شرح وتدريبات الوحدة الثانية Motion in a Straight-Line الحركة في بعد واحد

المزيد من الملفات بحسب الصف الحادي عشر المتقدم والمادة فيزياء في الفصل الأول

5	مراجعة المتجهات على شكل أسئلة الامتحان النهائي

2. motion in a Straight line

2.1 introduction to Kinematics

Dynamics

The study of motion and of physical concepts such as force and mass

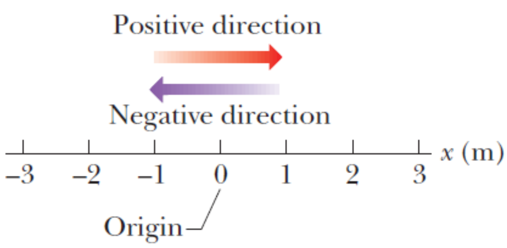
kinematics

The part of dynamics that describes motion without regard to its causes.

Assumptions for dealing with different objects

1. we will neglect all internal structure of a moving object and consider it to be a point particle, or point like object.
2. the point location of an object is called the center of mass
3. to determine the equations of motion for an object, we imagine it to be located at a single point in space at each instant of time

2.2-Position vector, Displacement vector, and Distance



position vector $\vec{r}$

1D $\vec{r}$ = 5 m 2D $\vec{r}$ = (2,6) m 3D $\vec{r}$ = (4,6,8) m

Displacement $\Delta\vec{r}$

is the difference between the final position vector, $\vec{r}_2$ at the end of a motion and the initial position vector $\vec{r}_1$

$$\Delta\vec{r} = \vec{r}_2 - \vec{r}_1$$

Checkpoint 1

Here are three pairs of initial and final positions, respectively, along an x axis. Which pairs give a negative displacement: (a) –3 m, +5 m; (b) –3 m, –7 m; (c) 7 m, –3 m?

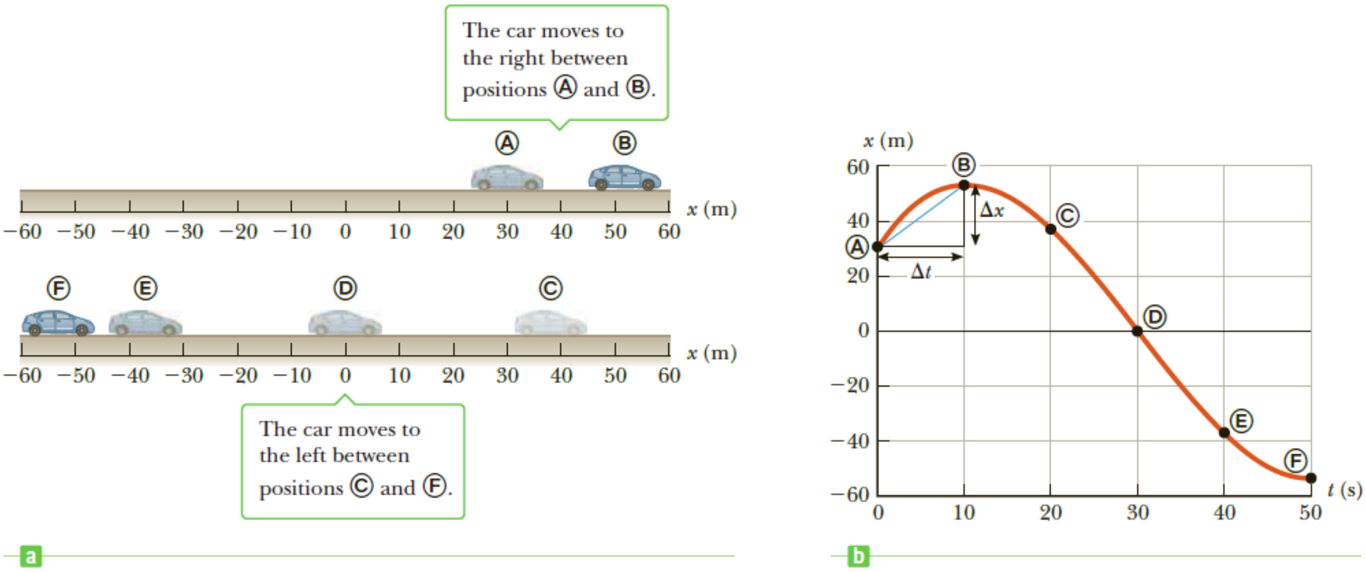


Figure 2.2 (a) A car moves back and forth along a straight line taken to be the x-axis. Because we are interested only in the car's translational motion, we can model it as a particle. (b) Graph of position vs. time for the motion of the "particle."

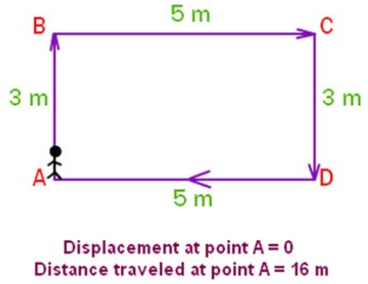
Distance ℓ

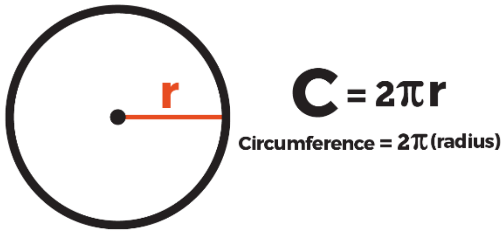
distance, ℓ, that a moving object travels is the absolute value of the displacement vector

$$\ell = \left|\Delta\vec{r}\right|$$

Your dorm room is located 0.25 mile from the Dairy Store. You walk from your room to the Dairy Store and back. Which of the following statements about your trip is true?

A. The distance is 0.50 mile, and the displacement is 0.50 mile.
B. The distance is 0.50 mile, and the displacement is 0.00 mile.
C. The distance is 0.00 mile, and the displacement is 0.50 mile.
D. The distance is 0.00 mile, and the displacement is 0.00 mile.





Solved problem 2.1

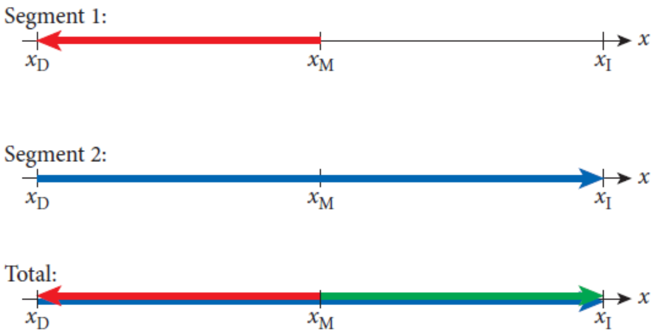
The distance between Des Moines and Iowa City is 170.5 km along Interstate 80, and as you can see from the map, the route is a straight line to a good approximation.

Approximately halfway between the two cities, where I80 crosses highway US63, is the city of Malcom, 89.9 km (55.9 miles) from Des Moines

Problem

If we drive from Malcom to Des Moines and then go to Iowa City, what are the **total distance** and **total displacement** for this trip?

Solution



$$\Delta x_1 = x_D - x_M \qquad \ell_1 = |\Delta x_1| = |x_D - x_M|$$

$$\Delta x_2 = x_I - x_D \qquad \ell_2 = |\Delta x_2| = |x_I - x_D|$$

$$\Delta x_{total} = \Delta x_1 + \Delta x_2 \qquad \ell_{total} = \ell_1 + \ell_2$$

$$\begin{aligned}\Delta x_{total} &= \Delta x_1 + \Delta x_2 \\ &= (x_D - x_M) + (x_I - x_D) \\ &= x_I - x_M. \\ &= (+170.5\text{ km}) - (+89.9\text{ km}) = +80.6\text{ km}.\end{aligned}$$

$$\ell_{total} = \ell_1 + \ell_2$$

$$\ell_{total} = |89.9\text{ km}| + |170.5\text{ km}| = 260.4\text{ km}$$

2.3 Velocity Vector, Average Velocity, and Speed

average velocity

$$\bar{v}_x = \frac{\Delta x}{\Delta t}$$

Notation: A bar above a symbol is the notation for averaging over a finite time interval.

instantaneous velocity

$$v_x = \lim_{\Delta t \to 0} \bar{v}_x = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} \equiv \frac{dx}{dt}$$

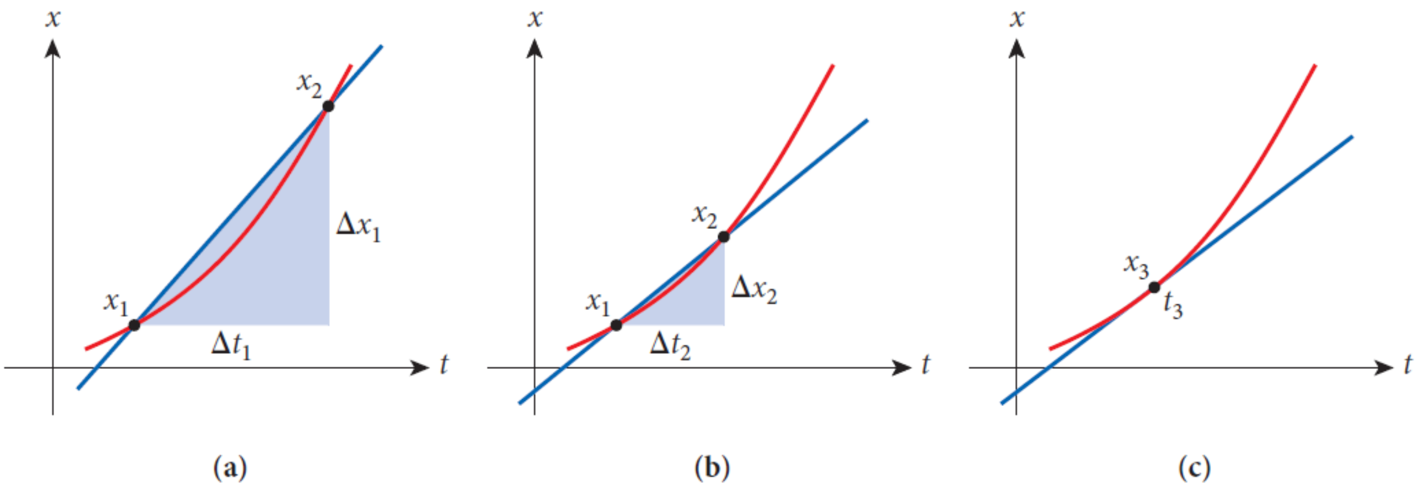


FIGURE 2.6 Instantaneous velocity as the limit of the ratio of displacement to time interval: (a) an average velocity over a large time interval; (b) an average velocity over a smaller time interval; and (c) the instantaneous velocity at a specific time, t_3.

