Chapter 2: Motion Along a Straight Line

Due: 11:00pm on Tuesday, September 4, 2012

Note: You will receive no credit for late submissions. To learn more, read your instructor's Grading Policy

Kinematic Vocabulary

One of the difficulties in studying mechanics is that many common words are used with highly specific technical meanings, among them *velocity*, *acceleratio n*, *position*, *speed*, and *displacement*. The series of questions in this problem is designed to get you to try to think of these quantities like a physicist.

Answer the questions in this problem using words from the following list:

A. position
B. direction
C. displacement
D. coordinates
E. velocity
F. acceleration
G. distance
H. magnitude
I. vector
J. scalar
K. components

Part A

Velocity differs from *speed* in that *velocity* indicates a particle's __________ of motion.

Enter the letter from the list given in the problem introduction that best completes the sentence.

ANSWER:

B

Also accepted: direction

Part B

Unlike *speed*, *velocity* is a __________ quantity.

Enter the letter from the list given in the problem introduction that best completes the sentence.

ANSWER:

I

Also accepted: vector

Part C

A vector has, by definition, both __________ and direction.

Enter the letter from the list given in the problem introduction that best completes the sentence.

ANSWER:

H

Also accepted: magnitude

Part D

Once you have selected a coordinate system, you can express a two-dimensional vector using a pair of quantities known collectively as __________.

Enter the letter from the list given in the problem introduction that best completes the sentence.

ANSWER:

K

Also accepted: components, D, coordinates

Part E

Speed differs from *velocity* in the same way that __________ differs from *displacement*.

Enter the letter from the list given in the problem introduction that best completes the sentence.

Hint 1. Definition of displacement

Displacement is the vector that indicates the difference of two positions (e.g., the final position from the initial position). Being a vector, it is independent of the coordinate system used to describe it (although its vector components depend on the coordinate system).

ANSWER:

G

Also accepted: distance

Part F

Consider a physical situation in which a particle moves from point A to point B. This process is described from two coordinate systems that are identical except that they have different origins.

The __________ of the particle at point A differ(s) as expressed in one coordinate system compared to the other, but the __________ from A to B is/are the same as expressed in both coordinate systems.

Type the letters from the list given in the problem introduction that best complete the sentence. Separate the letters with commas. There is more than one correct answer, but you should only enter one pair of comma-separated letters. For example, if the words "vector" and "scalar" fit best in the blanks, enter I, J.

ANSWER:

A,C

Also accepted: position,C, D,C, coordinates,C, A,displacement, position,displacement, D,displacement, coordinates,displacement, A,G, position,G, D,G, coordinates,G, A,distance, position,distance, D,distance, coordinates,distance, A,E, position,E, D,E, coordinates,E, A,velocity, position,velocity, D,velocity, coordinates,velocity, A,B, position,B, D,B, coordinates,B, A,direction, position,direction, D,direction, coordinates,direction

The coordinates of a point will depend on the coordinate system that is chosen, but there are several other quantities that are independent of the choice of origin for a coordinate system: in particular, distance, displacement, direction, and velocity. In working physics problems, unless you are interested in the position of an object or event relative to a specific origin, you can usually choose the coordinate system origin to be wherever is most convenient or intuitive.

Note that the vector indicating a displacement from A to B is usually represented as $\vec{r}_{\rm BA} = \vec{r}_{\rm B} - \vec{r}_{\rm A}$.

Part G

Identify the following physical quantities as scalars or vectors.

ANSWER:

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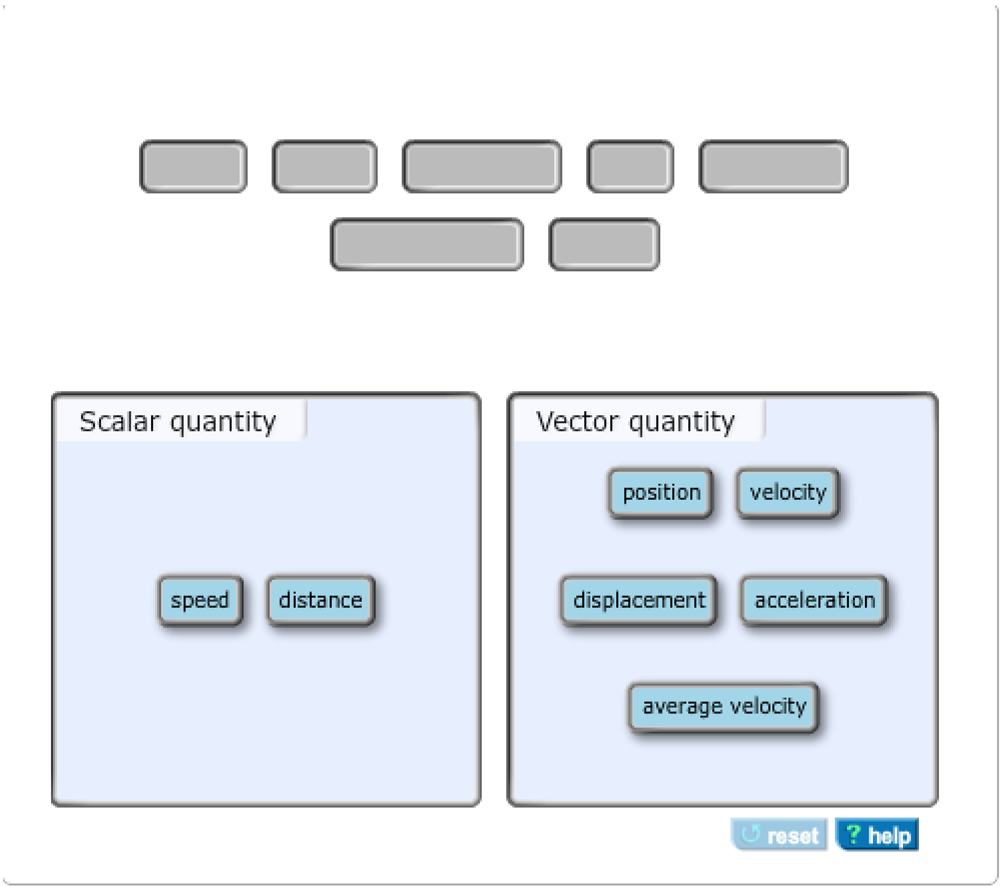
Kinematic Vocabulary

