1 Concepts of Motion

1.1 Motion Diagrams

1.2 The Particle Model

Exercises 1–5: Draw a motion diagram for each motion described below.

- Use the particle model to represent the object as a particle.
- Six to eight dots are appropriate for most motion diagrams.
- Number the positions in order, as shown in Figure 1.4 in the text.
- Be neat and accurate!

1. A car accelerates forward from a stop sign. It eventually reaches a steady speed of 45 mph.

2. An elevator starts from rest at the 100th floor of the Empire State Building and descends, with no stops, until coming to rest on the ground floor. (Draw this one *vertically* since the motion is vertical.)

3. A skier starts *from rest* at the top of a 30° snow-covered slope and steadily speeds up as she skies to the bottom. (Orient your diagram as seen from the *side*. Label the 30° angle.)

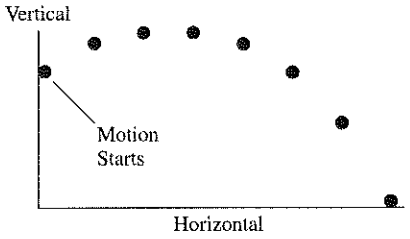
4. The space shuttle orbits the earth in a circular orbit, completing one revolution in 90 minutes.

5. Bob throws a ball at an upward 45° angle from a third-story balcony. The ball lands on the ground below.

Exercises 6–9: For each motion diagram, write a short description of the motion of an object that will match the diagram. Your descriptions should name *specific* objects and be phrased similarly to the descriptions of Exercises 1 to 5. Note the axis labels on Exercises 8 and 9.

6.

8.



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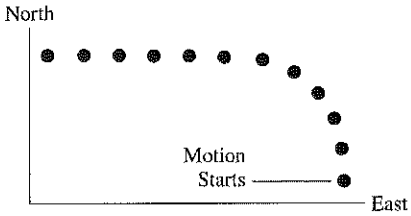
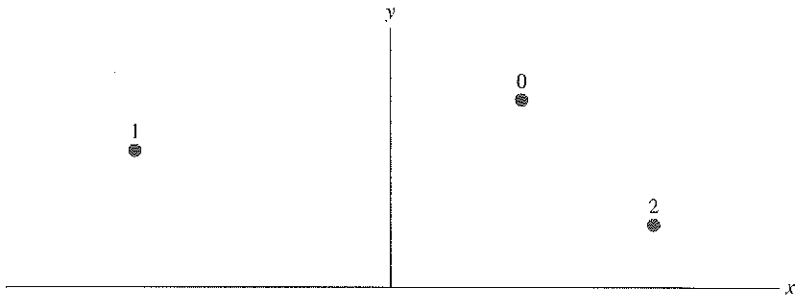
9.



1.3 Position and Time

10. The figure below shows the location of an object at three successive instants of time.



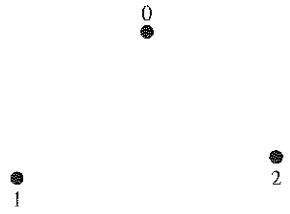
a. Use a **red** pencil to draw and label on the figure the three position vectors $\vec{r}_0$, $\vec{r}_1$, and $\vec{r}_2$ at times 0, 1, and 2.
b. Use a **blue** or **green** pencil to draw a possible trajectory from 0 to 1 to 2.
c. Use a **black** pencil to draw the displacement vector $\Delta\vec{r}$ from the initial to the final position.

11. In Exercise 10, is the object's displacement equal to the distance the object travels? Explain.

12. Redraw your motion diagrams from Exercises 1 to 4 in the space below. Then add and label the displacement vectors $\Delta\vec{r}$ on each diagram.

1.4 Velocity

13. The figure below shows the positions of a moving object in three successive frames of film. Draw and label the velocity vector $\vec{v}_0$ for the motion from 0 to 1 and the vector $\vec{v}_1$ for the motion from 1 to 2.



Exercises 14–20: Draw a motion diagram for each motion described below.

- Use the particle model.
- Show and label the *velocity* vectors.

14. A rocket-powered car on a test track accelerates from rest to a high speed, then coasts at constant speed after running out of fuel. Draw a dashed line across your diagram to indicate the point at which the car runs out of fuel.

15. Galileo drops a ball from the Leaning Tower of Pisa. Consider the ball's motion from the moment it leaves his hand until a microsecond before it hits the ground. Your diagram should be vertical.

16. An elevator starts from rest at the ground floor. It accelerates upward for a short time, then moves with constant speed, and finally brakes to a halt at the tenth floor. Draw dashed lines across your diagram to indicate where the acceleration stops and where the braking begins. You'll need 10 or 12 points to indicate the motion clearly.

17. A bowling ball being returned from the pin area to the bowler starts out rolling at a constant speed. It then goes up a ramp and exits onto a level section at very low speed. You'll need 10 or 12 points to indicate the motion clearly.

18. A track star runs once around a running track at constant speed. The track has straight sides and semi-circular ends. Use a bird's-eye view looking down on the track. Use about 20 points for your motion diagram.

19. A car is parked on a hill. The brakes fail, and the car rolls down the hill with an ever-increasing speed. At the bottom of the hill it runs into a thick hedge and gently comes to a halt.

20. Andy is standing on the street. Bob is standing on the second-floor balcony of their apartment, about 30 feet back from the street. Andy throws a baseball to Bob. Consider the ball's motion from the moment it leaves Andy's hand until a microsecond before Bob catches it.

1.5 Linear Acceleration

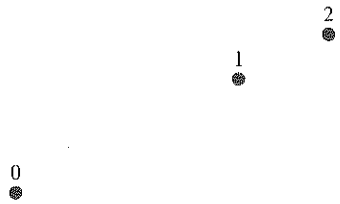
Note: Beginning with this section, and for future motion diagrams, you will "color code" the vectors. Draw velocity vectors **black** and acceleration vectors **red**.

Exercises 21–24: The figures below show an object's position in three successive frames of film. The object is moving in the direction 0 → 1 → 2. For each diagram:

- Draw and label the initial and final velocity vectors $\vec{v}_0$ and $\vec{v}_1$. Use **black**.
- Use the steps of Tactics Box 1.3 to find the change in velocity $\Delta\vec{v}$.
- Draw and label $\vec{a}$ next to dot 1 on the motion diagram. Use **red**.
- Determine whether the object is speeding up, slowing down, or moving at a constant speed. Write your answer beside the diagram.

21. 

22. 

23. 

24. 

Exercises 25–29: Draw a complete motion diagram for each of the following.

- Draw and label the velocity vectors $\vec{v}$. Use **black**.
- Draw and label the acceleration vectors $\vec{a}$. Use **red**.

25. Galileo drops a ball from the Leaning Tower of Pisa. Consider its motion from the moment it leaves his hand until a microsecond before it hits the ground.

26. Trish is driving her car at a steady 30 mph when a small furry creature runs into the road in front of her. She hits the brakes and skids to a stop. Show her motion from 2 seconds before she starts braking until she comes to a complete stop.

27. A ball rolls up a smooth board tilted at a 30° angle. Then it rolls back to its starting position.

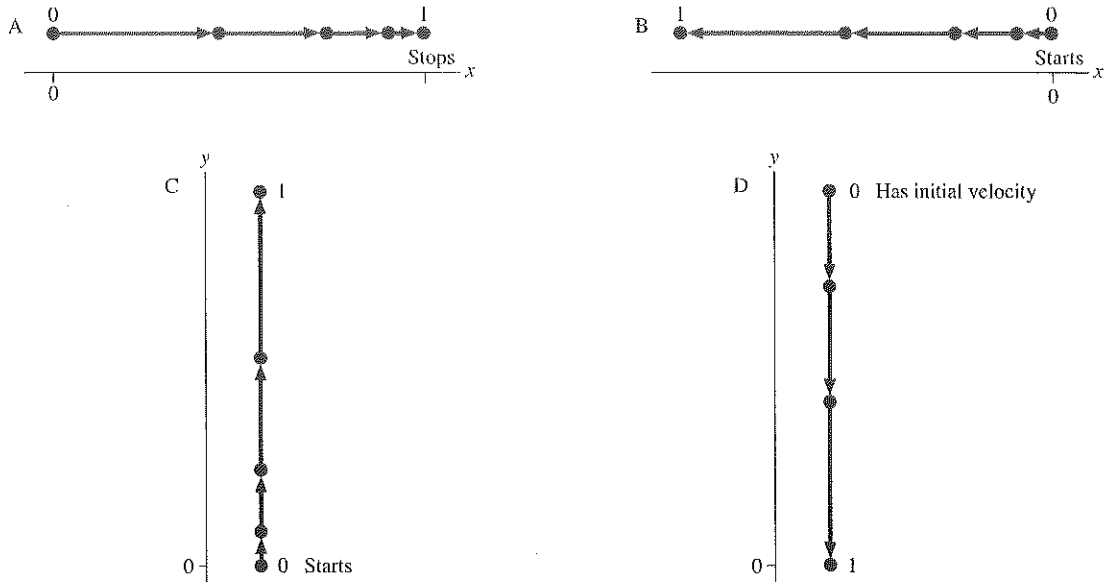
28. A bowling ball being returned from the pin area to the bowler rolls at a constant speed, then up a ramp, and finally exits onto a level section at very low speed.

29. Two sprinters, Cynthia and Diane, start side by side. Diane has run only 80 m when Cynthia crosses the finish line of the 100 m dash.