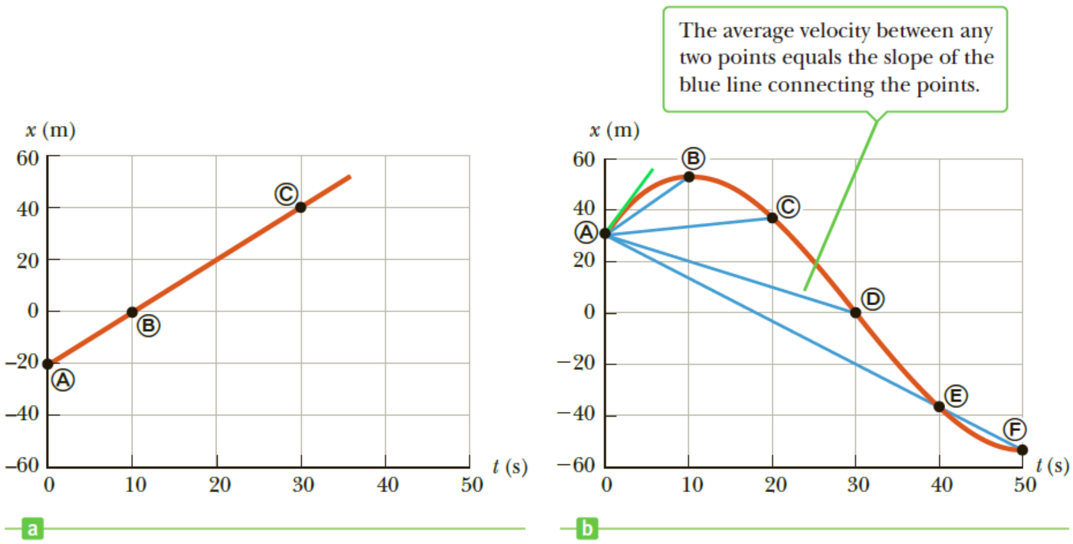


Figure 2.5 (a) Position vs. time graph for the motion of a car moving along the *x*-axis at constant velocity. (b) Position vs. time graph for the motion of a car with changing velocity, using the data in Table 2.1.

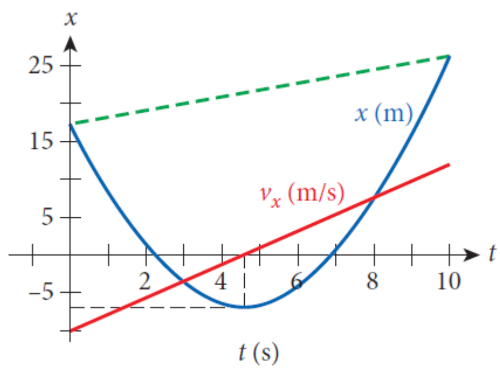
EXAMPLE 2.1 Time Dependence of Velocity

PROBLEM

During the time interval from 0.0 to 10.0 s, the position vector of a car on a road is given by $x(t) = a + bt + ct^2$, with $a = 17.2$ m, $b = -10.1$ m/s, and $c = 1.10$ m/s^2. What is the car's velocity as a function of time? What is the car's average velocity during this interval?

SOLUTION

$$v_x = \frac{dx}{dt} = \frac{d}{dt}(a + bt + ct^2) = b + 2ct = -10.1 \text{ m/s} + 2\cdot(1.10 \text{ m/s}^2)t$$



At $t = 4.59$ s, the position graph $x(t)$ shows an extremum (a minimum in this case)

$$\frac{dx}{dt} = b + 2ct_0 = 0 \Rightarrow t_0 = -\frac{b}{2c} = -\frac{-10.1 \text{ m/s}}{2.20 \text{ m/s}^2} = 4.59 \text{ s.}$$

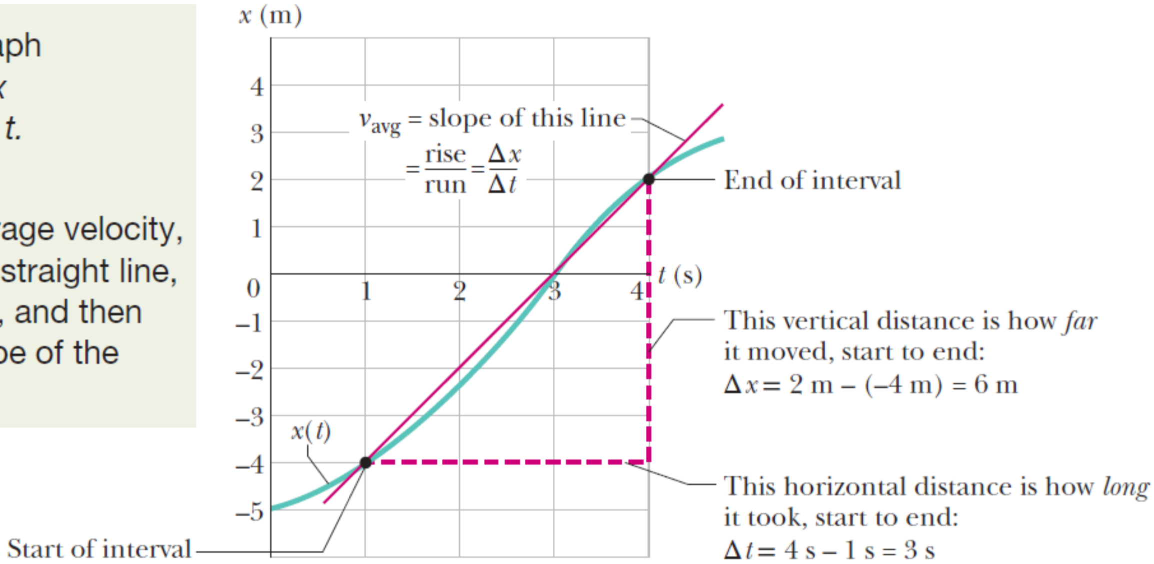
$$\Delta x = x(t=10) - x(t=0) = 26.2 \text{ m} - 17.2 \text{ m} = 9.0 \text{ m}$$

$$\bar{v}_x = \frac{\Delta x}{\Delta t} = \frac{9.0 \text{ m}}{10 \text{ s}} = 0.90 \text{ m/s}$$

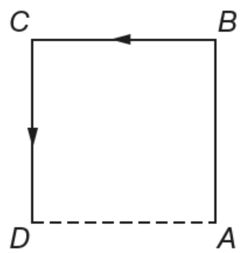
- The slope of the **green dashed line** is the average velocity over this time interval

This is a graph of position x versus time t.

To find average velocity, first draw a straight line, start to end, and then find the slope of the line.



1. A particle moves along the sides AB, BC, CD of a square of side 25 m with a velocity of 15 m/s. Its average velocity is



(A) 15 m/s (B) 10 m/s
(C) 7.5 m/s (D) 5 m/s

A particle moves according to the equation $x = 2t^2 - 5t + 6$, find average velocity in the first 3 s and instantaneous velocity at $t = 3$ s.

(A) 1 m/s, 7 m/s (B) 4 m/s, 3 m/s
(C) 2 m/s, 5 m/s (D) 3 m/s, 7 m/s

Speed

Speed is the absolute value of the velocity vector.

The **average speed** of an object over a given time interval is the length of the path it travels divided by the total elapsed time:

$$\text{Average speed} \equiv \frac{\text{path length}}{\text{elapsed time}}$$

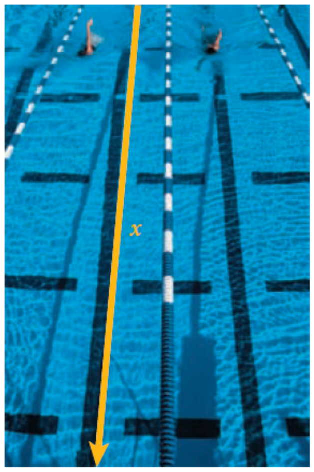
Tip 2.3 Path Length vs. Distance

Distance is the length of a straight line joining two points. *Path length* is the length of an actual path traversed between two points, including any retracing of steps or deviations from a straight line.

$$\text{average speed} \equiv \bar{v} = \frac{\ell}{\Delta t}$$

EXAMPLE 2.2 Speed and Velocity

Suppose a swimmer completes the first 50 m of the 100-m freestyle in 38.2 s. Once she reaches the far side of the 50-m-long pool, she turns around and swims back to the start in 42.5 s.