Part G

Identify the following physical quantities as scalars or vectors.

ANSWER:

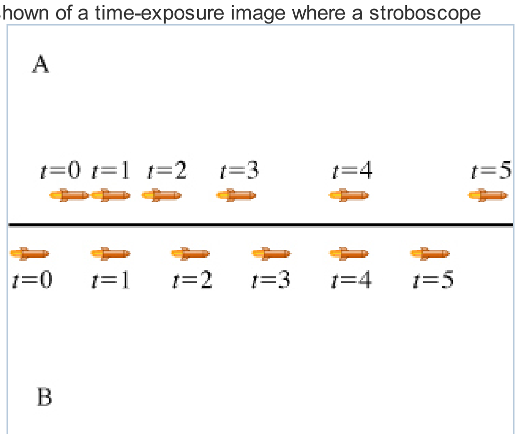


Motion of Two Rockets

Learning Goal:

To learn to use images of an object in motion to determine velocity and acceleration.

Two toy rockets are traveling in the same direction (taken to be the *x* axis). A diagram is shown of a time-exposure image where a stroboscope has illuminated the rockets at the uniform time intervals indicated.



Part A

At what time(s) do the rockets have the same velocity?

Hint 1. How to determine the velocity

The diagram shows position, not velocity. You can't find instantaneous velocity from this diagram, but you can determine the average velocity between two times t_1 and t_2:

$$v_{\rm avg}[t_1, t_2] = \frac{x(t_2) - x(t_1)}{t_2 - t_1}.$$

Note that no position values are given in the diagram; you will need to estimate these based on the distance between successive positions of the rockets.

ANSWER:

- at time $t = 1$ only
- at time $t = 4$ only
- at times $t = 1$ and $t = 4$
- (selected) at some instant in time between $t = 1$ and $t = 4$
- at no time shown in the figure

Part B

At what time(s) do the rockets have the same *x* position?

ANSWER:

- at time $t = 1$ only
- at time $t = 4$ only
- (selected) at times $t = 1$ and $t = 4$
- at some instant in time between $t = 1$ and $t = 4$
- at no time shown in the figure

Part C

At what time(s) do the two rockets have the same acceleration?

Hint 1. How to determine the acceleration

The velocity is related to the spacing between images in a stroboscopic diagram. Since acceleration is the rate at which velocity changes, the acceleration is related to the how much this spacing changes from one interval to the next.

ANSWER:

- at time $t = 1$ only
- at time $t = 4$ only
- at times $t = 1$ and $t = 4$
- at some instant in time between $t = 1$ and $t = 4$
- (selected) at no time shown in the figure

Part D

The motion of the rocket labeled A is an example of motion with uniform (i.e., constant) __________.

ANSWER:

- (selected) and nonzero acceleration
- velocity
- displacement
- time

Part E

The motion of the rocket labeled B is an example of motion with uniform (i.e., constant) __________.

ANSWER:

- and nonzero acceleration
- velocity
- displacement
- time

Part F

At what time(s) is rocket A ahead of rocket B?

Hint 1. Use the diagram

You can answer this question by looking at the diagram and identifying the time(s) when rocket A is to the right of rocket B.

ANSWER:

- before $t = 1$ only
- after $t = 4$ only
- before $t = 1$ and after $t = 4$
- between $t = 1$ and $t = 4$
- at no time(s) shown in the figure

One-Dimensional Kinematics with Constant Acceleration

Learning Goal:

To understand the meaning of the variables that appear in the equations for one-dimensional kinematics with constant acceleration.

Motion with a constant, nonzero acceleration is not uncommon in the world around us. Falling (or thrown) objects and cars starting and stopping approximate this type of motion. It is also the type of motion most frequently involved in introductory kinematics problems.

The kinematic equations for such motion can be written as

$$x(t) = x_i + v_i t + \frac{1}{2}at^2,$$

$$v(t) = v_i + at,$$

where the symbols are defined as follows:

- $x(t)$ is the position of the particle;
- x_i is the *initial* position of the particle;
- $v(t)$ is the velocity of the particle;
- v_i is the *initial* velocity of the particle;
- a is the acceleration of the particle.

In anwering the following questions, assume that the acceleration is constant and nonzero: $a \neq 0$.

Part A

The quantity represented by x is a function of time (i.e., is not constant).