1.6 Motion in One Dimension

1.7 Solving Problems in Physics

30. The four motion diagrams below show an initial point 0 and a final point 1. A pictorial representation would define the five symbols: x_0, x_1, v_{0x}, v_{1x}, and a_x for horizontal motion and equivalent symbols with y for vertical motion. Determine whether each of these quantities is positive, negative, or zero. Give your answer by writing +, −, or 0 in the table below.



	A	B	C	D
x_0 or y_0				
x_1 or x_1				
v_{0x} or v_{0y}				
v_{1x} or v_{1x}				
a_x or a_y				

31. The three symbols x, v_x, and a_x have eight possible combinations of *signs*. For example, one combination is $(x, v_x, a_x) = (+, -, +)$.

a. List all eight combinations of signs for x, v_x, a_x.

1. _____ 5. _____

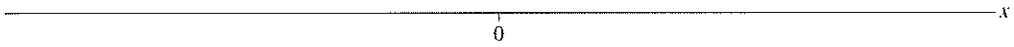
2. _____ 6. _____

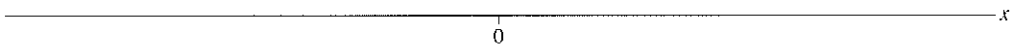
3. _____ 7. _____

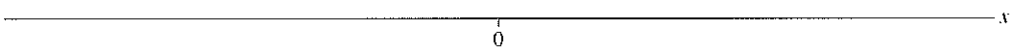
4. _____ 8. _____

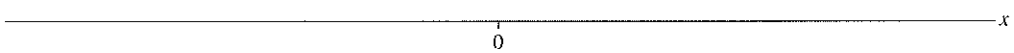
b. For each of the eight combinations of signs you identified in part a:

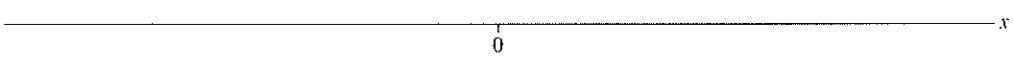
- Draw a four-dot motion diagram of an object that has these signs for x, v_x, and a_x.
- Draw the diagram *above* the axis whose number corresponds to part a.
- Use **black** and **red** for your $\vec{v}$ and $\vec{a}$. vectors. Be sure to label the vectors.

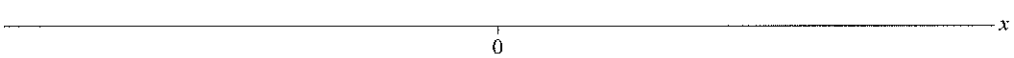
1. 

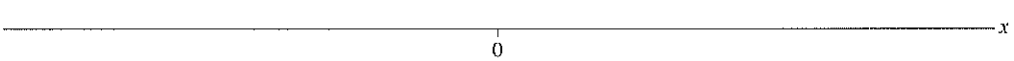
2. 

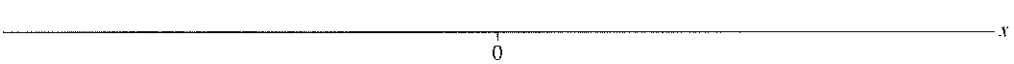
3. 

4. 

5. 

6. 

7. 

8. 

32. Sketch position-versus-time graphs for the following motions. Include a numerical scale on both axes with units that are *reasonable* for this motion. Some numerical information is given in the problem, but for other quantities make reasonable estimates.

Note: A *sketched* graph simply means hand-drawn, rather than carefully measured and laid out with a ruler. But a sketch should still be neat and as accurate as is feasible by hand. It also should include labeled axes and, if appropriate, tick-marks and numerical scales along the axes.

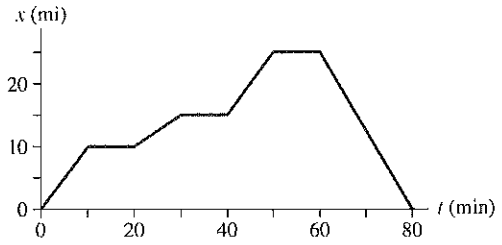
a. A student walks to the bus stop, waits for the bus, then rides to campus. Assume that all the motion is along a straight street.

b. A student walks slowly to the bus stop, realizes he forgot his paper that is due, and *quickly* walks home to get it.

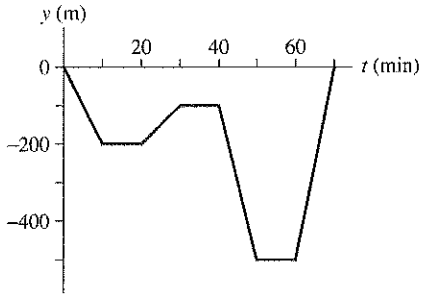
c. The quarterback drops back 10 yards from the line of scrimmage, then throws a pass 20 yards to the tight end, who catches it and sprints 20 yards to the goal. Draw your graph for the *football*. Think carefully about what the slopes of the lines should be.

33. Interpret the following position-versus-time graphs by writing a very short "story" of what is happening. Be creative! Have characters and situations! Simply saying that "a car moves 100 meters to the right" doesn't qualify as a story. Your stories should make *specific reference* to information you obtain from the graphs, such as distances moved or time elapsed.

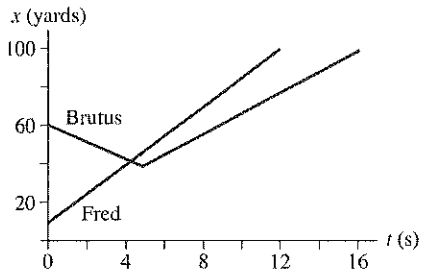
a. Moving car



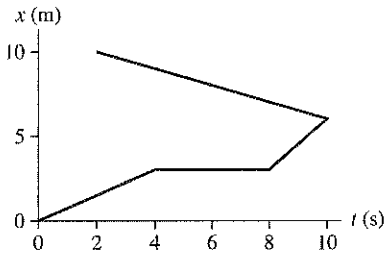
b. Submarine



c. Two football players



34. Can you give an interpretation to this position-versus-time graph? If so, then do so. If not, why not?



1.8 Units and Significant Figures

35. Convert the following to SI units. Work across the line and show all steps in the conversion.

a. 9.12 μs ×

b. 3.42 km ×

c. 44 cm/ms ×

d. 80 km/h ×

e. 60 mph ×

f. 8 in ×

g. 14 in^2 ×

h. 250 cm^3 ×

Note: Think carefully about g and h. A picture may help.

36. Use Table 1.5 to assess whether or not the following statements are *reasonable*.

a. Joe is 180 cm tall.

b. I rode my bike to campus at a speed of 50 m/s.

c. A skier reaches the bottom of the hill going 25 m/s.

d. I can throw a ball a distance of 2 km.

e. I can throw a ball at a speed of 50 km/h.

37. Justify the assertion that 1 m/s ≈ 2 mph by *exactly* converting 1 m/s to English units. By what percentage is this rough conversion in error?

38. How many significant figures does each of the following numbers have?

a. 6.21	e. 0.0621	i. 1.0621
b. 62.1	f. 0.620	j. 6.21×10^{3}
c. 6210	g. 0.62	k. 6.21×10^{-3}
d. 6210.0	h. .62	l. 6.21×10^{3}

39. Compute the following numbers, applying the significant figure standards adopted for this text.

a. $33.3\times25.4=$	e. $2.345\times3.321=$
b. $33.3-25.4=$	f. $(4.32\times1.23)-5.1=$
c. $33.3\div45.1=$	g. $33.3^{2}=$
d. $33.3\times45.1=$	h. $\sqrt{33.3}=$

2 Kinematics in One Dimension

2.1 Uniform Motion

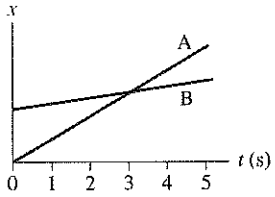
1. Sketch position-versus-time graphs (x versus t or y versus t) for the following motions. Include appropriate numerical scales along both axes. A small amount of computation may be necessary.

   a. A parachutist opens her parachute at an altitude of 1500 m. She then descends slowly to earth at a steady speed of 5 m/s. Start your graph as her parachute opens.

   b. Trucker Bob starts the day 120 miles west of Denver. He drives east for 3 hours at a steady 60 miles/hour before stopping for his coffee break. Let Denver be located at $x = 0$ mi and assume that the x-axis points to the east.

   c. Quarterback Bill throws the ball to the right at a speed of 15 m/s. It is intercepted 45 m away by Carlos, who is running to the left at 7.5 m/s. Carlos carries the ball 60 m to score. Let $x = 0$ m be the point where Bill throws the ball. Draw the graph for the *football*.

2. The figure shows a position-versus-time graph for the motion of objects A and B that are moving along the same axis.

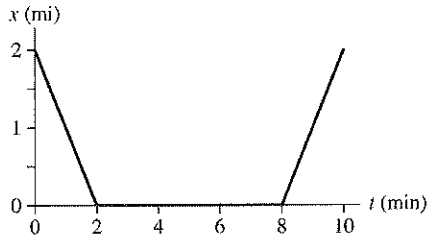


a. At the instant $t = 1$ s, is the speed of A greater than, less than, or equal to the speed of B? Explain.

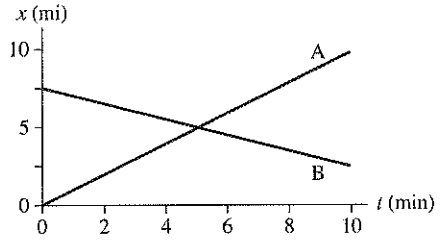
b. Do objects A and B ever have the *same* speed? If so, at what time or times? Explain.