PROBLEM

What are the swimmer's average velocity and average speed for (a) the leg from the start to the far side of the pool, (b) the return leg, and (c) the total lap?

SOLUTION

(a) *First leg of the swim:*

$$\bar{v}_{x1} = \frac{x_2 - x_1}{\Delta t} = \frac{50\text{ m} - 0\text{ m}}{38.2\text{ s}} = \frac{50}{38.2}\text{ m/s} = 1.31\text{ m/s}$$

(b) *Second leg of the swim:*

$$\bar{v}_{x2} = \frac{x_2 - x_1}{\Delta t} = \frac{0\text{ m} - 50\text{ m}}{42.5\text{ s}} = \frac{-50}{42.5}\text{ m/s} = -1.18\text{ m/s}$$

(c) *The entire lap:*

$$\bar{v}_x = \frac{\bar{v}_{x1}\cdot\Delta t_1 + \bar{v}_{x2}\cdot\Delta t_2}{\Delta t_1 + \Delta t_2} = \frac{(1.31\text{ m/s})(38.2\text{ s}) + (-1.18\text{ m/s})(42.5\text{ s})}{(38.2\text{ s}) + (42.5\text{ s})} = 0$$

average speed

$$\bar{v} = \frac{\ell}{\Delta t} = \frac{100\text{ m}}{80.7\text{ s}} = 1.24\text{ m/s}$$

The speedometer in your car shows

a) average speed.

b) instantaneous speed.

c) average displacement.

d) instantaneous displacement.

2.4 Acceleration Vector

average acceleration is defined as the velocity change per time interval:

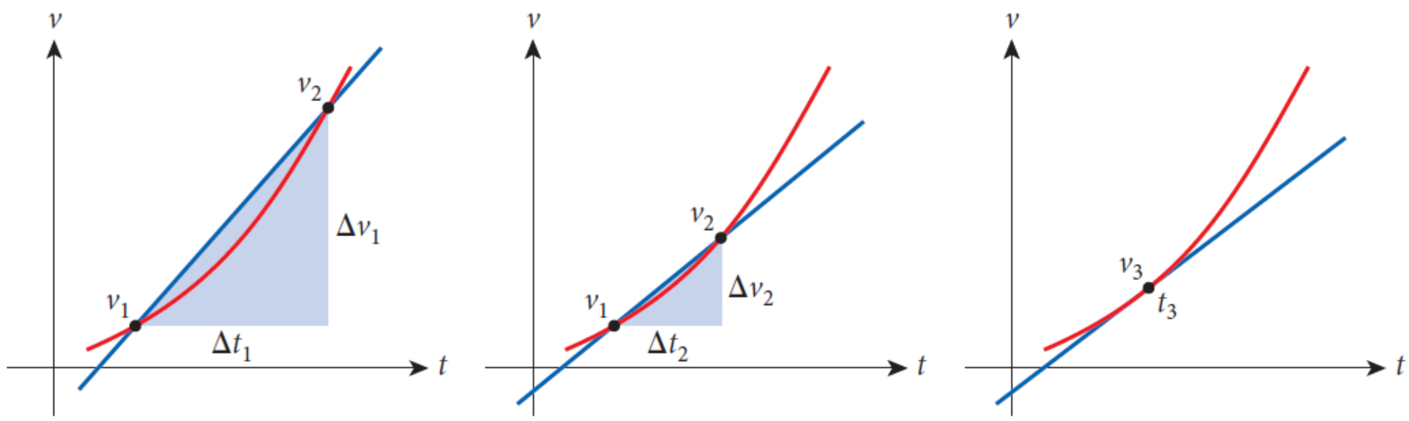
$$\bar{a}_x = \frac{\Delta v_x}{\Delta t}$$

the **instantaneous acceleration** is defined as the limit of the average acceleration as the time interval approaches 0.

$$a_x = \lim_{\Delta t \to 0} \bar{a}_x = \lim_{\Delta t \to 0} \frac{\Delta v_x}{\Delta t} \equiv \frac{dv_x}{dt}$$

The acceleration is the time derivative of the velocity, and the velocity is the time derivative of the displacement. The acceleration is therefore the second derivative of the displacement.

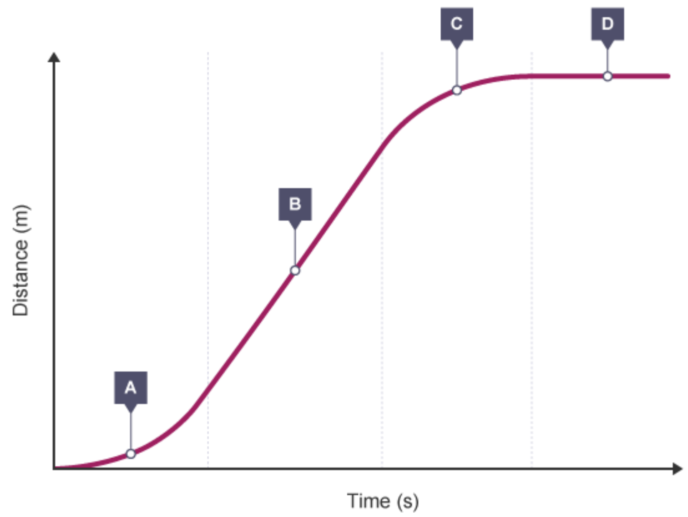
$$a_x = \frac{d}{dt} v_x = \frac{d}{dt}\left(\frac{d}{dt} x\right) = \frac{d^2}{dt^2} x$$



4. If the velocity of a particle is $(10 + 2t^2)$ m/s, then the average acceleration of the particle between 2 s and 5 s is

(A) 2 m/s^2 (B) 4 m/s^2
(C) 12 m/s^2 (D) 14 m/s^2

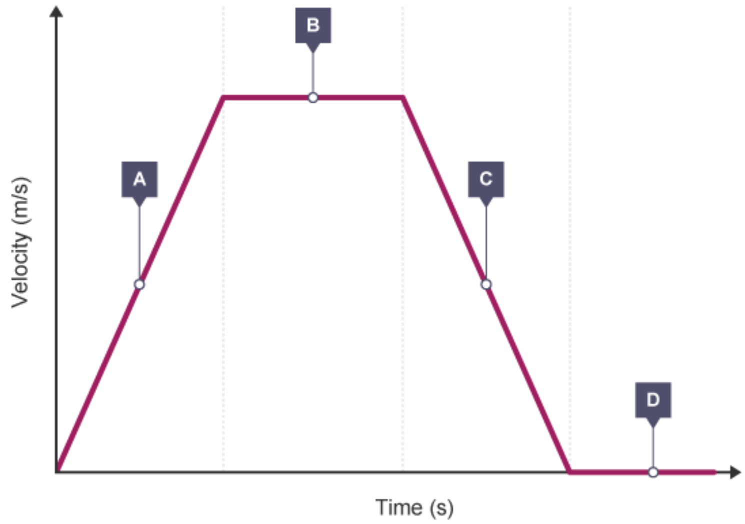
If the speed of an object changes, it will be accelerating or decelerating. This can be shown as a curved line on a distance-time graph.



A graph to show distance travelled by time. A shows acceleration, B shows constant speed, C shows deceleration and D shows stationary position

The table shows what each section of the graph represents:

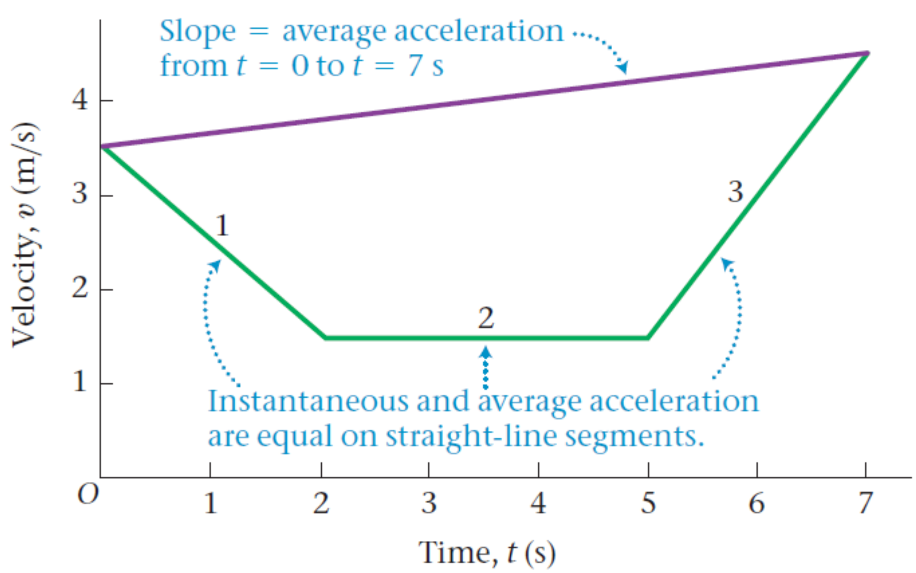
Section of graph	Gradient	Speed
A	Increasing	Increasing
B	Constant	Constant
C	Decreasing	Decreasing
D	Zero	Stationary (at rest)