ANSWER:

- true
- false

Part B

The quantity represented by x_i is a function of time (i.e., is not constant).

ANSWER:

- true
- false (selected)

Recall that x_i represents an initial value, not a variable. It refers to the position of an object at some initial moment.

Part C

The quantity represented by v_i is a function of time (i.e., is not constant).

ANSWER:

- true
- false (selected)

Part D

The quantity represented by v is a function of time (i.e., is not constant).

ANSWER:

- true (selected)
- false

The velocity v always varies with time when the linear acceleration is nonzero.

Part E

Which of the given equations is not an explicit function of t and is therefore useful when you don't know or don't need the time?

ANSWER:

- $x = x_i + v_i t + \frac{1}{2}at^2$
- $v = v_i + at$
- $v^2 = v_i^2 + 2a(x - x_i)$ (selected)

Part F

A particle moves with constant acceleration a. The expression $v_i + at$ represents the particle's velocity at what instant in time?

ANSWER:

- at time $t = 0$
- at the "initial" time
- when a time t has passed since the particle's velocity was v_i (selected)

More generally, the equations of motion can be written as

$$x(t) = x_i + v_i\,\Delta t + \frac{1}{2}a\,(\Delta t)^2$$

and

$$v(t) = v_i + a\,\Delta t.$$

Here Δt is the time that has elapsed since the beginning of the particle's motion, that is, $\Delta t = t - t_i$, where t is the current time and t_i is the time at which we start measuring the particle's motion. The terms x_i and v_i are, respectively, the position and velocity at $t = t_i$. As you can now see, the equations given at the beginning of this problem correspond to the case $t_i = 0$, which is a convenient choice if there is only one particle of interest.

To illustrate the use of these more general equations, consider the motion of two particles, A and B. The position of particle A depends on time as $x_A(t) = x_i + v_i t + (1/2)at^2$. That is, particle A starts moving at time $t = t_{iA} = 0$ with velocity $v_{iA} = v_i$, from $x_{iA} = x_i$. At time $t = t_1$, particle B has twice the acceleration, half the velocity, and the same position that particle A had at time $t = 0$.

Part G

What is the equation describing the position of particle B?

Hint 1. How to approach the problem

The general equation for the distance traveled by particle B is

$$x_B(t) = x_{iB} + v_{iB}\Delta t + \frac{1}{2}a_B(\Delta t)^2,$$

or

$$x_B(t) = x_B(t = t_1) + v_B(t = t_1)(t - t_1) + \frac{1}{2}a_B(t - t_1)^2,$$

since $\Delta t = t - t_1$ is a good choice for B. From the information given, deduce the correct values of the constants that go into the equation for $x_B(t)$ given here, in terms of A's constants of motion.

ANSWER:

- ○ $x_B(t) = x_i + 2v_i t + \frac{1}{4}at^2$
- ○ $x_B(t) = x_i + 0.5v_i t + at^2$
- ○ $x_B(t) = x_i + 2v_i(t + t_1) + \frac{1}{4}a(t + t_1)^2$
- ○ $x_B(t) = x_i + 0.5v_i(t + t_1) + a(t + t_1)^2$
- ○ $x_B(t) = x_i + 2v_i(t - t_1) + \frac{1}{4}a(t - t_1)^2$
- ◉ $x_B(t) = x_i + 0.5v_i(t - t_1) + a(t - t_1)^2$

Part H

At what time does the velocity of particle B equal that of particle A?

Hint 1. Velocity of particle A

Type an expression for particle A's velocity as a function of time.

Express your answer in terms of t and some or all of the variables x_i, v_i, and a.

Hint 1. How to approach this part

Look at the general expression for $v(t)$ given in the problem introduction.

ANSWER:

$v_A(t) = v_i + at$

Hint 2. Velocity of particle B

Type an expression for particle B's velocity as a function of time.

Express your answer in terms of t and some or all of the variables t_1, x_i, v_i, and a.

Hint 1. How to approach this part

The general expression for $v_B(t)$ is

$$v_B(t) = v_B(t = t_1) + a_B(t - t_1).$$

From the information given, deduce the correct values of the constants that go into this equation in terms of particle A's constants of motion.

ANSWER:

$v_B(t) =$ $0.5v_i + 2a(t - t_1)$

Once you have expressions for the velocities of A and B as functions of time, set them equal and find the time t at which this happens.

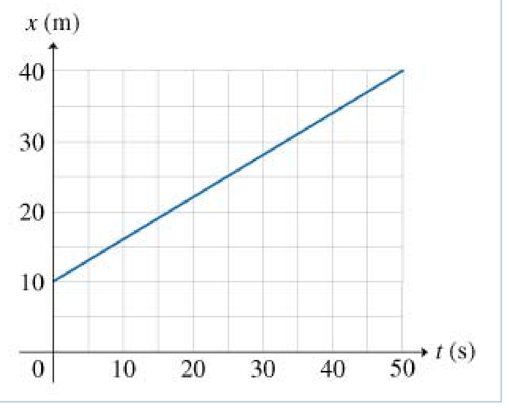
ANSWER:

- ○ $t = t_1 + \frac{v_i}{4a}$
- ◉ $t = 2t_1 + \frac{v_i}{2a}$
- ○ $t = 3t_1 + \frac{v_i}{2a}$
- ○ The two particles never have the same velocity.

