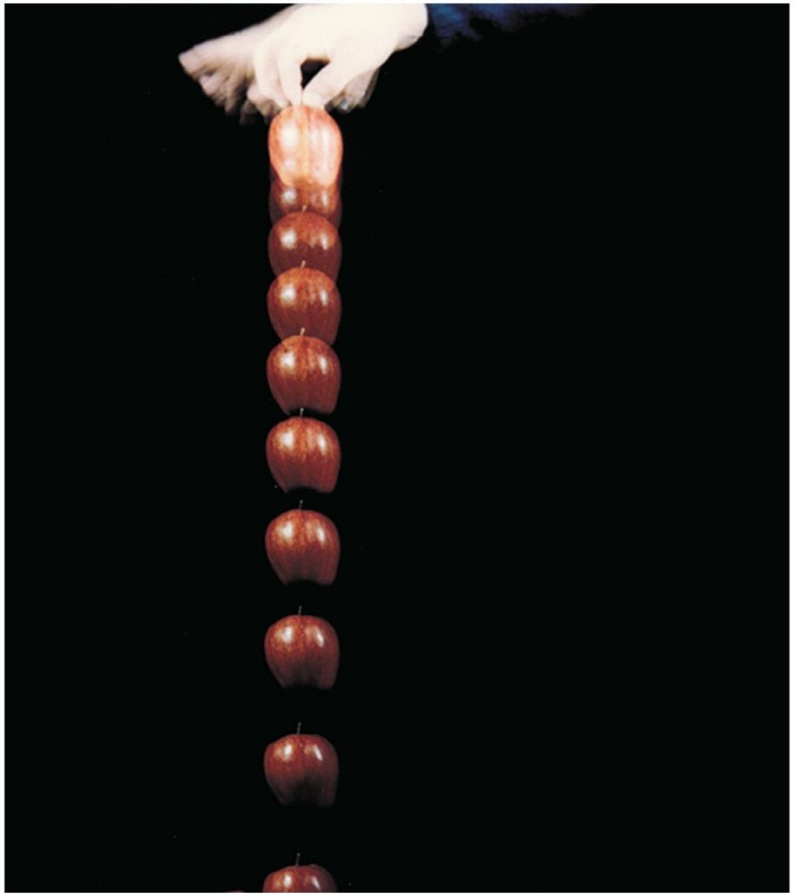
$$x = x_0 + v_0 t + \tfrac{1}{2}at^2$$

$$v^2 = v_0^2 + 2a(x - x_0)$$

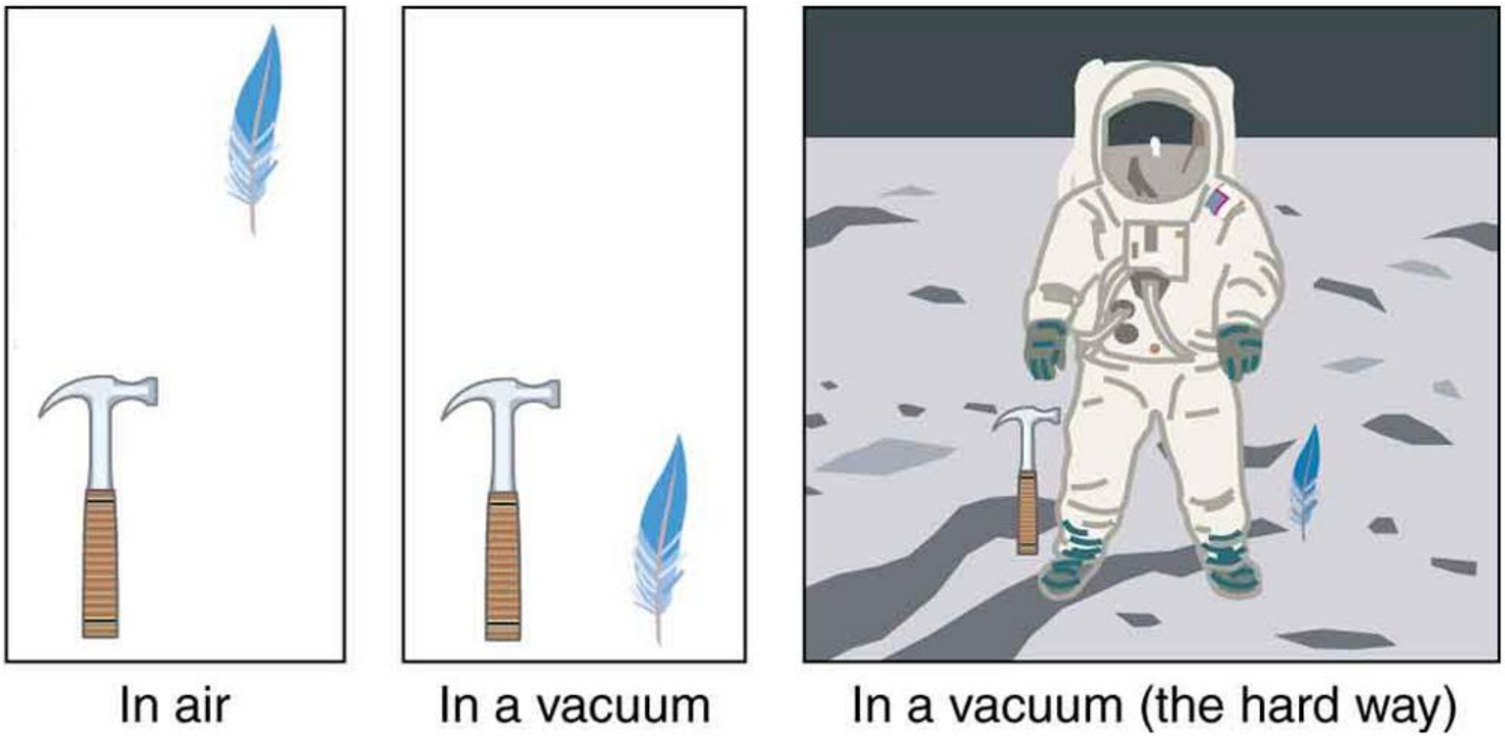
$$\bar{v} = \frac{v + v_0}{2}.$$