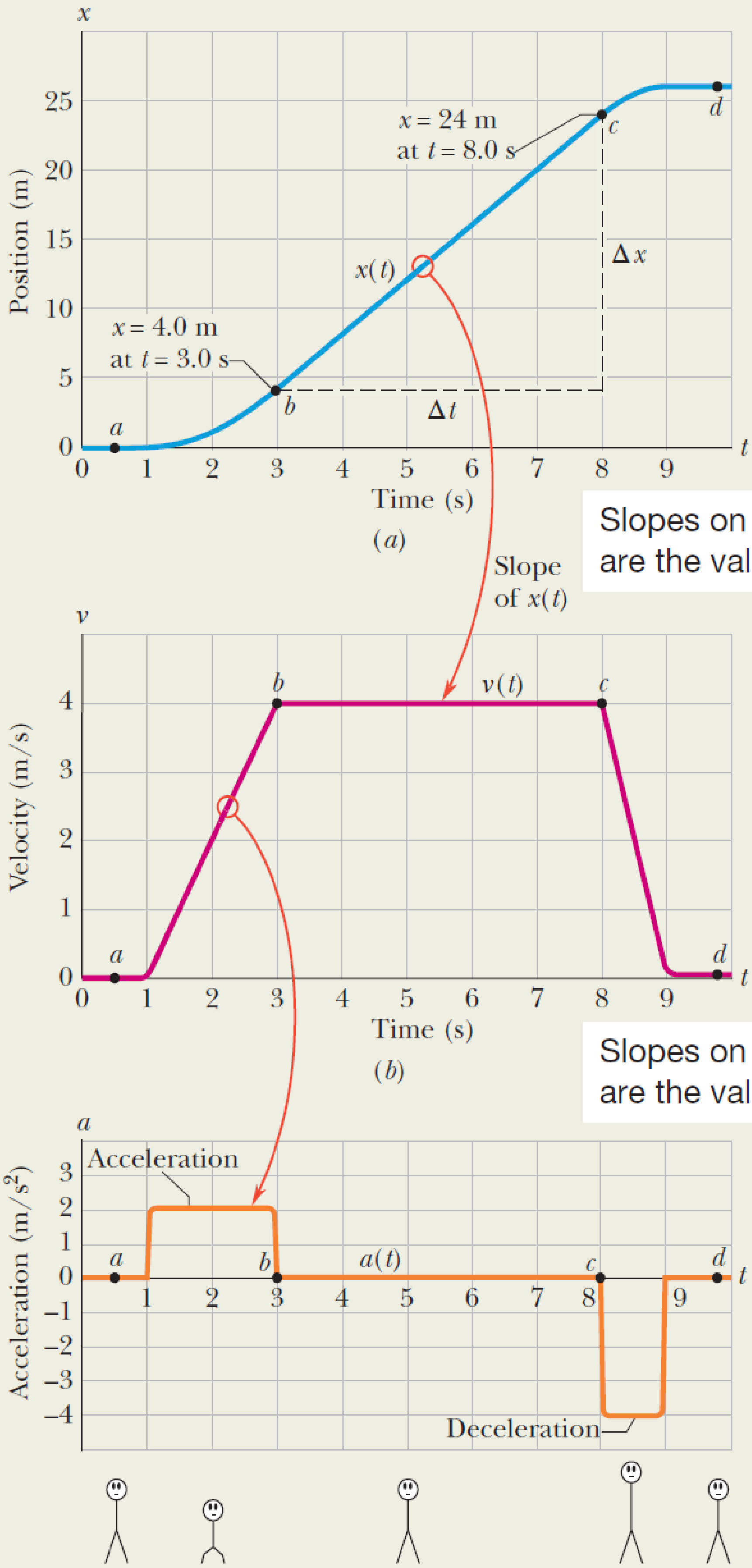


The table shows what each section of the red line on the graph represents:

Section of graph	Gradient	Velocity	Acceleration
A	positive	increasing	positive
B	zero	constant	zero
C	negative	decreasing	negative
D (v = 0)	zero	stationary (at rest)	zero

Tips



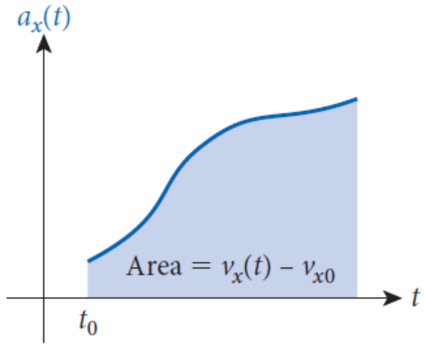


Slopes on the *x* versus *t* graph are the values on the *v* versus *t* graph.

Slopes on the *v* versus *t* graph are the values on the *a* versus *t* graph.

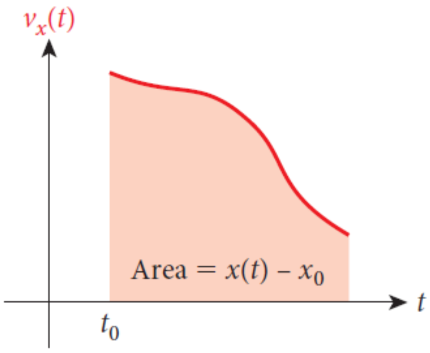
What you would feel.

2.6 Finding Displacement and Velocity from Acceleration



$$v_x(t) = v_{x0} + \int_0^t a_x\, dt' = v_{x0} + a_x \int_0^t dt' \Rightarrow$$

$$v_x(t) = v_{x0} + a_x t,$$



$$x = x_0 + \int_0^t v_x(t')dt' = x_0 + \int_0^t (v_{x0} + a_x t')dt'$$

$$= x_0 + v_{x0}\int_0^t dt' + a_x \int_0^t t'dt' \Rightarrow$$

$$x(t) = x_0 + v_{x0}t + \tfrac{1}{2}a_x t^2.$$

Equations of motion with uniform acceleration

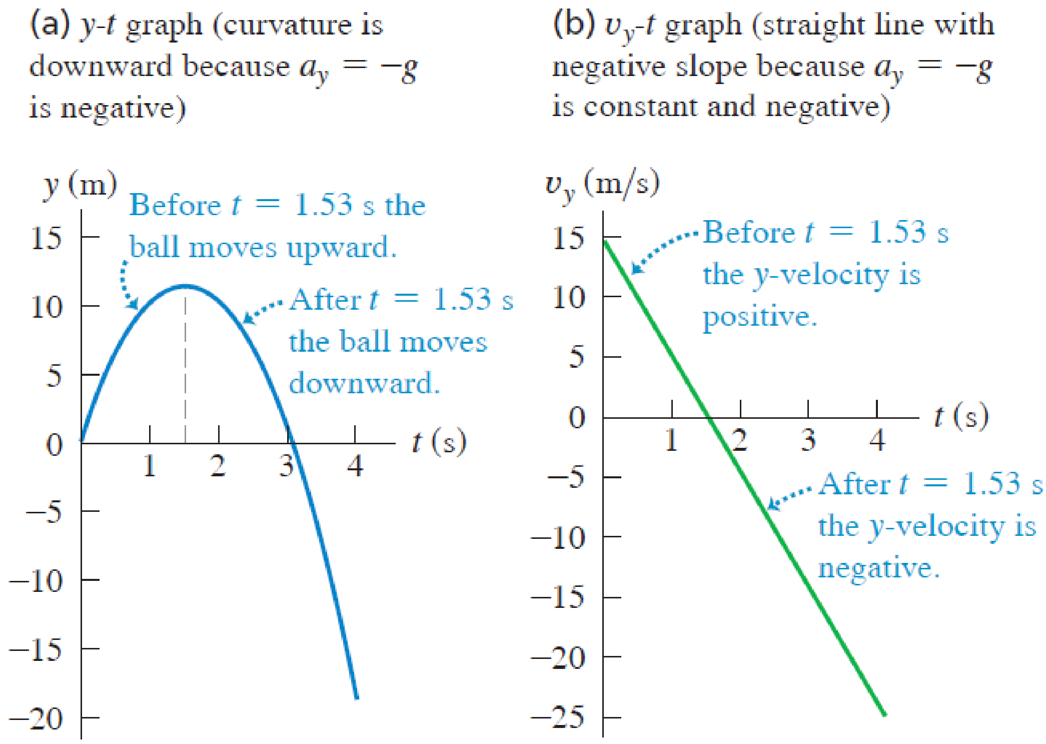
(i)	$x = x_0 + v_{x0}t + \frac{1}{2}a_x t^2$
(ii)	$x = x_0 + \overline{v}_x t$
(iii)	$v_x = v_{x0} + a_x t$
(iv)	$\overline{v}_x = \frac{1}{2}(v_x + v_{x0})$
(v)	$v_x^2 = v_{x0}^2 + 2a_x(x - x_0)$

2.8 Free Fall

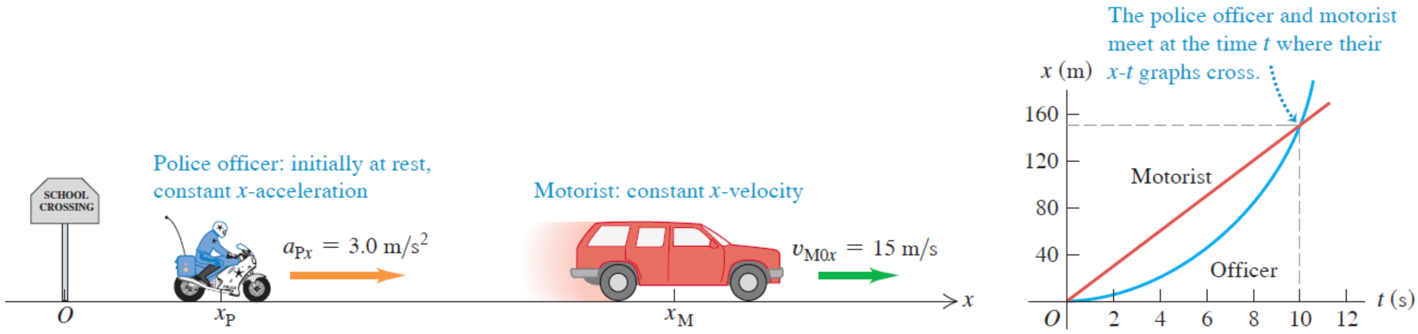
constant acceleration due to gravity a_y = - g