What x vs. t Graphs Can Tell You

To describe the motion of a particle along a straight line, it is often convenient to draw a graph representing the position of the particle at different times. This type of graph is usually referred to as an *x vs. t graph.* To draw such a graph, choose an axis system in which time t is plotted on the horizontal axis and position x on the vertical axis. Then, indicate the values of x at various times t. Mathematically, this corresponds to plotting the variable x as a function of t. An example of a graph of position as a function of time for a particle traveling along a straight line is shown below. Note that an x vs. t graph like this does *not* represent the path of the particle in space.

Now let's study the graph shown in the figure in more detail. Refer to this graph to answer Parts A, B, and C.



Part A

What is the total distance Δx traveled by the particle?

Express your answer in meters.

Hint 1. Total distance

The total distance Δx traveled by the particle is given by the difference between the initial position x_0 at $t = 0.0 \text{ s}$ and the position x at $t = 50.0 \text{ s}$. In symbols,

$$\Delta x = x - x_0.$$

Hint 2. How to read an x vs. t graph

Remember that in an x vs. t graph, time t is plotted on the horizontal axis and position x on the vertical axis. For example, in the plot shown in the figure, $x = 16.0 \text{ m}$ at $t = 10.0 \text{ s}$.

ANSWER:

$\Delta x =$ 30 m

Part B

What is the average velocity v_{av} of the particle over the time interval $\Delta t = 50.0 \text{ s}$?

Express your answer in meters per second.

Hint 1. Definition and graphical interpretation of average velocity

The average velocity v_{av} of a particle that travels a distance Δx along a straight line in a time interval Δt is defined as

$$v_{\text{av}} = \frac{\Delta x}{\Delta t}.$$

In an x vs. t graph, then, the average velocity equals the slope of the line connecting the initial and final positions.

Hint 2. Slope of a line

The slope m of a line from point A, with coordinates $(x_{\text{A}}, y_{\text{A}})$, to point B, with coordinates $(x_{\text{B}}, y_{\text{B}})$, is equal to the "rise" over the "run," or

$$m = \frac{x_{\text{B}} - x_{\text{A}}}{y_{\text{B}} - y_{\text{A}}}.$$

ANSWER:

$v_{\text{av}} =$ 0.600 m/s

The average velocity of a particle between two positions is equal to the slope of the line connecting the two corresponding points in an x vs. t graph.

Part C

What is the instantaneous velocity v of the particle at $t = 10.0 \text{ s}$?

Express your answer in meters per second.

Hint 1. Graphical interpretation of instantaneous velocity

The velocity of a particle at any given instant of time or at any point in its path is called instantaneous velocity. In an x vs. t graph of the particle's motion, you can determine the instantaneous velocity of the particle at any point in the curve. The instantaneous velocity at any point is equal to the slope of the line tangent to the curve at that point.

ANSWER:

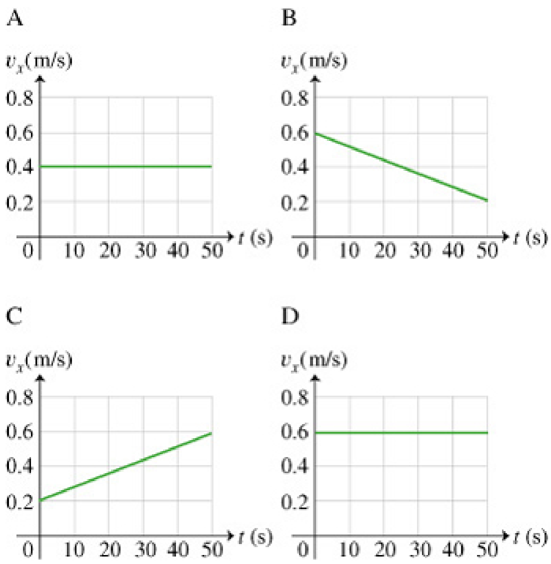
$v =$ 0.600 m/s

The instantaneous velocity of a particle at any point on its x vs. t graph is the slope of the line tangent to the curve at that point. Since in the case at hand the curve is a straight line, the tangent line is the curve itself. Physically, this means that the instantaneous velocity of the particle is *constant* over the entire time interval of motion. This is true for any motion where distance increases linearly with time.

Another common graphical representation of motion along a straight line is the *v vs. t graph*, that is, the graph of (instantaneous) velocity as a function of time. In this graph, time t is plotted on the horizontal axis and velocity v on the vertical axis. Note that by definition, velocity and acceleration are vector quantities. In straight-line motion, however, these vectors have only one nonzero component in the direction of motion. Thus, in this problem, we will call v the velocity and a the acceleration, even though they are really the components of the velocity and acceleration vectors in the direction of motion.

Part D

Which of the graphs shown is the correct v vs. t plot for the motion described in the previous parts?



Hint 1. How to approach the problem

Recall your results found in the previous parts, namely the fact that the instantaneous velocity of the particle is constant. Which graph represents a variable that always has the same constant value at any time?