Falling Objects

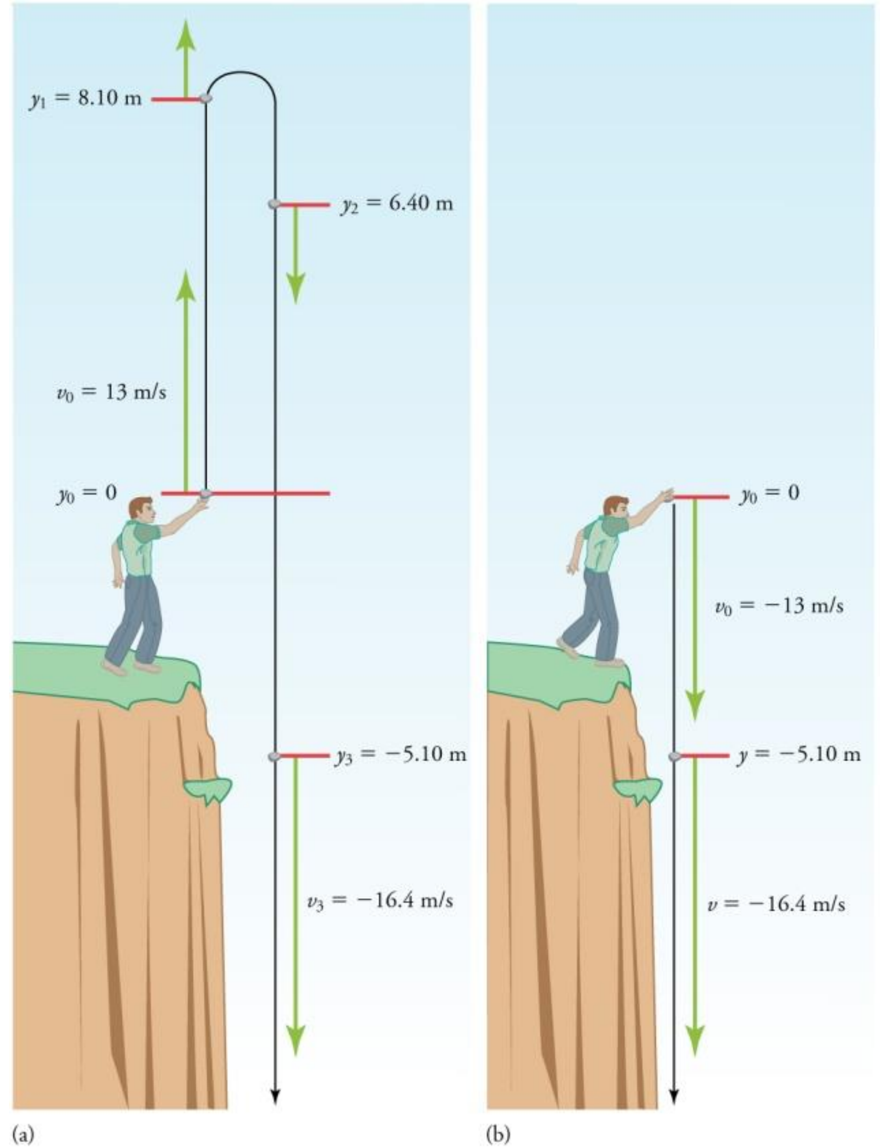
Near the surface of the Earth, all objects experience approximately the same acceleration due to gravity.