(i)	$y = y_0 + v_{y0}t - \frac{1}{2}gt^2$
(ii)	$y = y_0 + \overline{v}_y t$
(iii)	$v_y = v_{y0} - gt$
(iv)	$\overline{v}_y = \frac{1}{2}(v_y + v_{y0})$
(v)	$v_y^2 = v_{y0}^2 - 2g(y - y_0)$

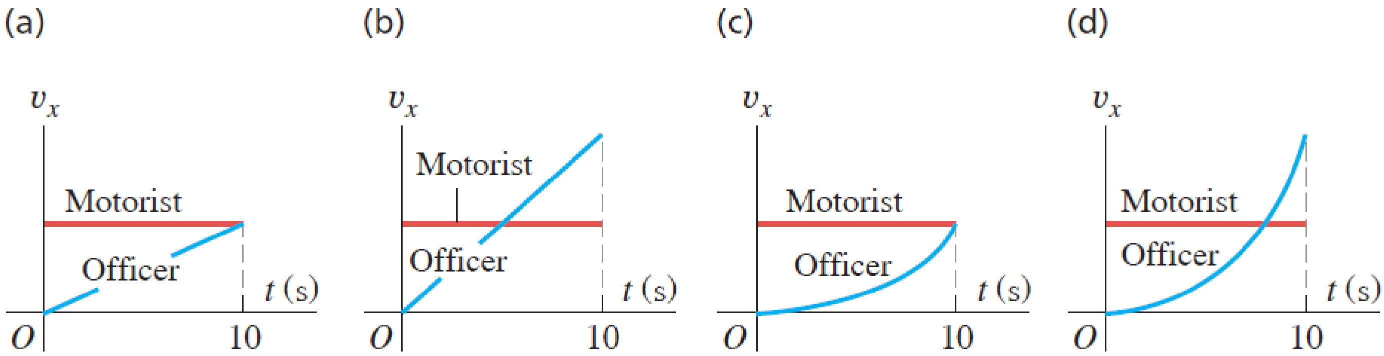
(a) Position and (b) velocity as functions of time for a ball thrown upward with an initial speed of 15.0 m/s.



Motion with constant acceleration overtaking motion with constant velocity.

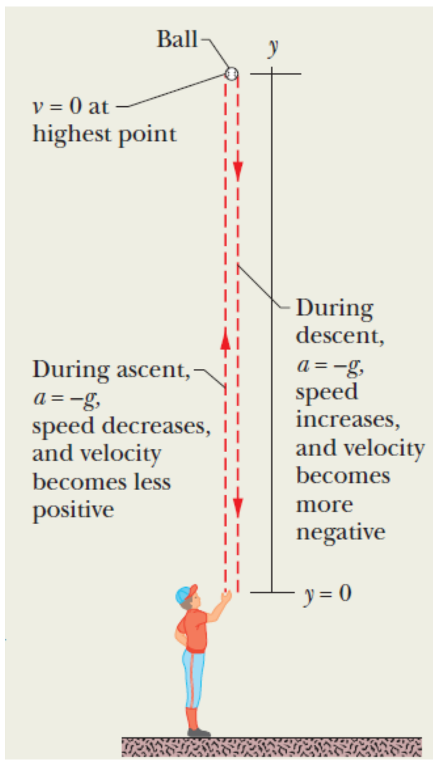


Four possible v_x-t graphs are shown for the two vehicles. Which graph is correct?



a pitcher tosses a baseball up along a *y* axis, with an initial speed of 12 m/s.

(a) How long does the ball take to reach its maximum height?
(b) What is the ball's maximum height above its release point?
(c) How long does the ball take to reach a point 5.0 m above its release point?



$$t = \frac{v - v_0}{a} = \frac{0 - 12\ m/s}{-9.8\ m/s^2} = 1.2\ s$$

$$y = \frac{v^2 - v_0^2}{2a} = \frac{0 - (12\ m/s)^2}{2(-9.8\ m/s^2)} = 7.3\ m$$

$$y = v_0 t - \tfrac{1}{2} g t^2$$

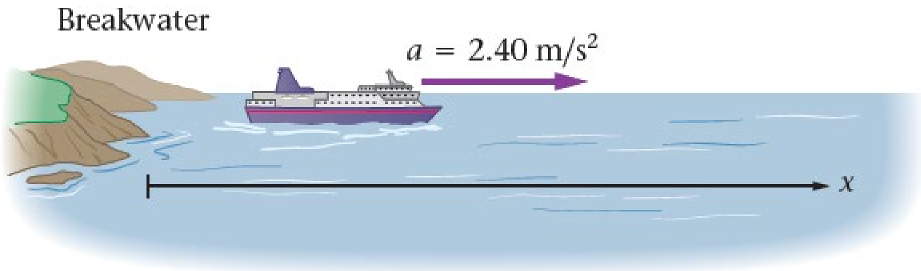
$$5.0\ m = (12\ m/s)t - (\tfrac{1}{2})(9.8\ m/s^2)t^2$$

$$t = 0.53\ s \quad \text{and} \quad t = 1.9\ s$$

A boat moves slowly inside a marina (so as not to leave a wake) with a constant speed of 1.50 m/s. As soon as it passes the breakwater, leaving the marina, it throttles up and accelerates at 2.40 m/s².

(a) How fast is the boat moving after accelerating for 5.00 s? **13.5 m/s**

(b) How far has the boat travelled in these 5.00 s? **37.5 m**



EXAMPLE 2.5 Reaction Time

It takes time for a person to react to any external stimulus. For example, at the beginning of a 100-m dash in a track-and-field meet, a gun is fired by the starter. A slight time delay occurs before the runners come out of the starting blocks, due to their nonzero reaction time. In fact, it counts as a false start if a runner leaves the blocks less than 0.1 s after the gun is fired. Any shorter time indicates that the runner has "jumped the gun."

There is a simple test, shown in Figure 2.25, that you can perform to determine your reaction time. Your partner holds a meter stick, and you get ready to catch it when your partner releases it, as shown in the left frame of the figure. From the distance h that the meter stick falls after it is released until you grab it (shown in the right frame), you can determine your reaction time.

PROBLEM

If the meter stick falls 0.20 m before you catch it, what is your reaction time?

$$y = y_0 - \tfrac{1}{2}gt^2$$

$$\Rightarrow h = \tfrac{1}{2}gt^2$$

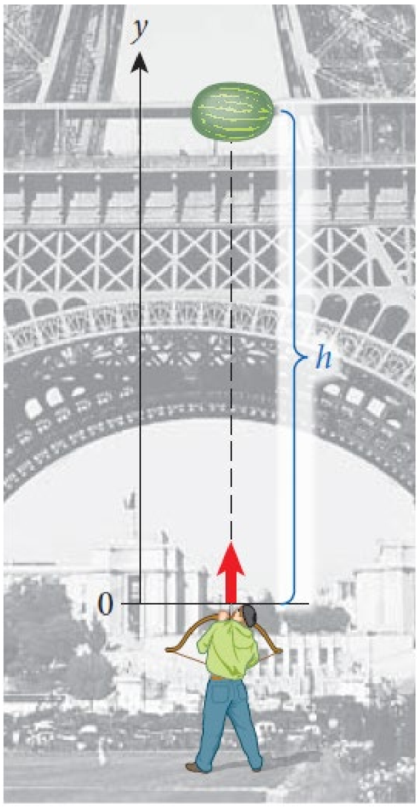
$$\Rightarrow t = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2 \cdot 0.20\ \text{m}}{9.81\ \text{m/s}^2}} = 0.20\ \text{s}.$$

SOLVED PROBLEM 2.5 Melon Drop

Suppose you decide to drop a melon from rest from the first observation platform of the Eiffel Tower. The initial height h from which the melon is released is 58.3 m above the head of your French friend Pierre, who is standing on the ground right below you. At the same instant you release the melon, Pierre shoots an arrow straight up with an initial velocity of 25.1 m/s. (Of course, Pierre makes sure the area around him is cleared and gets out of the way quickly after he shoots his arrow.)