ANSWER:

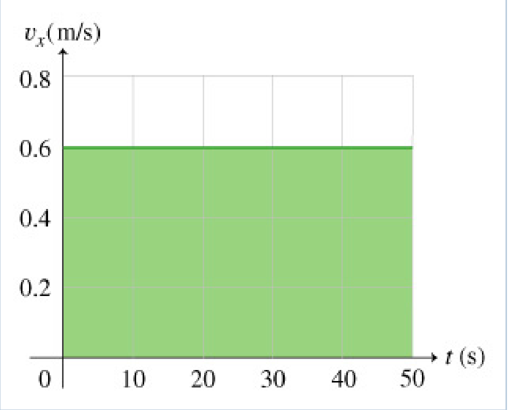
- ○ Graph A
- ○ Graph B
- ○ Graph C
- ◉ Graph D

Whenever a particle moves with constant nonzero velocity, its x vs. t graph is a straight line with a nonzero slope, and its v vs. t curve is a horizontal line.

Part E

Shown in the figure is the v vs. t curve selected in the previous part. What is the area A of the shaded region under the curve?

Express your answer in meters.



Hint 1. How to approach the problem

The shaded region under the v vs. t curve is a rectangle whose horizontal and vertical sides lie on the t axis and the v axis, respectively. Since the area of a rectangle is the product of its sides, in this case the area of the shaded region is the product of a certain quantity expressed in seconds and another quantity expressed in meters per second. The area itself, then, will be in meters.

ANSWER:

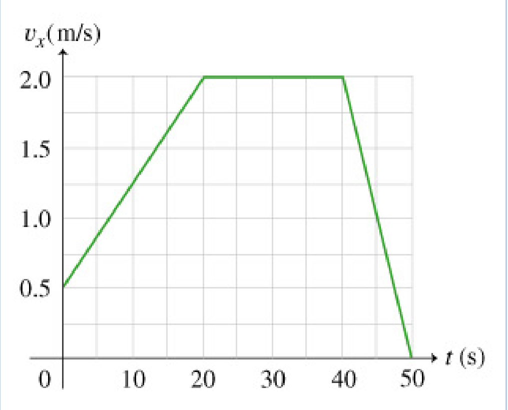
A = 30 m

Compare this result with what you found in Part A. As you can see, the area of the region under the v vs. t curve equals the total distance traveled by the particle. This is true for any velocity curve and any time interval: The area of the region that extends over a time interval Δt under the v vs. t curve is always equal to the distance traveled in Δt.

What Velocity vs. Time Graphs Can Tell You

A common graphical representation of motion along a straight line is the *v vs. t graph*, that is, the graph of (instantaneous) velocity as a function of time. In this graph, time t is plotted on the horizontal axis and velocity v on the vertical axis. Note that by definition, velocity and acceleration are vector quantities. In straight-line motion, however, these vectors have only a single nonzero component in the direction of motion. Thus, in this problem, we will call v the velocity and a the acceleration, even though they are really the components of the velocity and acceleration vectors in the direction of motion, respectively.

Here is a plot of velocity versus time for a particle that travels along a straight line with a varying velocity. Refer to this plot to answer the following questions.



Part A

What is the initial velocity of the particle, v_0?

Express your answer in meters per second.

Hint 1. Initial velocity

The initial velocity is the velocity at $t = 0\ \mathrm{s}$.

Hint 2. How to read a v vs. t graph

Recall that in a graph of velocity versus time, time is plotted on the horizontal axis and velocity on the vertical axis. For example, in the plot shown in the figure, $v = 2.00\ \mathrm{m/s}$ at $t = 30.0\ \mathrm{s}$.

ANSWER:

v_0 = 0.5 $\mathrm{m/s}$

Part B

What is the total distance Δx traveled by the particle?

Express your answer in meters.

Hint 1. How to approach the problem

Recall that the area of the region that extends over a time interval Δt under the v vs. t curve is always equal to the distance traveled in Δt. Thus, to calculate the total distance, you need to find the area of the entire region under the v vs. t curve. In the case at hand, the entire region under the v vs. t curve is not an elementary geometrical figure, but rather a combination of triangles and rectangles.

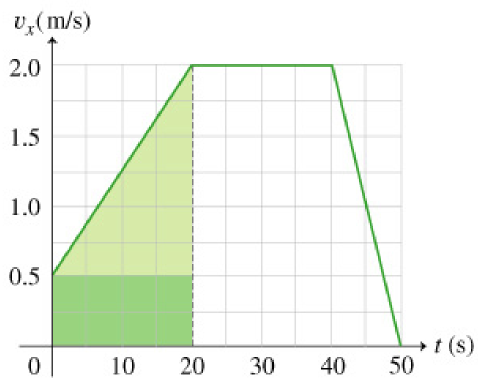
Hint 2. Find the distance traveled in the first 20.0 seconds

What is the distance Δx_1 traveled in the first 20 seconds of motion, between $t = 0.0\ \mathrm{s}$ and $t = 20.0\ \mathrm{s}$?

Express your answer in meters.

Hint 1. Area of the region under the v vs. t curve

The region under the v vs. t curve between $t = 0.0\ \mathrm{s}$ and $t = 20.0\ \mathrm{s}$ can be divided into a rectangle of dimensions $20.0\ \mathrm{s}$ by $0.50\ \mathrm{m/s}$, and a triangle of base $20.0\ \mathrm{s}$ and height $1.50\ \mathrm{m/s}$, as shown in the figure.