3. Interpret the following position-versus-time graphs by writing a short "story" about what is happening. Your stories should make specific references to the *speeds* of the moving objects, which you can determine from the graphs. Assume that the motion takes place along a horizontal line.

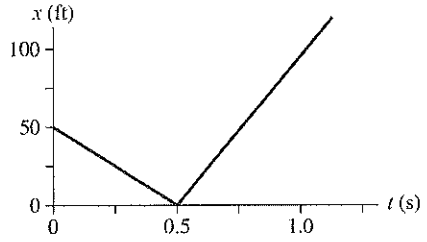
a.



b.

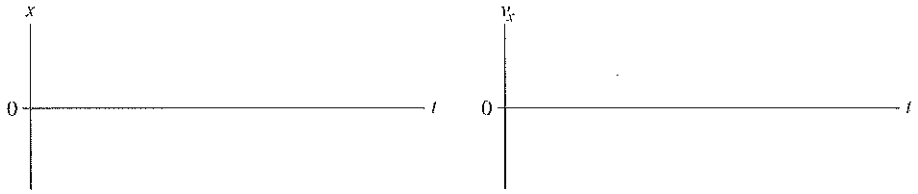


c.

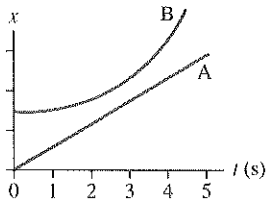


2.2 Instantaneous Velocity

4. Draw both a position-versus-time graph *and* a velocity-versus-time graph for an object at rest at $x = 1$ m.



5. The figure shows the position-versus-time graphs for two objects, A and B, that are moving along the same axis.

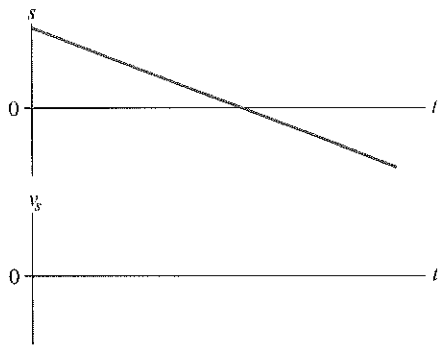


a. At the instant $t = 1$ s, is the speed of A greater than, less than, or equal to the speed of B? Explain.

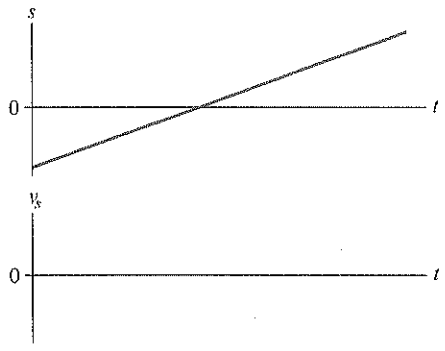
b. Do objects A and B ever have the *same* speed? If so, at what time or times? Explain.

6. Below are six position-versus-time graphs. For each, draw the corresponding velocity-versus-time graph directly below it. A vertical line drawn through both graphs should connect the velocity v_s at time t with the position s at the *same* time t. There are no numbers, but your graphs should correctly indicate the *relative* speeds.

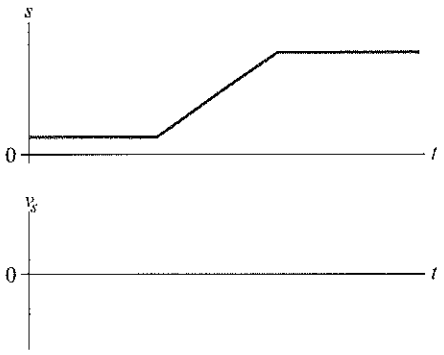
a.



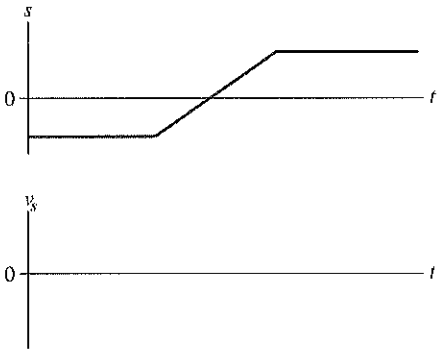
b.



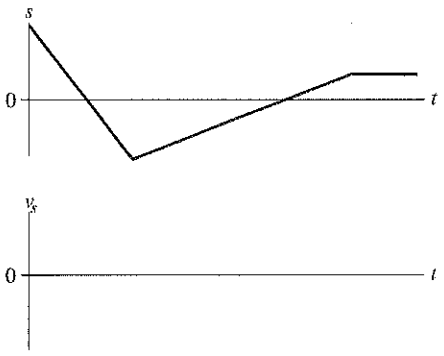
c.



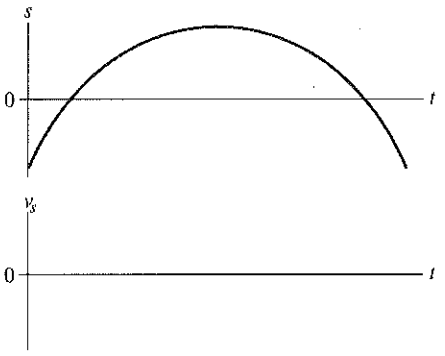
d.



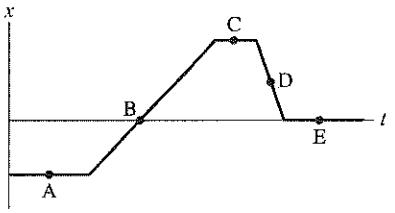
e.



f.

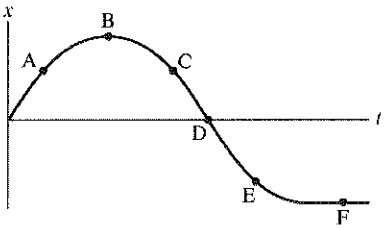


7. The figure shows a position-versus-time graph for a moving object. At which lettered point or points:



   a. Is the object *moving* the slowest? _____
   b. Is the object moving the fastest? _____
   c. Is the object at rest? _____
   d. Does the object have a constant nonzero velocity? _____
   e. Is the object moving to the left? _____

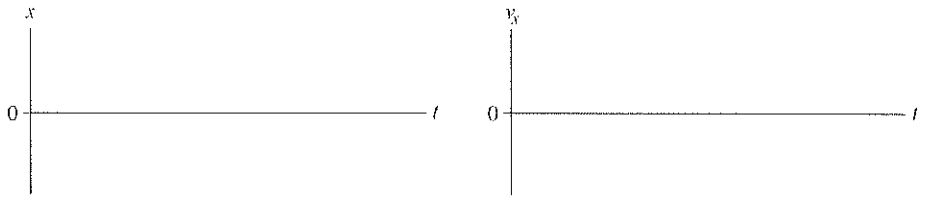
8. The figure shows a position-versus-time graph for a moving object. At which lettered point or points:



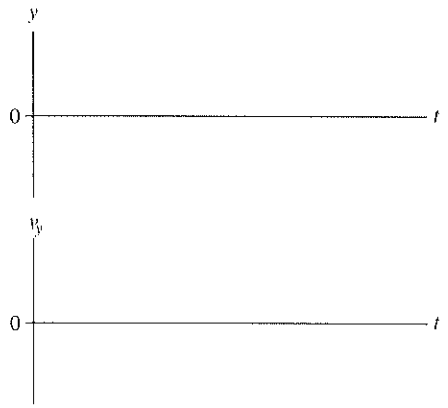
   a. Is the object moving the fastest? _____
   b. Is the object moving to the left? _____
   c. Is the object speeding up? _____
   d. Is the object slowing down? _____
   e. Is the object turning around? _____

9. For each of the following motions, draw
   - A motion diagam,
   - A position-versus-time graph, and
   - A velocity-versus-time graph.

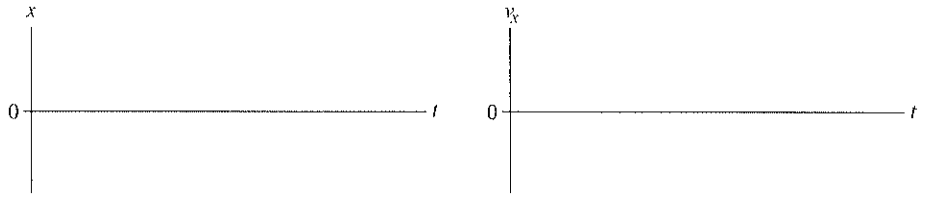
a. A car starts from rest, steadily speeds up to 40 mph in 15 s, moves at a constant speed for 30 s, then comes to a halt in 5 s.



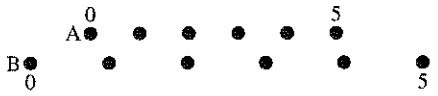
b. A rock is dropped from a bridge and steadily speeds up as it falls. It is moving at 30 m/s when it hits the ground 3 s later. Think carefully about the signs.