PROBLEM

(a) How long after you drop the melon will the arrow hit it? (b) At what height above Pierre's head does this collision occur?



$$y_m(t) = h - \tfrac{1}{2}gt^2$$

$$y_a(t) = v_{a0}t - \tfrac{1}{2}gt^2.$$

$$y_a(t_c) = y_m(t_c).$$

$$h - \tfrac{1}{2}gt_c^2 = v_{a0}t_c - \tfrac{1}{2}gt_c^2 \Rightarrow$$

$$h = v_{a0}t_c \Rightarrow$$

$$t_c = \frac{h}{v_{a0}}.$$

$$t_c = \frac{58.3 \text{ m}}{25.1 \text{ m/s}} = 2.32271 \text{ s}$$

$$y_m(t_c) = h - \tfrac{1}{2}gt_c^2.$$

$$y_m(t_c) = 58.3 \text{ m} - \tfrac{1}{2}(9.81 \text{ m/s}^2)(2.32271 \text{ s})^2 = 31.8376 \text{ m}.$$

Additional Question

What are the velocities of melon and arrow at the moment of the collision?

$$y_m(t) = h - \tfrac{1}{2}gt^2 \Rightarrow v_m(t) = \frac{dy_m(t)}{dt} = -gt$$

$$y_a(t) = v_{a0}t - \tfrac{1}{2}gt^2 \Rightarrow v_a(t) = \frac{dy_a(t)}{dt} = v_{a0} - gt.$$

$$v_m(t_c) = -(9.81 \text{ m/s}^2)(2.32 \text{ s}) = -22.8 \text{ m/s}$$

$$v_a(t_c) = (25.1 \text{ m/s}) - (9.81 \text{ m/s}^2)(2.32 \text{ s}) = 2.34 \text{ m/s}.$$

2.3 A car is traveling due west at 20.0 m/s. Find the velocity of the car after 3.00 s if its acceleration is 1.0 m/s^2 due west. Assume that the acceleration remains constant.

a) 17.0 m/s west
c) 23.0 m/s west
e) 11.0 m/s south
b) 17.0 m/s east
d) 23.0 m/s east

2.4 A car is traveling due west at 20.0 m/s. Find the velocity of the car after 37.00 s if its acceleration is 1.0 m/s^2 due east. Assume that the acceleration remains constant.

a) 17.0 m/s west
c) 23.0 m/s west
e) 11.0 m/s south
b) 17.0 m/s east
d) 23.0 m/s east

2.6 A car travels at 22.0 m/s north for 30.0 min and then reverses direction and travels at 28.0 m/s for 15.0 min. What is the car's total displacement?

a) 1.44×10^4 m
b) 6.48×10^4 m
c) 3.96×10^4 m
d) 9.98×10^4 m

2.9 You drop a rock from a cliff. If air resistance is neglected, which of the following statements is (are) true?

1. The speed of the rock will increase.
2. The speed of the rock will decrease.
3. The acceleration of the rock will increase.
4. The acceleration of the rock will decrease.

a) 1
b) 1 and 4
c) 2
d) 2 and 3

2.10 A car travels at 22.0 kph for 15.0 min and at 35.0 kph for 30.0 min. How far does it travel overall?

a) 23.0 km b) 3.70×10^4 km c) 1.38×10^3 km d) 3.30×10^2 km

2.11 If the melon in Solved Problem 2.5 is thrown straight up with an initial velocity of 5.00 m/s at the same time that the arrow is shot upward, how long does it take before the collision occurs?

a) 2.32 s
b) 2.90 s
c) 1.94 s
d) They do not collide before the melon hits the ground.

2.34 The position of a particle moving along the x-axis is given by $x = (11 + 14t - 2.0t^2)$, where t is in seconds and x is in meters. What is the average velocity during the time interval from $t = 1.0$ s to $t = 4.0$ s?

$\bar{v} = \dfrac{x(t_2) - x(t_1)}{t_2 - t_1}$, with $t_2 = 4.0$ s and $t_1 = 1.0$ s.

SIMPLIFY: $\bar{v} = \dfrac{x(t_2) - x(t_1)}{t_2 - t_1} = \dfrac{\left(11 + 14t_2 - 2.0t_2^{\ 2}\right) - \left(11 + 14t_1 - 2.0t_1^{\ 2}\right)}{t_2 - t_1} = \dfrac{14(t_2 - t_1) - 2.0(t_2^{\ 2} - t_1^{\ 2})}{t_2 - t_1}$

CALCULATE: $\bar{v} = \dfrac{14(4.0\text{ s} - 1.0\text{ s}) - 2.0((4.0\text{ s})^2 - (1.0\text{ s})^2)}{4.0\text{ s} - 1.0\text{ s}} = 4.0\text{ m/s}$

•2.37 The position of an object as a function of time is given as $x = At^3 + Bt^2 + Ct + D$. The constants are $A = 2.10\ \text{m/s}^3$, $B = 1.00\ \text{m/s}^2$, $C = -4.10\ \text{m/s}$, and $D = 3.00\ \text{m}$.

a) What is the velocity of the object at $t = 10.0$ s?

b) At what time(s) is the object at rest?

c) What is the acceleration of the object at $t = 0.50$ s?

d) Plot the acceleration as a function of time for the time interval from $t = -10.0$ s to $t = 10.0$ s.

(a) $v(t) = \frac{d}{dt}x(t) = \frac{d}{dt}(At^3 + Bt^2 + Ct + D) = 3At^2 + 2Bt + C$

(b) Set the velocity equal to zero and solve for t using the quadratic formula:

$$t = \frac{-2B \pm \sqrt{4B^2 - 4(3A)(C)}}{2(3A)} = \frac{-2B \pm \sqrt{4B^2 - 12AC}}{6A}$$

(c) $a(t) = \frac{d}{dt}v(t) = \frac{d}{dt}(3At^2 + 2Bt + C) = 6At + 2B$

(d) There is no need to simplify this equation.

Calculate

(a) $v(t = 10.0\ \text{s}) = 3(2.10\ \text{m/s}^3)(10.0\ \text{s})^2 + 2(1.00\ \text{m/s}^2)(10.0\ \text{s}) - 4.10\ \text{m/s} = 645.9\ \text{m/s}$

(b) $t = \frac{-2(1.00\ \text{m/s}^2) \pm \sqrt{4(1.00\ \text{m/s}^2)^2 - 12(2.10\ \text{m/s}^3)(-4.10\ \text{m/s})}}{6(2.1\ 0\text{m/s}^3)}$

$= 0.6634553\ \text{s}, -0.9809156\ \text{s}$

(c) $a(t = 0.50\ \text{s}) = 6(2.10\ \text{m/s}^3)(0.50\ \text{s}) + 2(1.00\ \text{m/s}^2) = 8.30\ \text{m/s}^2$

On a strange, airless planet, a ball is thrown downward from a height of 17 m. The ball initially travels at 15 m/s. If the ball hits the ground in 1 s, what is this planet's gravitational acceleration?

A. 2 m/s^2 .
B. 32 m/s^2 .
C. 46 m/s^2 .
D. 4 m/s^2 .

•2.37 The position of an object as a function of time is given as $x = At^3 + Bt^2 + Ct + D$. The constants are $A = 2.10\ \text{m/s}^3$, $B = 1.00\ \text{m/s}^2$, $C = -4.10\ \text{m/s}$, and $D = 3.00\ \text{m}$.

a) What is the velocity of the object at $t = 10.0$ s?

b) At what time(s) is the object at rest?

c) What is the acceleration of the object at $t = 0.50$ s?

d) Plot the acceleration as a function of time for the time interval from $t = -10.0$ s to $t = 10.0$ s.

(a) $v(t) = \frac{d}{dt}x(t) = \frac{d}{dt}(At^3 + Bt^2 + Ct + D) = 3At^2 + 2Bt + C$

(b) Set the velocity equal to zero and solve for t using the quadratic formula:

$$t = \frac{-2B \pm \sqrt{4B^2 - 4(3A)(C)}}{2(3A)} = \frac{-2B \pm \sqrt{4B^2 - 12AC}}{6A}$$

(c) $a(t) = \frac{d}{dt}v(t) = \frac{d}{dt}(3At^2 + 2Bt + C) = 6At + 2B$

(d) There is no need to simplify this equation.

CALCULATE:

(a) $v(t = 10.0\ s) = 3(2.10\ \text{m/s}^3)(10.0\ \text{s})^2 + 2(1.00\ \text{m/s}^2)(10.0\ \text{s}) - 4.10\ \text{m/s} = 645.9\ \text{m/s}$

(b) $t = \dfrac{-2(1.00\ \text{m/s}^2) \pm \sqrt{4(1.00\ \text{m/s}^2)^2 - 12(2.10\ \text{m/s}^3)(-4.10\ \text{m/s})}}{6(2.1\ 0\text{m/s}^3)}$

$= 0.6634553\ \text{s}, -0.9809156\ \text{s}$

(c) $a(t = 0.50\ \text{s}) = 6(2.10\ \text{m/s}^3)(0.50\ \text{s}) + 2(1.00\ \text{m/s}^2) = 8.30\ \text{m/s}^2$

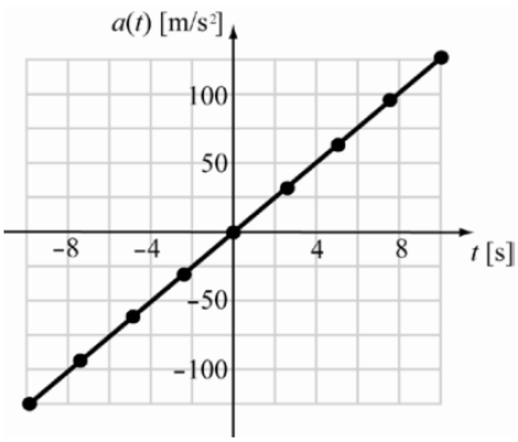
(d) The acceleration function, $a(t) = 6At + 2B$, can be used to compute the acceleration for time steps of 2.5 s. For example:

$$a(t = -2.5\ \text{s}) = 6(2.10\ \text{m/s}^3)(-2.5\ \text{s}) + 2(1.00\ \text{m/s}^2) = -29.5\ \text{m/s}^2$$

The result is given in the following table.