ANSWER:

Δx_1 = 25 m

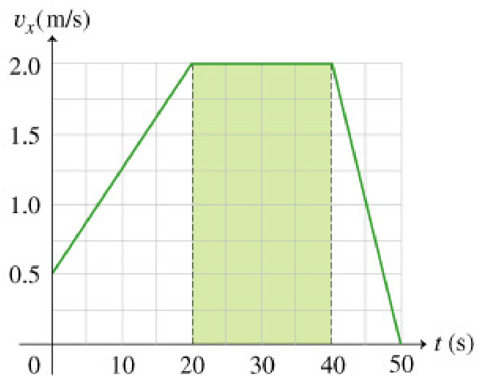
Hint 3. Find the distance traveled in the second 20.0 seconds

What is the distance Δx_2 traveled in the second 20 seconds of motion, from $t = 20.0\ \mathrm{s}$ to $t = 40.0\ \mathrm{s}$?

Express your answer in meters.

Hint 1. Area of the region under the v vs. t curve

The region under the v vs. t curve between $t = 20.0\ \mathrm{s}$ and $t = 40.0\ \mathrm{s}$ is a rectangle of dimensions $20.0\ \mathrm{s}$ by $2.00\ \mathrm{m/s}$, as shown in the figure.



ANSWER:

Δx_2 = 40 m

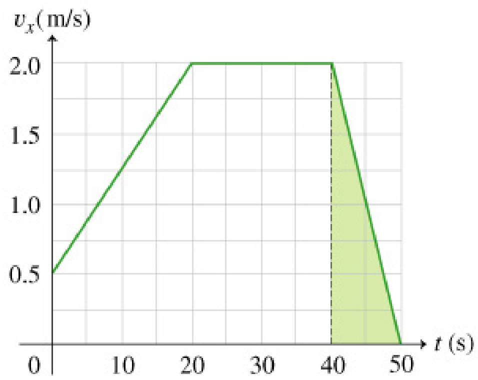
Hint 4. Find the distance traveled in the last 10.0 seconds

What is the distance Δx_3 traveled in the last 10 seconds of motion, from $t = 40.0\ \mathrm{s}$ to $t = 50.0\ \mathrm{s}$?

Express your answer in meters.

Hint 1. Area of the region under the v vs. t curve

The region under the v vs. t curve between $t = 40.0\ \mathrm{s}$ and $t = 50.0\ \mathrm{s}$ is a triangle of base $10.0\ \mathrm{s}$ and height $2.00\ \mathrm{m/s}$, as shown in the figure.



ANSWER:

Δx_3 = 10 m

Now simply add the distances traveled in each time interval to find the total distance.

ANSWER:

Δx = 75 m

Part C

What is the average acceleration a_{av} of the particle over the first 20.0 seconds?

Express your answer in meters per second per second.

Hint 1. Definition and graphical interpretation of average acceleration

The average acceleration a_{av} of a particle that travels along a straight line in a time interval Δt is the ratio of the change in velocity Δv experienced by the particle to the time interval Δt, or

$$a_{av} = \frac{\Delta v}{\Delta t}.$$

In a v vs. t graph, then, the average acceleration equals the slope of the line connecting the two points representing the initial and final velocities.

Hint 2. Slope of a line

The slope m of a line from point A, of coordinates (x_A, y_A), to point B, of coordinates (x_B, y_B), is equal to the "rise" over the "run," or

$$m = \frac{y_B - y_A}{x_B - x_A}.$$

ANSWER:

a_{av} = 0.075 m/s^2

The average acceleration of a particle between two instants of time is the slope of the line connecting the two corresponding points in a v vs. t graph.

Part D

What is the instantaneous acceleration a of the particle at $t = 45.0\ s$?

Hint 1. Graphical interpretation of instantaneous acceleration

The acceleration of a particle at any given instant of time or at any point in its path is called the instantaneous acceleration. If the v vs. t graph of the particle's motion is known, you can directly determine the instantaneous acceleration at any point on the curve. The instantaneous acceleration at any point is equal to the slope of the line tangent to the curve at that point.

Hint 2. Slope of a line

The slope m of a line from point A, of coordinates (x_A, y_A), to point B, of coordinates (x_B, y_B), is equal to the "rise" over the "run," or

$$m = \frac{y_B - y_A}{x_B - x_A}.$$

ANSWER:

a =

- ○ 1 m/s^2
- ○ 0.20 m/s^2
- ◉ -0.20 m/s^2
- ○ 0.022 m/s^2
- ○ -0.022 m/s^2

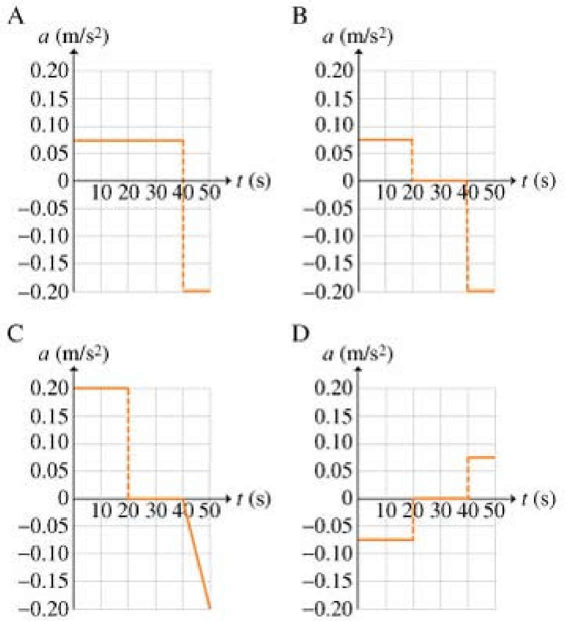
The instantaneous acceleration of a particle at any point on a v vs. t graph is the slope of the line tangent to the curve at that point. Since in the last 10 seconds of motion, between $t = 40.0\ s$ and $t = 50.0\ s$, the curve is a straight line, the tangent line is the curve itself.