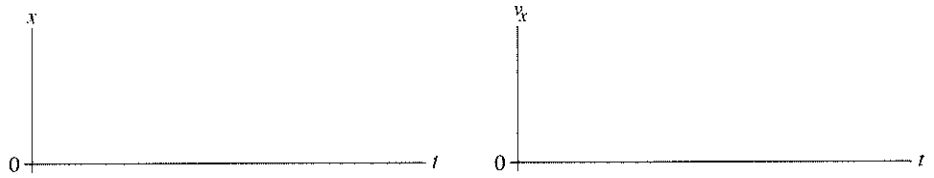
c. A pitcher winds up and throws a baseball with a speed of 40 m/s. One-half second later the batter hits a line drive with a speed of 60 m/s. The ball is caught 1 s after it is hit. From where you are sitting, the batter is to the right of the pitcher. Draw your motion diagram and graph for the *horizontal* motion of the ball.



10. The figure shows six frames from the motion diagram of two moving cars, A and B.



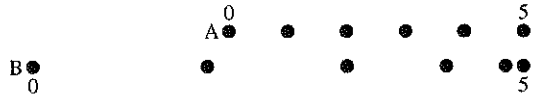
a. Draw both a position-versus-time graph and a velocity-versus-time graph. Show the motion of *both* cars on each graph. Label them A and B.



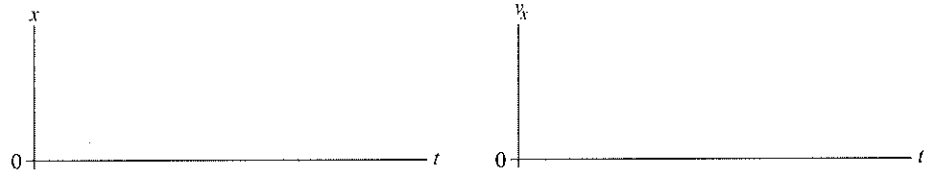
b. Do the two cars ever have the same position at one instant of time?
If so, in which frame number (or numbers)? _____
Draw a vertical line through your graphs of part a to indicate this instant of time.

c. Do the two cars ever have the same velocity at one instant of time?
If so, between which two frames? _____

11. The figure shows six frames from the motion diagram of two moving cars, A and B.



a. Draw both a position-versus-time graph and a velocity-versus-time graph. Show *both* cars on each graph. Label them A and B.



b. Do the two cars ever have the same position at one instant of time?
If so, in which frame number (or numbers)? _____
Draw a vertical line through your graphs of part a to indicate this instant of time.

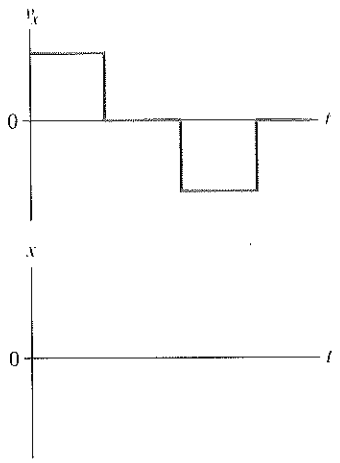
c. Do the two cars ever have the same velocity at one instant of time?
If so, between which two frames? _____

2.3 Finding Position from Velocity

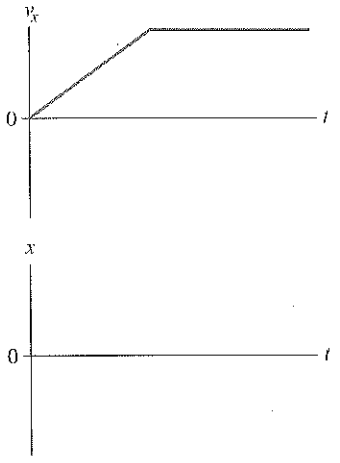
12. Below are shown four velocity-versus-time graphs. For each:
    - Draw the corresponding position-versus-time graph.
    - Give a written description of the motion.

    Assume that the motion takes place along a horizontal line and that $x_0 = 0$.

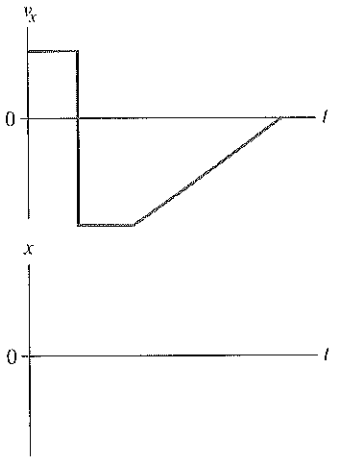
a.



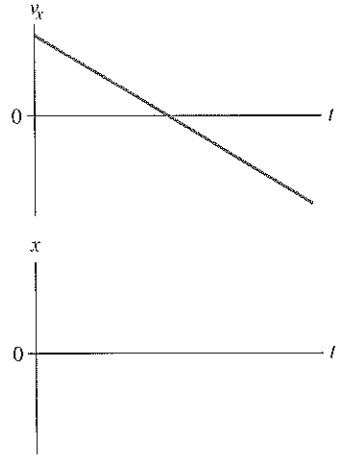
b.



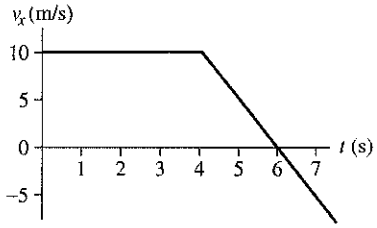
c.



d.



13. The figure shows the velocity-versus-time graph for a moving object whose initial position is $x_0 = 20$ m. Find the object's position graphically, using the geometry of the graph, at the following times.



a. At $t = 3$ s.

b. At $t = 5$ s.

c. At $t = 7$ s.

d. You should have found a simple relationship between your answers to parts b and c. Can you explain this? What is the object doing?

2.4 Motion with Constant Acceleration

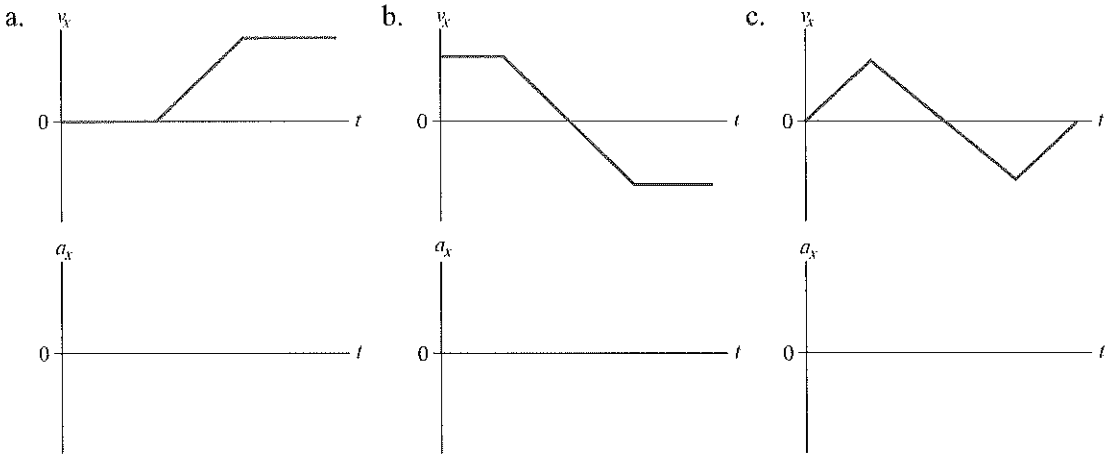
14. Give a specific example for each of the following situations. For each, provide:
    - A description, and
    - A motion diagram.

a. $a_x = 0$ but $v_x \neq 0$.

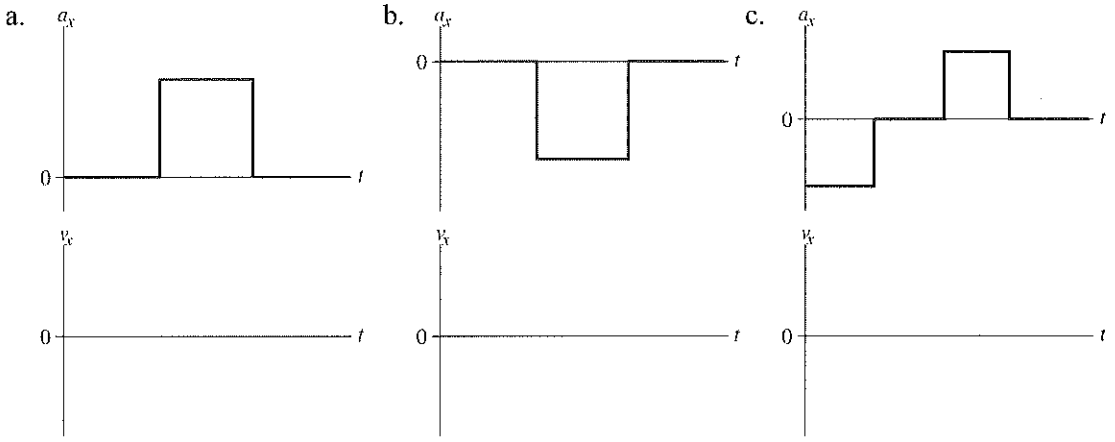
b. $v_x = 0$ but $a_x \neq 0$.

c. $v_x < 0$ and $a_x > 0$.

15. Below are three velocity-versus-time graphs. For each:
    - Draw the corresponding acceleration-versus-time graph.
    - Draw a motion diagram below the graphs.



16. Below are three acceleration-versus-time graphs. For each, draw the corresponding velocity-versus-time graph. Assume that $v_{0x} = 0$.