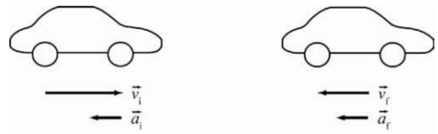
t [s]	−10.0	−7.5	−5.0	−2.5	0.0	2.5	5.0	7.5	10.0
a [m/s^2]	−124.0	−92.5	−61.0	−29.5	2.0	33.5	65.0	96.5	128.0

These values are used to plot the function.



2.39 A car approaches an intersection at a speed of 72 kph. Just as the driver passes the intersection, he realizes that he needed to turn. So he steps on the brakes, comes to a complete stop, and then accelerates driving straight backward. He reaches a speed of 36 kph moving backward. Altogether his deceleration and re-acceleration in the opposite direction take 12.4 s. What is the average acceleration during this time?

SKETCH:

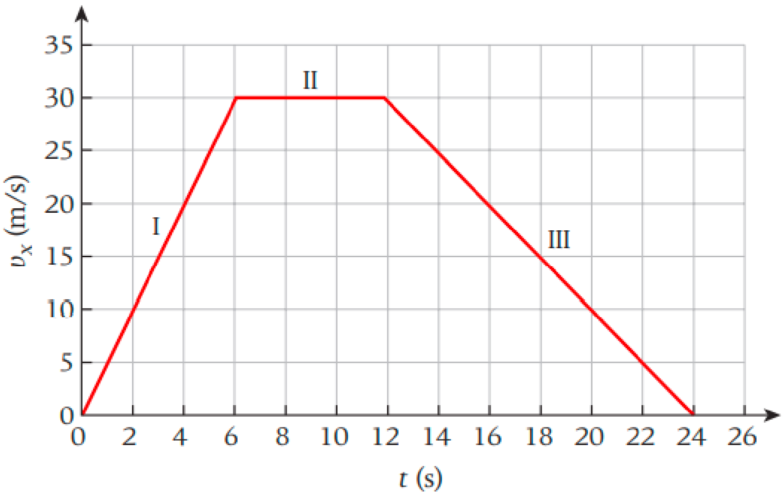


RESEARCH: average acceleration = $\dfrac{\text{change in velocity}}{\text{change in time}}$

SIMPLIFY: $\bar{a} = \dfrac{v_f - v_i}{t}$

CALCULATE: $\bar{a} = \dfrac{(-10.0575 \text{ m/s}) - (20.115 \text{ m/s})}{12.4 \text{ s}} = -2.433 \text{ m/s}^2$

2.42 A fellow student found in the performance data for his new car the velocity-versus-time graph shown in the figure.



a) Find the average acceleration of the car during each of the segments I, II, and III.

b) What is the total distance traveled by the car from $t = 0$ s to $t = 24$ s?

SIMPLIFY:

(a) $a_I = \dfrac{v_{I_2} - v_{I_1}}{t_{I_2} - t_{I_1}}$, $a_{II} = \dfrac{v_{II_2} - v_{II_1}}{t_{II_2} - t_{II_1}}$, $a_{III} = \dfrac{v_{III_2} - v_{III_1}}{t_{III_2} - t_{III_1}}$

(b) $x = \dfrac{1}{2} v_{I_2}(t_{I_2} - t_{I_1}) + v_{II_2}(t_{II_2} - t_{II_1}) + \dfrac{1}{2} v_{III_2}(t_{III_2} - t_{III_1})$

CALCULATE:

(a) $a_I = \dfrac{30.0 \text{ m/s} - 0 \text{ m/s}}{6.0 \text{ s} - 0 \text{ s}} = 5.0 \text{ m/s}^2$, $a_{II} = \dfrac{30.0 \text{ m/s} - 30.0 \text{ m/s}}{12.0 \text{ s} - 6.0 \text{ s}} = 0.0 \text{ m/s}^2$,

$a_{III} = \dfrac{0.0 \text{ m/s} - 30.0 \text{ m/s}}{24.0 \text{ s} - 12.0 \text{ s}} = -2.50 \text{ m/s}^2$

(b) $x = \dfrac{1}{2}(30.0 \text{ m/s})(6.0 \text{ s} - 0.0 \text{ s}) + (30.0 \text{ m/s})(12.0 \text{ s} - 6.0 \text{ s}) + \dfrac{1}{2}(30.0 \text{ m/s})(24.0 \text{ s} - 12.0 \text{ s}) = 450.0 \text{ m}$

2.59 A car starts from rest and accelerates at 10.0 m/s². How far does it travel in 2.00 s?

RESEARCH: $\Delta x = v_0 t + \frac{1}{2}at^2$

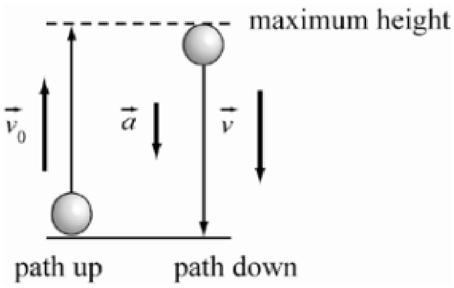
SIMPLIFY: Since $v_0 = 0$ m/s, $\Delta x = \frac{1}{2}at^2$.

CALCULATE: $\Delta x = \frac{1}{2}(10.0 \text{ m/s}^2)(2.00 \text{ s})^2 = 20.0 \text{ m}$

ROUND: $\Delta x = 20.0$ m

2.66 A ball is tossed vertically upward with an initial speed of 26.4 m/s. How long does it take before the ball is back on the ground?

SKETCH:



RESEARCH: $v = v_0 + at$

SIMPLIFY: $t = \frac{v - v_0}{a} = \frac{-v_0 - v_0}{-g} = \frac{2v_0}{g}$

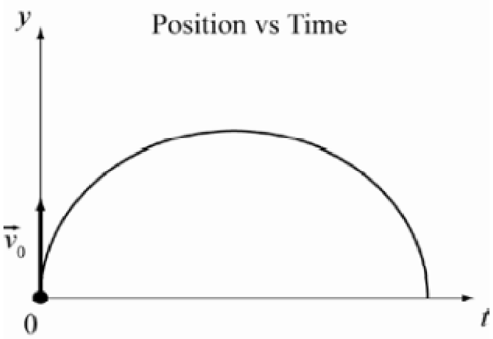
CALCULATE: $t = \frac{2(26.4 \text{ m/s})}{9.81 \text{ m/s}^2} = 5.38226 \text{ s}$

ROUND: Since all the values given have three significant digits, $t = 5.38$ s.

2.67 A stone is thrown upward, from ground level, with an initial velocity of 10.0 m/s.

a) What is the velocity of the stone after 0.50 s?

b) How high above ground level is the stone after 0.50 s?



RESEARCH:

(a) $v = v_0 + at$

(b) $\Delta y = v_0 t + \frac{1}{2}at^2$ and $\Delta y = h$

SIMPLIFY:

(a) $v = v_0 - gt$

(b) $h = v_0 t + \frac{1}{2}at^2 = v_0 t - \frac{1}{2}gt^2$

CALCULATE:

(a) $v = 10.0 \text{ m/s} - (9.81 \text{ m/s}^2)(0.50 \text{ s})$

$= 10.0 \text{ m/s} - 4.905 \text{m/s}$

$= 5.095 \text{ m/s}$

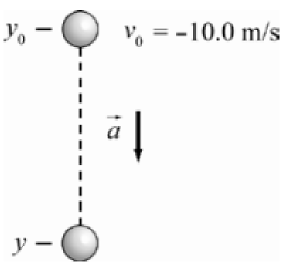
(b) $h = (10.0 \text{ m/s})(0.50 \text{ s}) - \frac{1}{2}(9.81 \text{ m/s}^2)(0.50 \text{ s})^2$

$= 5.0 \text{ m} - 1.226 \text{ m}$

$= 3.774 \text{ m}$

2.68 A stone is thrown downward with an initial velocity of 10.0 m/s. The acceleration of the stone is constant and has the value of the free-fall acceleration, 9.81 m/s^2. What is the velocity of the stone after 0.500 s?

SKETCH:



RESEARCH: $v = v_0 + at$

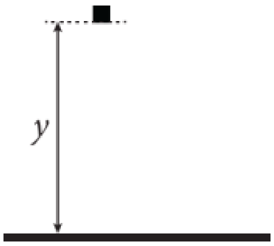
SIMPLIFY: $v = v_0 - gt$

CALCULATE: $v = -10.0 \text{ m/s} - (9.81 \text{ m/s}^2)(0.500 \text{ s}) = -10.0 \text{ m/s} - 4.905 \text{ m/s} = -14.905 \text{ m/s}$

ROUND: Subtracting two numbers is precise to the least precise decimal place of the numbers. Therefore, $v = -14.9$ m/s.

2.72 On August 2, 1971, Astronaut David Scott, while standing on the surface of the Moon, dropped a 1.3-kg hammer and a 0.030-kg falcon feather from a height of 1.6 m. Both objects hit the Moon's surface 1.4 s after being released. What is the acceleration due to gravity on the surface of the Moon?

SKETCH:



RESEARCH: We can use $y = \frac{1}{2}gt^2$, where y is the distance the objects fall, t is the time it takes for the objects to fall, and g is the acceleration of gravity on the Moon.

SIMPLIFY: We can solve our equation for g: $y = \frac{1}{2}gt^2 \Rightarrow g = \frac{2y}{t^2}$.

CALCULATE: $g = \frac{2y}{t^2} = \frac{2(1.6 \text{ m})}{(1.4 \text{ s})^2} = 1.6327 \text{ m/s}^2$.

ROUND: The values given are all accurate to two significant digits, so the answer is given two by two significant digits: $g = 1.6 \text{ m/s}^2$.