Physically, this means that the instantaneous acceleration of the particle is *constant* over that time interval. This is true for any motion where velocity increases linearly with time. In the case at hand, can you think of another time interval in which the acceleration of the particle is constant?

Now that you have reviewed how to plot variables as a function of time, you can use the same technique and draw an acceleration vs. time graph, that is, the graph of (instantaneous) acceleration as a function of time. As usual in these types of graphs, time t is plotted on the horizontal axis, while the vertical axis is used to indicate acceleration a.

Part E

Which of the graphs shown below is the correct acceleration vs. time plot for the motion described in the previous parts?



Hint 1. How to approach the problem

Recall that whenever velocity increases linearly with time, acceleration is constant. In the example here, the particle's velocity increases linearly with time in the first 20.0 s of motion. In the second 20.0 s , the particle's velocity is constant, and then it decreases linearly with time in the last 10 s. This means that the particle's acceleration is constant over each time interval, but its value is different in each interval.

Hint 2. Find the acceleration in the first 20 s

What is a_1, the particle's acceleration in the first 20 s of motion, between $t = 0.0\ \mathrm{s}$ and $t = 20.0\ \mathrm{s}$?

Express your answer in meters per second per second.

Hint 1. Constant acceleration

Since we have already determined that in the first 20 s of motion the particle's acceleration is constant, its constant value will be equal to the average acceleration that you calculated in Part C.

ANSWER:

a_1 = 0.075 $\mathrm{m/s^2}$

Hint 3. Find the acceleration in the second 20 s

What is a_2, the particle's acceleration in the second 20 s of motion, between $t = 20.0\ \mathrm{s}$ and $t = 40.0\ \mathrm{s}$?

Express your answer in meters per second per second.

Hint 1. Constant velocity

In the second 20 s of motion, the particle's velocity remains unchanged. This means that in this time interval, the particle does not accelerate.

ANSWER:

a_2 = 0 $\mathrm{m/s^2}$

Hint 4. Find the acceleration in the last 10 s

What is a_3, the particle's acceleration in the last 10 s of motion, between $t = 40.0\ \mathrm{s}$ and $t = 50.0\ \mathrm{s}$?

Express your answer in meters per second per second.

Hint 1. Constant acceleration

Since we have already determined that in the last 10 s of motion the particle's acceleration is constant, its constant value will be equal to the instantaneous acceleration that you calculated in Part D.

ANSWER:

a_3 = -0.20 $\mathrm{m/s^2}$

ANSWER:

- Graph A
- Graph B
- Graph C
- Graph D

In conclusion, graphs of velocity as a function of time are a useful representation of straight-line motion. If read correctly, they can provide you with all the information you need to study the motion.

Exercise 2.5

Starting from the front door of your ranch house, you walk 60.0m due east to your windmill, and then you turn around and slowly walk 35.0m west to a bench where you sit and watch the sunrise. It takes you 30.0s to walk from your house to the windmill and then 39.0s to walk from the windmill to the bench.

Part A

For the entire trip from your front door to the bench, what is your average velocity?

Express your answer with the appropriate units.

ANSWER:

$v_{\mathrm{av}-x} = \left.\frac{s1 - s2}{t1 + t2}\right| = 0.362\,\frac{\mathrm{m}}{\mathrm{s}}$

Also accepted: $\left.\frac{s2 - s1}{t1 + t2}\right| = -0.362\,\frac{\mathrm{m}}{\mathrm{s}}$

Part B

For the entire trip from your front door to the bench, what is your average speed?

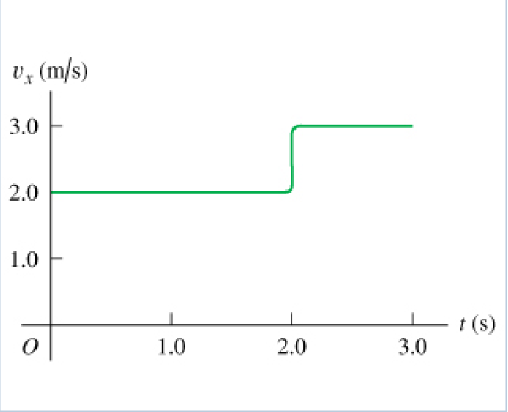
Express your answer with the appropriate units.

ANSWER:

average speed = $\frac{s1 + s2}{t1 + t2} = 1.38\,\frac{\mathrm{m}}{\mathrm{s}}$

Exercise 2.9

A ball moves in a straight line (the *x*-axis). The graph in the figure shows this ball's velocity as a function of time.



Part A

What are the ball's average velocity during the first 3.0s ?

Express your answer using two significant figures.

ANSWER:

v_{av} = $\frac{4+3(t-2)}{t}$ = 2.3 $\mathrm{m/s}$

Part B

What are the ball's average speed during the first 3.0s ?

Express your answer using two significant figures.