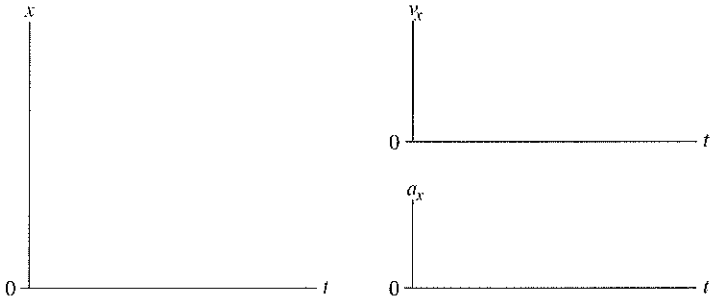


17. The figure below shows nine frames from the motion diagram of two cars. Both cars begin to accelerate, with constant acceleration, in frame 3.

a. Which car has the larger initial velocity? _____ The larger final velocity? _____

b. Which car has the larger acceleration after frame 3? How can you tell?

c. Draw position, velocity, and acceleration graphs, showing the motion of both cars on each graph. (Label them A and B.) This is a total of three graphs with two curves on each.



d. Do the cars ever have the same position at one instant of time? If so, in which frame? _____

e. Do the two cars ever have the same velocity at one instant of time? _____

If so, identify the *two* frames between which this velocity occurs. _____

Identify this instant on your graphs by drawing a vertical line through the graphs.

2.5 Free Fall

18. A ball is thrown straight up into the air. At each of the following instants, is the magnitude of the ball's acceleration greater than g, equal to g, less than g, or zero?

    a. Just after leaving your hand?

    b. At the very top (maximum height)?

    c. Just before hitting the ground?

19. A rock is *thrown* (not dropped) straight down from a bridge into the river below.

    a. Immediately *after* being released, is the magnitude of the rock's acceleration greater than g, less than g, or equal to g? Explain.

    b. Immediately before hitting the water, is the magnitude of the rock's acceleration greater than g, less than g, or equal to g? Explain.

20. A model rocket is launched straight up with constant acceleration a. It runs out of fuel at time t.
PSS 2.1 Suppose you need to determine the maximum height reached by the rocket. We'll assume that air resistance is negligible.

a. Is the rocket at maximum height the instant it runs out of fuel? _____

b. Is there anything other than gravity acting on the rocket after it runs out of fuel? _____

c. What is the name of motion under the influence of only gravity? _____

d. Draw a pictorial representation for this problem. You should have three identified points in the motion: launch, out of fuel, maximum height. Call these points 1, 2, and 3.
   - Using subscripts, define 11 quantities: y, v_y, and t at each of the three points, plus acceleration a_1 connecting points 1 and 2 and acceleration a_2 connecting points 2 and 3.
   - Identify 7 of these quantities as Knowns, either 0 or given symbolically in terms of a, t, and g. Be careful with signs!
   - Identify which one of the 4 unknown quantities you're trying to find.

e. This is a two-part problem. Write two kinematic equations for the first part of the motion to determine—again symbolically—the two unknown quantities at point 2.

f. Now write a kinematic equation for the second half of the motion that will allow you to find the desired unknown that will answer the question. Your equation should not contain the fourth unknown quantity. Just write the equation; don't solve it yet.

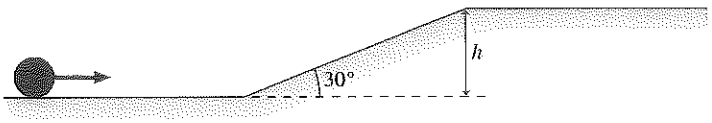
g. Now, substitute what you learned in part e into your equation of part f, do the algebra to solve for the unknown, and simplify the result as much as possible.

2.6 Motion on an Inclined Plane

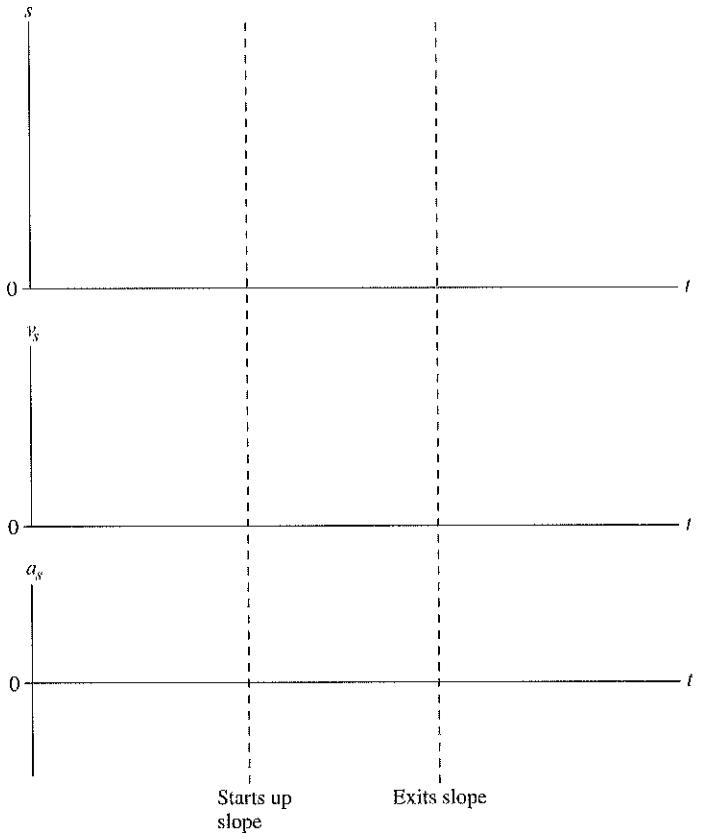
21. A ball released from rest on an inclined plane accelerates down the plane at 2 m/s^2. Complete the table below showing the ball's velocities at the times indicated. Do *not* use a calculator for this; this is a reasoning question, not a calculation problem.

Time (s)	Velocity (m/s)
0	0
1	
2	
3	
4	
5	

22. A bowling ball rolls along a level surface, then up a 30° slope, and finally exits onto another level surface at a much slower speed.



a. Draw position-, velocity-, and acceleration-versus-time graphs for the ball.



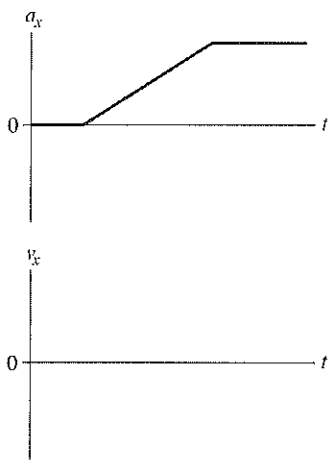
b. Suppose that the ball's initial speed is 5.0 m/s and its final speed is 1.0 m/s. Draw a pictorial representation that you would use to determine the height h of the slope. Establish a coordinate system, define all symbols, list known information, and identify desired unknowns.

Note: Don't actually solve the problem. Just draw the complete pictorial representation that you would use as a first step in solving the problem.

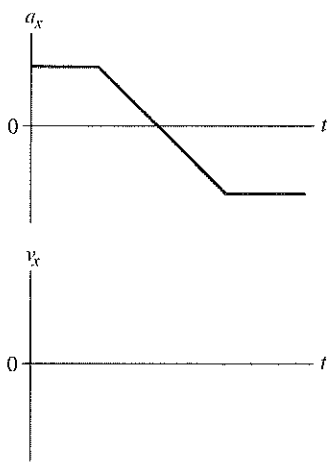
2.7 Instantaneous Acceleration

23. Below are two acceleration-versus-time curves. For each, draw the corresponding velocity-versus-time curve. Assume that $v_{0x} = 0$.

a.



b.



3 Vectors and Coordinate Systems

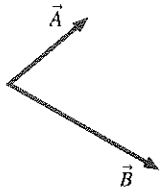
3.1 Vectors

3.2 Properties of Vectors

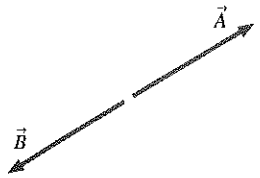
Exercises 1–3: Draw and label the vector sum $\vec{A}+\vec{B}$.

1.

2.



3.



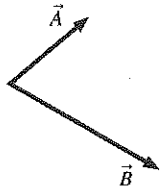
4. Use a figure and the properties of vector addition to show that vector addition is associative. That is, show that

$$(\vec{A}+\vec{B})+\vec{C}=\vec{A}+(\vec{B}+\vec{C})$$

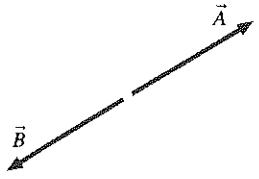
Exercises 5–7: Draw and label the vector difference $\vec{A}-\vec{B}$.

5.

6.



7.



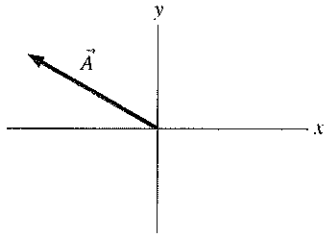
8. Draw and label the vector $2\vec{A}$ and the vector $\frac{1}{2}\vec{A}$.

9. Given vectors $\vec{A}$ and $\vec{B}$ below, find the vector $\vec{C} = 2\vec{A} - 3\vec{B}$.

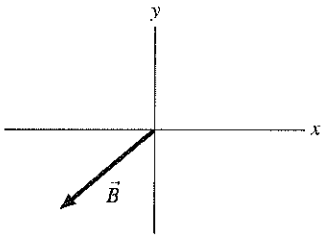
3.3 Coordinate Systems and Vector Components

Exercises 10–12: Draw and label the x- and y-component vectors of the vector shown.