This is one of the most common examples of motion with constant acceleration.



A hammer and a feather will fall with the same constant acceleration if air resistance is considered negligible. This is a general characteristic of gravity not unique to Earth, as astronaut David R. Scott demonstrated on the Moon in 1971, where the acceleration due to gravity is only 1.67 m/s2 .

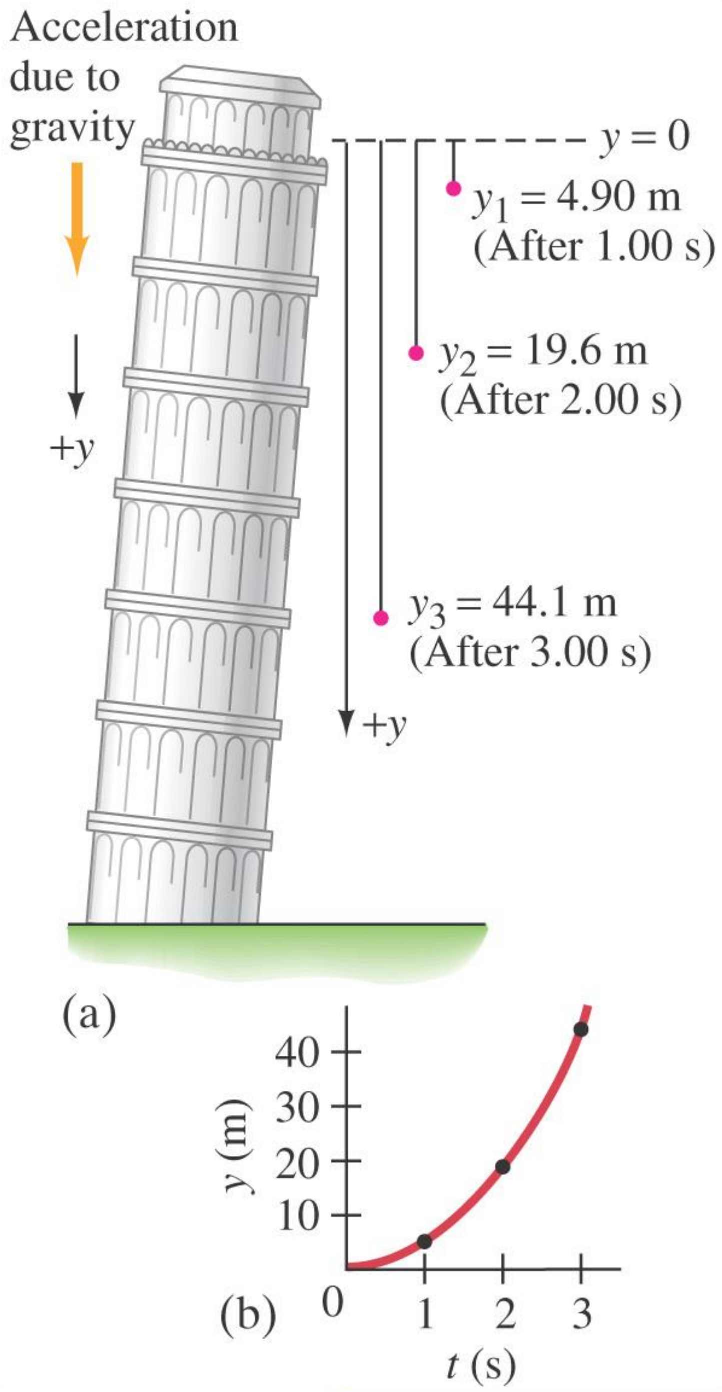


(a) A person throws a rock straight up. The arrows are velocity vectors at 0, 1.00, 2.00, and 3.00 s.

(b) A person throws a rock straight down from a cliff with the same initial speed as before. Note that at the same distance below the point of release, the rock has the same velocity in both cases.

Falling Objects

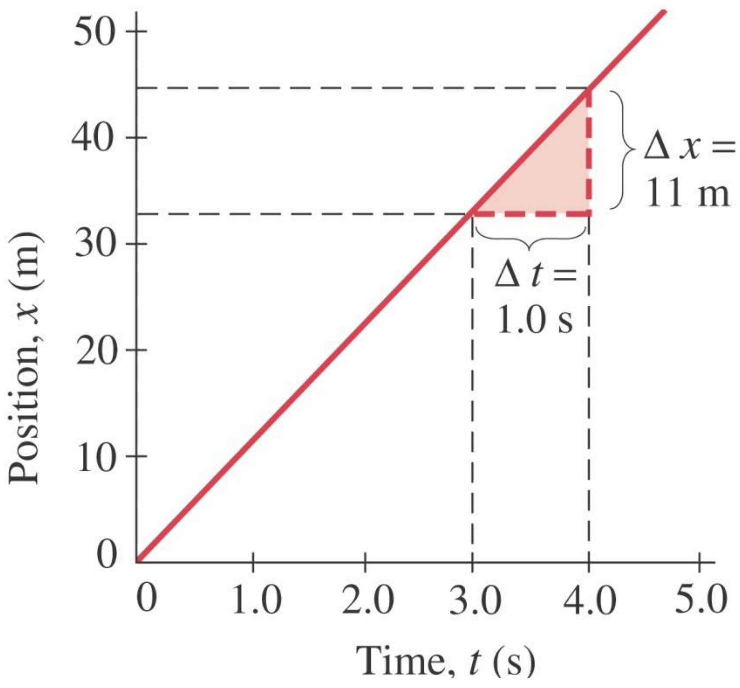
In the absence of air resistance, all objects fall with the same acceleration, although this may be hard to tell by testing in an environment where there is air resistance.



Falling Objects

The acceleration due to gravity at the Earth’s surface is approximately 9.80 m/s^2.

Graphical Analysis of Linear Motion



This is a graph of *x* vs. *t* for an object moving with constant velocity. The velocity is the slope of the *x*-*t* curve.

Summary

- Kinematics is the description of how objects move with respect to a defined reference frame.
- Displacement is the change in position of an object.
- Average speed is the distance traveled divided by the time it took; average velocity is the displacement divided by the time.
- Instantaneous velocity is the limit as the time becomes infinitesimally short.

Summary

- Average acceleration is the change in velocity divided by the time.

- Instantaneous acceleration is the limit as the time interval becomes infinitesimally small.

- The equations of motion for constant acceleration are given in the text; there are four, each one of which requires a different set of quantities.

- Objects falling (or having been projected) near the surface of the Earth experience a gravitational acceleration of $9.80\ m/s^2$.