ANSWER:

v_{av} = $\frac{4+3(t-2)}{t}$ = 2.3 $\mathrm{m/s}$

Part C

Suppose that the ball moved in such a way that the graph segment after 2.0 s was -3.0 $\mathrm{m/s}$ instead of +3.0 $\mathrm{m/s}$. Find the ball's and average velocity during the first 3.0s in this case.

Express your answer using two significant figures.

ANSWER:

v_{av} = $\frac{4-3(t-2)}{t}$ = 0.33 $\mathrm{m/s}$

Part D

Suppose that the ball moved in such a way that the graph segment after 2.0 s was -3.0 $\mathrm{m/s}$ instead of +3.0 $\mathrm{m/s}$. Find the ball's average speed during the first 3.0s in this case.

Express your answer using two significant figures.

ANSWER:

v_{av} = $\frac{4+3(t-2)}{t}$ = 2.3 $\mathrm{m/s}$

Exercise 2.13

Part A

The table shows test data for the Bugatti Veyron, the fastest car made. The car is moving in a straight line (the *x*-axis).

Time (s)	0	2.10	20.0	53.0
Speed $(\mathrm{mi/h})$	0	60.0	210	258

Calculate the car's average acceleration (in $\mathrm{m/s^2}$) between 0 and 2.1 s.

ANSWER:

a_{av} = $\frac{v1}{2.1}$ = 12.8 $\mathrm{m/s^2}$

Part B

Calculate the car's average acceleration (in $\mathrm{m/s^2}$) between 2.1 s and 20.0 s.

ANSWER:

a_{av} = $\frac{v2-v1}{20-2.1}$ = 3.75 $\mathrm{m/s^2}$

Part C

Calculate the car's average acceleration (in $\mathrm{m/s^2}$) between 20.0 s and 53 s.

ANSWER:

a_{av} = $\frac{v3-v2}{53-20}$ = 0.650 $\mathrm{m/s^2}$

Exercise 2.29

At launch the space shuttle weighs 4.5 million pounds. When it is launched from rest, it takes 8.00 s to reach 162$\mathrm{km/h}$, and at the end of the first 1.00 min its speed is 1620$\mathrm{km/h}$.

Part A

What is the average acceleration (in $\mathrm{m/s^2}$) of the shuttle during the first 8.00 s?

ANSWER:

a_{av} = $\frac{v}{8}$ = 5.63 $\mathrm{m/s^2}$

Part B

What is the average acceleration (in $\mathrm{m/s^2}$) of the shuttle between 8.00 s and the end of the first 1.00 min?

ANSWER:

a_{av} = $\frac{v1-v}{52}$ = 7.79 $\mathrm{m/s^2}$

Part C

Assuming the acceleration is constant during each time interval (but not necessarily the same in both intervals), what distance does the shuttle travel during the first 8.00 s?

ANSWER:

x = $v{\cdot}4$ = 180 m

Part D

Assuming the acceleration is constant during each time interval (but not necessarily the same in both intervals), what distance does the shuttle travel during the interval from 8.00 s to 1.00 min?

ANSWER:

$x = (v + v1) \cdot 26$ = 1.29×10^4 m

Exercise 2.38

You throw a glob of putty straight up toward the ceiling, which is 3.00m above the point where the putty leaves your hand. The initial speed of the putty as it leaves your hand is 8.10$\mathrm{m/s}$.

Part A

What is the speed of the putty just before it strikes the ceiling?

Express your answer with the appropriate units.

ANSWER:

$v = \sqrt{vv - 2h \cdot 9.80}$ = 2.61$\frac{\mathrm{m}}{\mathrm{s}}$

Part B

How much time from when it leaves your hand does it take the putty to reach the ceiling?

Express your answer with the appropriate units.

ANSWER:

$t = \frac{v - \sqrt{vv - 2h \cdot 9.80}}{9.80}$ = 0.560s

Problem 2.97

A student is running at her top speed of 4.9$\mathrm{m/s}$ to catch a bus, which is stopped at the bus stop. When the student is still a distance 39.5m from the bus, it starts to pull away, moving with a constant acceleration of 0.171$\mathrm{m/s^2}$.

Part A

For how much time does the student have to run at 4.9$\mathrm{m/s}$ before she overtakes the bus?

ANSWER:

$t = \frac{1}{a}\left(v - \sqrt{v^2 - 2as}\right)$ = 9.70 s

Part B

For what distance does the student have to run at 4.9$\mathrm{m/s}$ before she overtakes the bus?

ANSWER:

$d = \frac{v}{a}\left(v - \sqrt{v^2 - 2as}\right)$ = 47.6 m

Part C

When she reaches the bus, how fast is the bus traveling?

ANSWER:

$v = v - \sqrt{v^2 - 2as}$ = 1.66 $\mathrm{m/s}$

Part D

If the student's top speed is 2.50$\mathrm{m/s}$, will she catch the bus?

ANSWER:

- yes
- no

Part E

What is the *minimum* speed the student must have to just catch up with the bus?

ANSWER:

$v = \sqrt{2as} = 3.68\ \mathrm{m/s}$

Part F

For what time does she have to run in that case?

ANSWER:

$t = \frac{\sqrt{2as}}{a} = 21.5\ \mathrm{s}$

Part G

For what distance does she have to run in that case?

ANSWER:

$d = 2s = 79.0\ \mathrm{m}$