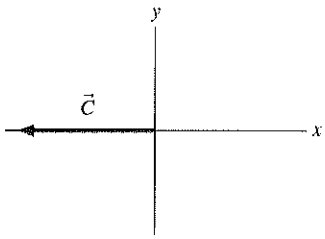
10.



11.

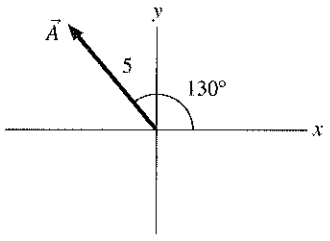


12.

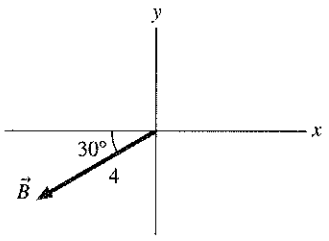


Exercises 13–15: Determine the numerical values of the x- and y-components of each vector.

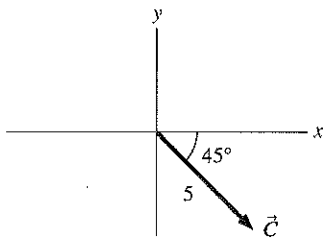
13.



14.



15.

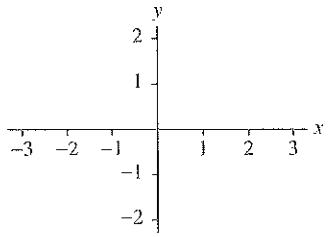


$A_x =$ _____ $B_x =$ _____ $C_x =$ _____

$A_y =$ _____ $B_y =$ _____ $C_y =$ _____

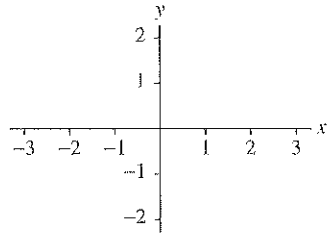
Exercises 16–18: Draw and label the vector with these components. Then determine the magnitude of the vector.

16. $A_x = 3, A_y = -2$



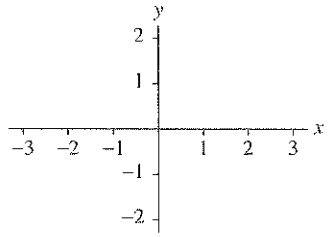
$A =$ _____

17. $B_x = -2, B_y = 2$



$B =$ _____

18. $C_x = 0, C_y = -2$

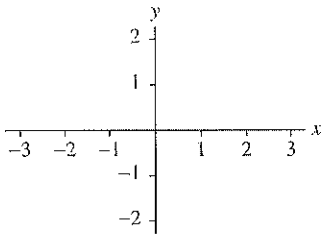


$C =$ _____

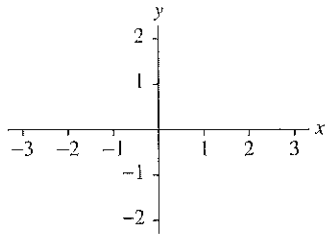
3.4 Vector Algebra

Exercises 19–21: Draw and label the vectors on the axes.

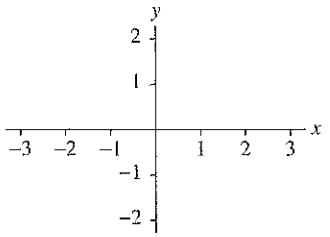
19. $\vec{A} = -\hat{\imath} + 2\hat{\jmath}$



20. $\vec{B} = -2\hat{\jmath}$

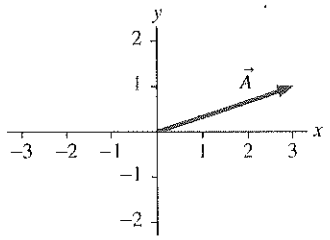


21. $\vec{C} = 3\hat{\imath} - 2\hat{\jmath}$



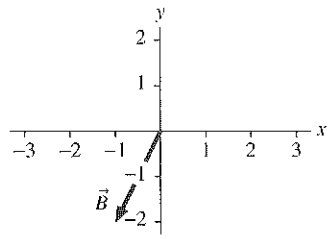
Exercises 22–24: Write the vector in component form (e.g., $3\hat{\imath} + 2\hat{\jmath}$).

22.



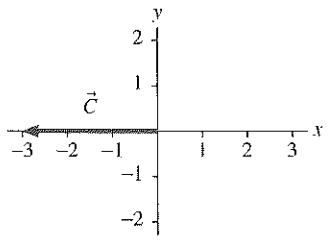
$\vec{A} =$ _____

23.



$\vec{B} =$ _____

24.



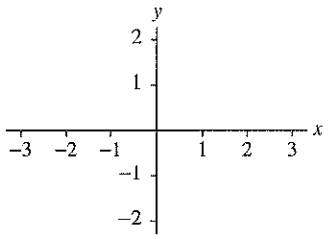
$\vec{C} =$ _____

25. What is the vector sum $\vec{D} = \vec{A} + \vec{B} + \vec{C}$ of the three vectors defined in Exercises 22–24? Write your answer in *component* form.

Exercises 26–28: For each vector:

- Draw the vector on the axes provided.
- Draw and label an angle θ to describe the direction of the vector.
- Find the magnitude and the angle of the vector.

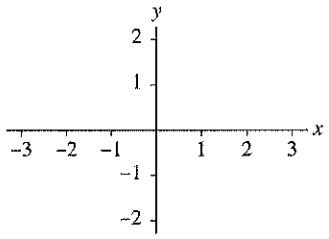
26. $\vec{A} = 2\hat{\imath} + 2\hat{\jmath}$



$A =$ _____

$\theta =$ _____

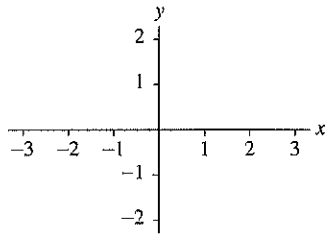
27. $\vec{B} = -2\hat{\imath} + 2\hat{\jmath}$



$B =$ _____

$\theta =$ _____

28. $\vec{C} = 3\hat{\imath} + \hat{\jmath}$

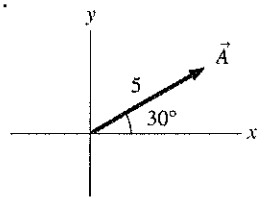


$C =$ _____

$\theta =$ _____

Exercises 29–31: Define vector $\vec{A} = (5, 30°$ above the horizontal). Determine the components A_x and A_y in the three coordinate systems shown below. Show your work below the figure.

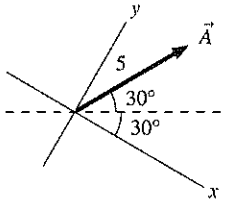
29.



$A_x =$ _____

$A_y =$ _____

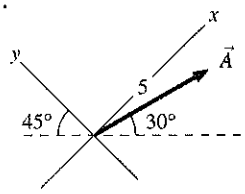
30.



$A_x =$ _____

$A_y =$ _____

31.



$A_x =$ _____

$A_y =$ _____

4 Kinematics in Two Dimensions

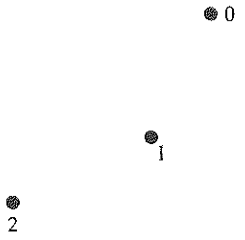
4.1 Acceleration

Exercises 1–2: The figures below show an object's position in three successive frames of film. The object is moving in the direction 0 → 1 → 2. For each diagram:

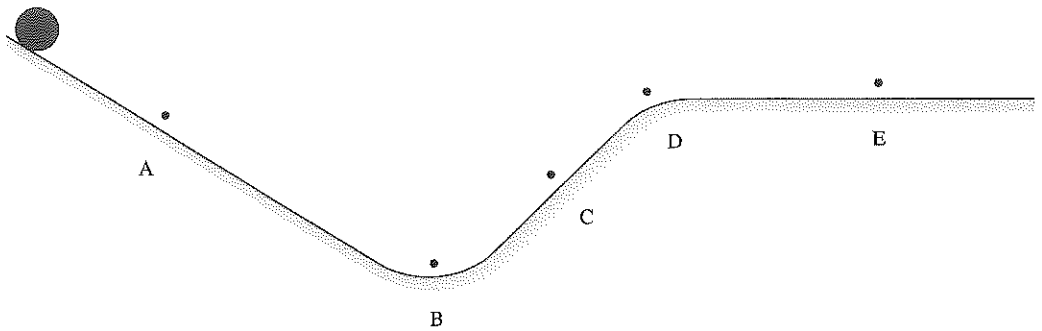
- Draw and label the initial and final velocity vectors $\vec{v}_0$ and $\vec{v}_1$. Use **black**.
- Use the steps of Figures 4.2 and 4.3 to find the change in velocity $\Delta\vec{v}$.
- Draw and label $\vec{a}$ next to dot 1 on the motion diagram. Use **red**.
- Determine whether the object is speeding up, slowing down, or moving at a constant speed. Write your answer beside the diagram.

1.

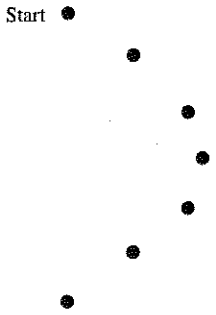
2.