An object of unknown mass is initially at rest and dropped from a height h. It reaches the ground with a velocity v_1 The same object is then raised again to the same height h, but this time is thrown downward with velocity v_1 now reaches the ground with a new velocity V_2 . How is v_2 related to v_1?

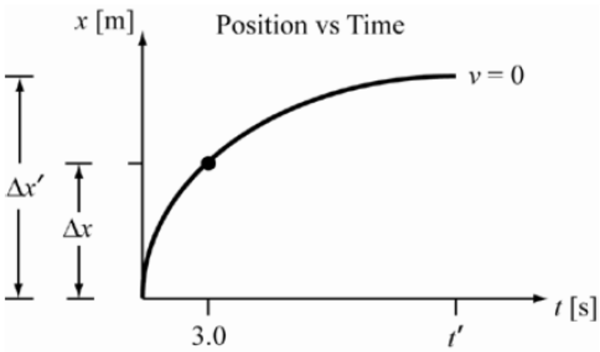
A. $V_2 = V_1$
B. $V_2 = \sqrt{2}\, V_1$
C. $V_2 = 2V_1$
D. $V_2 = 4V_1$

2.86 The edge of a cliff is 100. m above the ground. A rock is thrown straight upward just over the edge of the cliff with a speed 8.00 m/s.

a) How long does it take the rock to hit the ground?

b) What is the speed of the rock the instant before it hits the ground?

SKETCH:



RESEARCH:

(a) To determine Δx, use $\Delta x = v_0 t + \left(at^2\right)/2$.

(b) To determine v, use $v = v_0 + at$.

(c) To determine t', use $v = v_0 + at$.

(c) To determine $\Delta x'$, use $v^2 = v_0^2 + 2a\Delta x$.

SIMPLIFY:

(a) It is not necessary to simplify.

(b) It is not necessary to simplify.

(c) With $v' = 0$, $v' = v_0 + at' \Rightarrow t' = -v_0 / a$.

(d) With $v' = 0$, $v'^2 = v_0^2 + 2a\Delta x' \Rightarrow \Delta x' = -v_0^2 / 2a$.

CALCULATE:

(a) $\Delta x = (25.0 \text{ m/s})(3.0 \text{ s}) + \frac{1}{2}\left(-1.2 \text{ m/s}^2\right)(3.0 \text{ s})^2 = 69.6 \text{ m}$

(b) $v = 25.0 \text{ m/s} + \left(-1.2 \text{ m/s}^2\right)(3.0 \text{ s}) = 21.4 \text{ m/s}$

(c) $t' = -\frac{(25.0 \text{ m/s})}{\left(-1.2 \text{ m/s}^2\right)} = 20.83 \text{ s}$

(d) $\Delta x' = -\frac{(25.0 \text{ m/s})^2}{2\left(-1.2 \text{ m/s}^2\right)} = 260.4 \text{ m}$

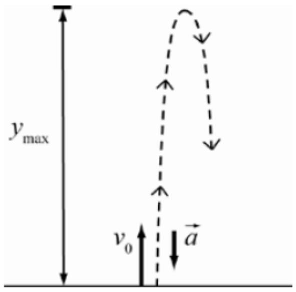
Hotel in Dubai is well known for its Musical Fountains, which use 192 Hyper Shooters to fire water hundreds of feet into the air to the rhythm of music. One of the Hyper Shooters fires water straight upward to a height of 73.152 m.

a) What is the initial speed of the water?

b) What is the speed of the water when it is at half this height on its way down?

c) How long will it take for the water to fall back to its original height from half its maximum height?

SKETCH:



RESEARCH: To solve this constant acceleration problem, use $v = v_0 - gt$ and $y = y_0 + v_0 t - (gt^2/2)$. $y_0 = 0$.

SIMPLIFY:

(a) At a maximum height, the velocity v is zero.

$$v_0 - gt = 0 \Rightarrow t = \frac{v_0}{g}$$

$$y_{max} = v_0\left(\frac{v_0}{g}\right) - \frac{1}{2}g\left(\frac{v_0}{g}\right)^2 = \frac{v_0^2}{2g} \Rightarrow v_0 = \sqrt{2gy_{max}}$$

(b) If the motion is considering as starting from the maximum height y_{max}, there is free fall motion with $v_0 = 0$.

$$v = -gt \Rightarrow t = \frac{v}{g}$$

$$y = y_{max} - \frac{1}{2}gt^2 = y_{max} - \frac{1}{2}g\left(\frac{v}{g}\right)^2 = y_{max} - \frac{v^2}{2g} \Rightarrow v = \sqrt{(y_{max} - y)2g}$$

(c) Note that v_0 is equal to the speed in part (b), $v_0 = -26.788$ m/s and v is equal to the original speed but in the opposite direction, $v = -37.884$ m/s.

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

CALCULATE:

(a) $v_0 = \sqrt{2(9.81)73.152} = 37.885$ m/s

(b) $y = \frac{y_{max}}{2}$, so $v = \sqrt{\left(y_{max} - \frac{y_{max}}{2}\right)2g} = \sqrt{gy_{max}} = \sqrt{(9.81)73.152} = 26.788$ m/s. Choose the positive root because the problem asks for the speed, which is never negative.

(c) $t = \frac{37.884 \text{ m/s} - 26.788 \text{ m/s}}{(9.81 \text{ m/s}^2)} = 1.131$ s

Important notes

All of the following are true:

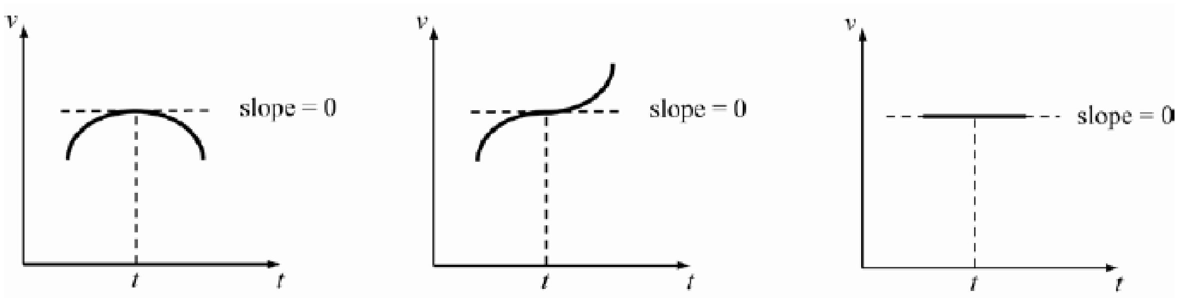
1. An object can have zero acceleration and be at rest.

2. An object can have nonzero acceleration and be at rest. (Object thrown up -at the top)

3. An object can have zero acceleration and be in motion. (move with constant speed)

- **The magnitude of average velocity and average speed are the same only when the direction of movement does not change.**
- **If the direction changes during movement, it is known that the net displacement is smaller than the net distance. it can be said that the magnitude of average velocity is less than the average speed when the direction changes during movement.**

If the acceleration of an object is zero and its velocity is nonzero



the object is moving at a constant velocity.

Two different masses free fall m_1 is twice as heavy as m_2. Neglecting air resistance so:

1. then the acceleration does not depend on the mass of an object.
2. Therefore, both snowballs have the **same acceleration**.
3. Since initial velocities are zero, and the snowballs will cover **the same distance**, both snowballs will hit the ground at the **same time**.
4. They will both have the **same speed.**

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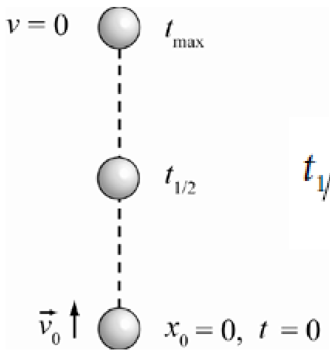
half of the maximum height and time to reach this distance

$$y_{1/2} = \frac{v_0^2}{4g}$$



$$t_{1/2} = \frac{v_0}{g}\left(1 \pm \frac{1}{\sqrt{2}}\right)$$

A truck travelling due north at 20 m/s turns west and travels at the same speed. Then the change in velocity is

A. 40 m/s northwest

B. 20 $\sqrt{2}$ m/s northwest

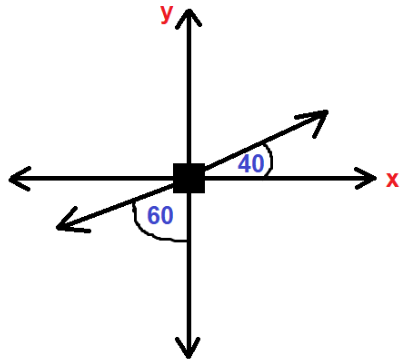
C. 20 $\sqrt{2}$ m/s southwest

D. 40 m/s southeast

A particle travels at 20.0 m/s north for 20.0 min and then it stops instantaneously and reverses the direction and travels at 25.00/s for 15.0 min. what is the particle's total displacement?

A. 150 m
B. 25 km
C. 2500 m
D. 1.5 km

The free body diagram below shows two forces acting on a mass. Which equation of the following represents the vector sum of the forces in N, on the x-axis?



A. $\sum F_x$ = 4 cos 210 ° + 6 cos 40 °

B. $\sum F_x$ = 4 sin 60 ° + 6 cos 40 °

C. $\sum F_x$ = - 4 cos 60 ° + 6 sin 40 °

D. $\sum F_x$ = - 4 cos 60 ° + 6 cos 40 °