3. The figure shows a ramp and a ball that rolls along the ramp. Draw vector arrows on the figure to show the ball's acceleration at each of the lettered points A to E (or write $\vec{a} = \vec{0}$, if appropriate).
Hint: At each point is the ball changing speed, changing direction, or both?



4. Complete the motion diagram for this trajectory, showing velocity and acceleration vectors.



Exercises 5–6: Draw a complete motion diagram for each of the following.

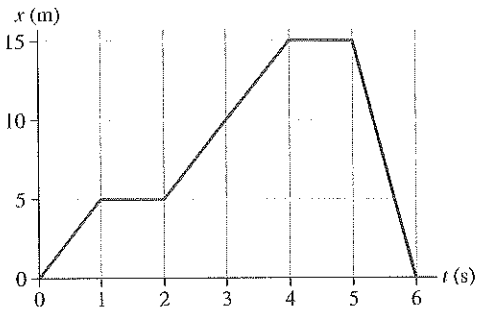
- Draw and label the velocity vectors $\vec{v}$. Use **black**.
- Draw and label the acceleration vectors $\vec{a}$. Use **red**.

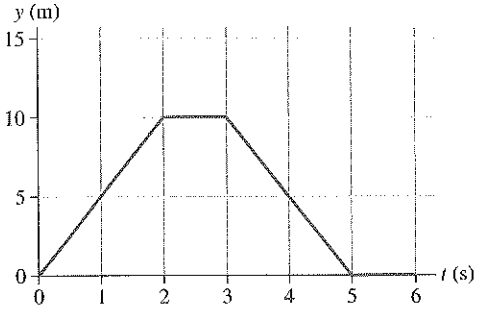
5. A cannon ball is fired from a Civil War cannon up onto a high cliff. Show the cannon ball's motion from the instant it leaves the cannon until a microsecond before it hits the ground.

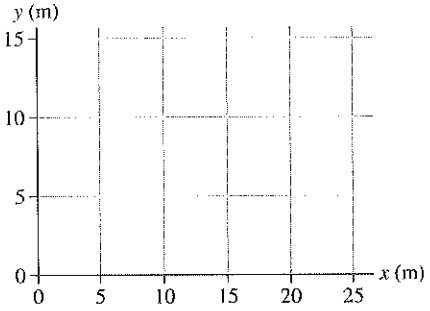
6. A plane flying north at 300 mph turns slowly to the west without changing speed, then continues to fly west. Draw the motion diagram from a viewpoint above the plane.

4.2 Two-Dimensional Kinematics

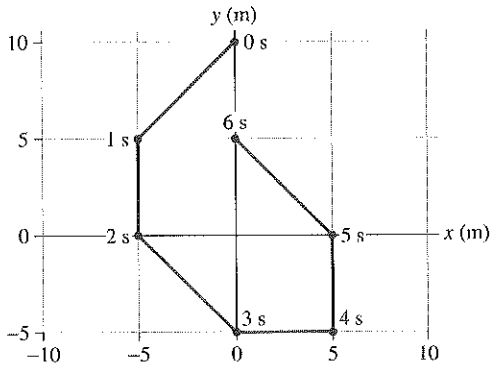
7. A particle moving in the xy-plane has the x-versus-t graph and the y-versus-t graphs shown below. Use the grid to draw a y-versus-x graph of the trajectory.

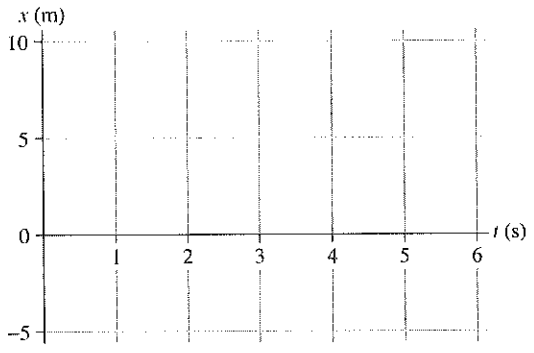


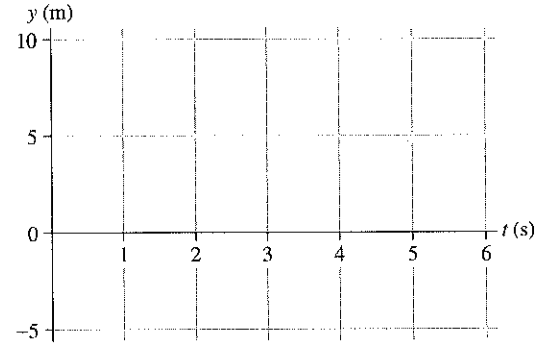




8. The trajectory of a particle is shown below. The particle's position is indicated with dots at 1-second intervals. The particle moves between each pair of dots at constant speed. Draw x-versus-t and y-versus-t graphs for the particle.

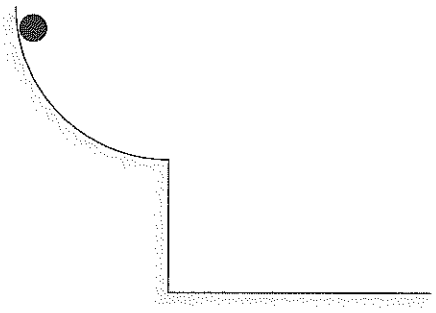




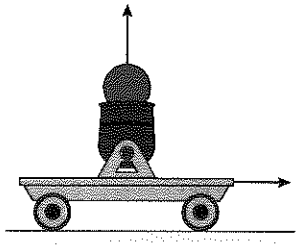


4.3 Projectile Motion

9. The figure shows a ball that rolls down a quarter-circle ramp, then off a cliff. Sketch the ball's trajectory from the instant it is released until it hits the ground.

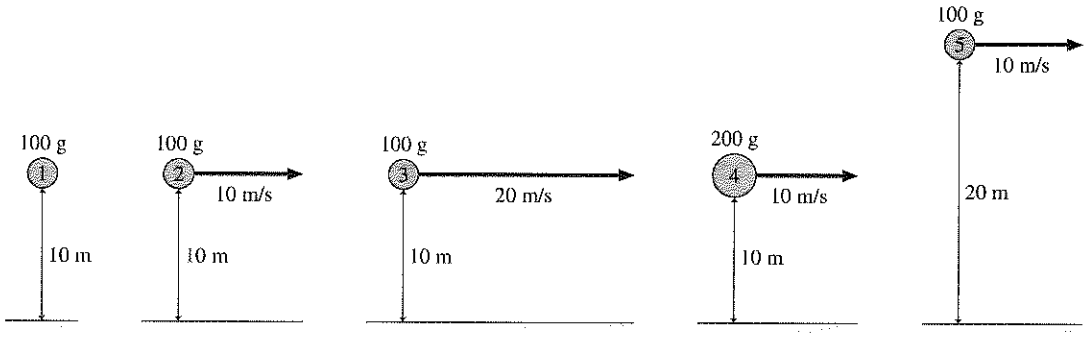


10. a. A cart that is rolling at constant velocity fires a ball straight up. When the ball comes back down, will it land in front of the launching tube, behind the launching tube, or directly in the tube? Explain.



b. Will your answer change if the cart is accelerating in the forward direction? If so, how?

11. Rank in order, from shortest to longest, the amount of time it takes each of these projectiles to hit the ground. Ignore air resistance. (Some may be simultaneous.)

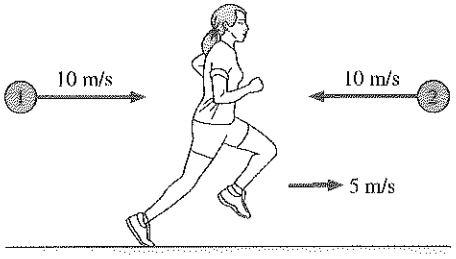


Order:

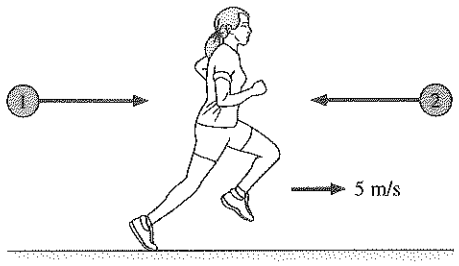
Explanation:

4.4 Relative Motion

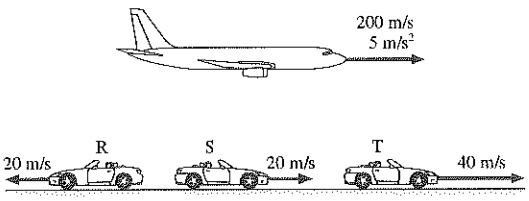
12. Anita is running to the right at 5 m/s. Balls 1 and 2 are thrown toward her at 10 m/s by friends standing on the ground. According to Anita, which ball is moving faster? Or are both speeds the same? Explain.



13. Anita is running to the right at 5 m/s. Balls 1 and 2 are thrown toward her by friends standing on the ground. According to Anita, both balls are approaching her at 10 m/s. Which ball was thrown at a faster speed? Or were they thrown with the same speed? Explain.

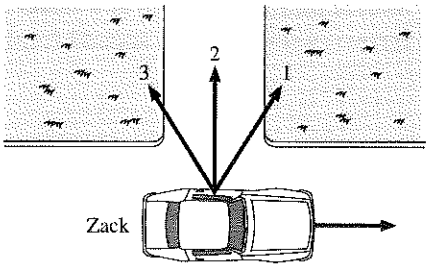


14. Ryan, Samantha, and Tomas are driving their convertibles at a steady speed. At the same instant, they each see a jet plane with an instantaneous velocity of 200 m/s and an acceleration of 5 m/s^2 relative to the ground. Rank in order, from largest to smallest, the jet's *speed* v_R, v_S, and v_T according to Ryan, Samantha, and Tomas. Explain.

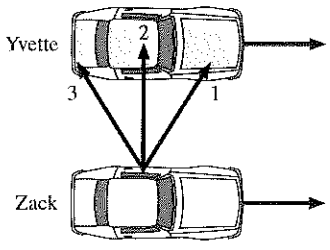


15. An electromagnet on the ceiling of an airplane holds a steel ball. When a button is pushed, the magnet releases the ball. The experiment is first done while the plane is parked on the ground, and the point where the ball hits the floor is marked with an X. Then the experiment is repeated while the plane is flying level at a steady 500 mph. Does the ball land slightly in front of the X (toward the nose of the plane), on the X, or slightly behind the X (toward the tail of the plane)? Explain.

16. Zack is driving past his house. He wants to toss his physics book out the window and have it land in his driveway. If he lets go of the book exactly as he passes the end of the driveway, should he direct his throw outward and toward the front of the car (throw 1), straight outward (throw 2), or outward and toward the back of the car (throw 3)? Explain. (Ignore air resistance.)



17. Yvette and Zack are driving down the freeway side by side with their windows rolled down. Zack wants to toss his physics book out the window and have it land in Yvette's front seat. Should he direct his throw outward and toward the front of the car (throw 1), straight outward (throw 2), or outward and toward the back of the car (throw 3)? Explain. (Ignore air resistance.)



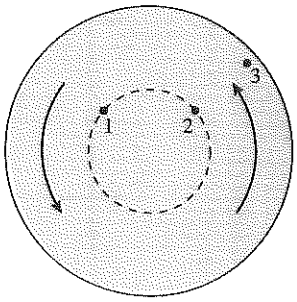
4.5 Uniform Circular Motion

4.6 Velocity and Acceleration in Uniform Circular Motion

18. a. The crankshaft in your car rotates at 3000 rpm. What is the frequency in revolutions per second?

b. A record turntable rotates at 33.3 rpm. What is the period in seconds?

19. The figure shows three points on a steadily rotating wheel.



a. Draw the velocity vectors at each of the three points

b. Rank in order, from largest to smallest, the angular velocities ω_1, ω_2, and ω_3 of these points.

Order:

Explanation:

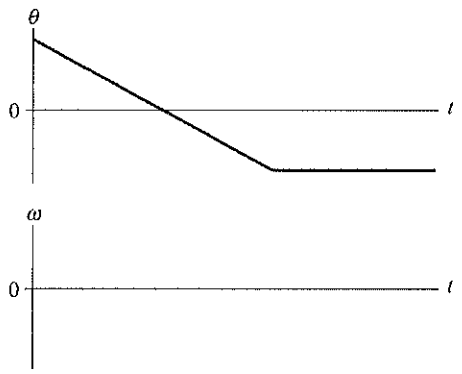
c. Rank in order, from largest to smallest, the speeds v_1, v_2, and v_3 of these points.

Order:

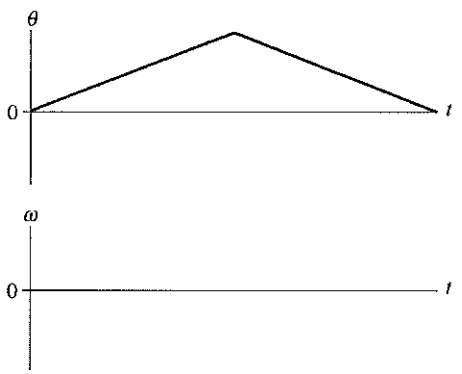
Explanation:

20. Below are two angular position-versus-time graphs. For each, draw the corresponding angular velocity-versus-time graph directly below it.

a.

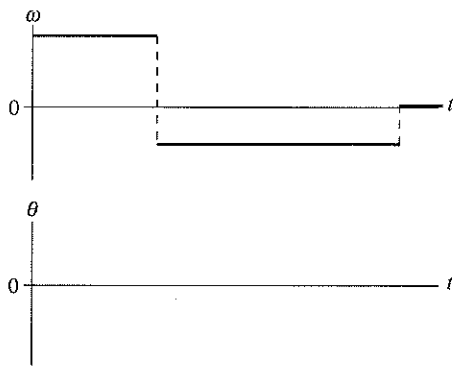


b.

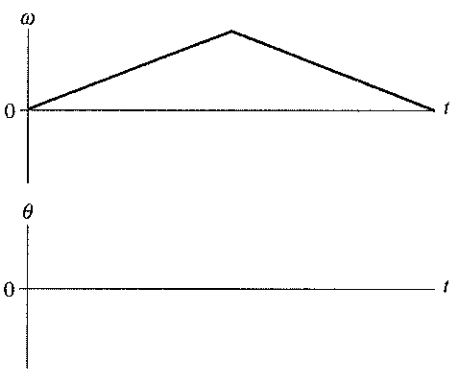


21. Below are two angular velocity-versus-time graphs. For each, draw the corresponding angular position-versus-time graph directly below it. Assume $\theta_0 = 0$ rad.

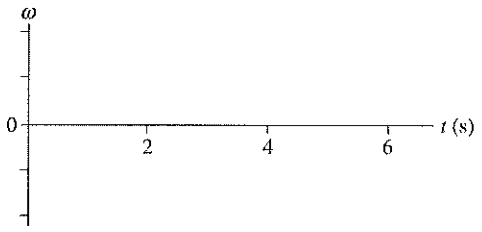
a.

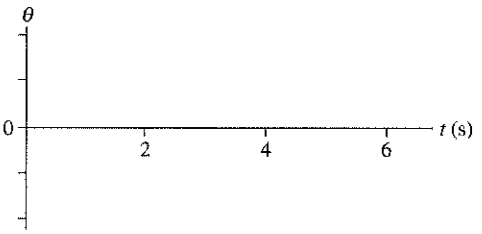


b.



22. A particle in circular motion rotates clockwise at 4 rad/s for 2 s, then counterclockwise at 2 rad/s for 4 s. The time required to change direction is negligible. Graph the angular velocity and the angular position, assuming $\theta_0 = 0$ rad.





23. A particle rotates in a circle with $a_r = 8$ m/s^2. What is a_r if

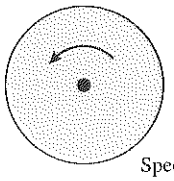
a. The radius is doubled without changing the angular velocity? _____

b. The radius is doubled without changing the particle's speed? _____

c. The angular velocity is doubled without changing the circle's radius? _____

4.7 Nonuniform Circular Motion and Angular Acceleration

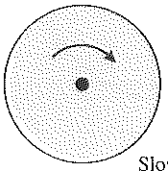
24. The following figures show a rotating wheel. Determine the signs (+ or –) of ω and α.



Speeding up

ω _____

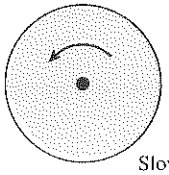
α _____



Slowing down

ω _____

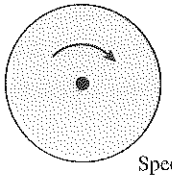
α _____



Slowing down

ω _____

α _____

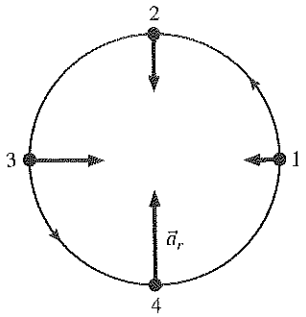


Speeding up

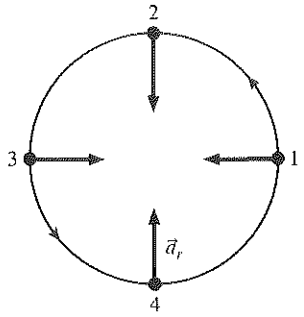
ω _____

α _____

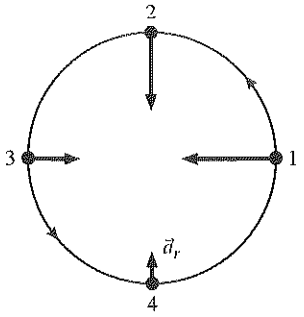
25. The figures below show the radial acceleration vector $\vec{a}_r$ at four successive points on the trajectory of a particle moving in a counterclockwise circle.
    a. For each, draw the tangential acceleration vector $\vec{a}_t$ at points 2 and 3 or, if appropriate, write $\vec{a}_t = \vec{0}$.
    b. Determine if the particle's angular acceleration α is positive (+), negative (–), or zero (0).



α = _____

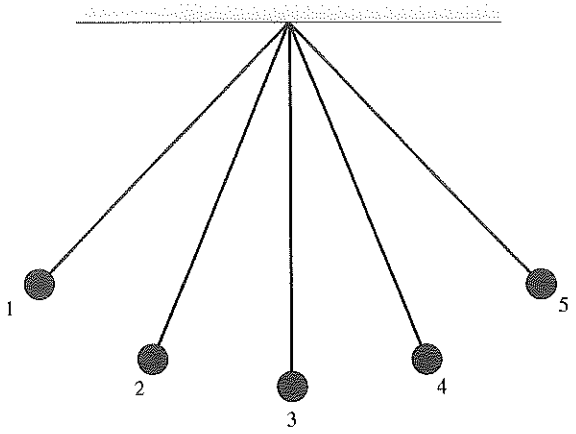


α = _____

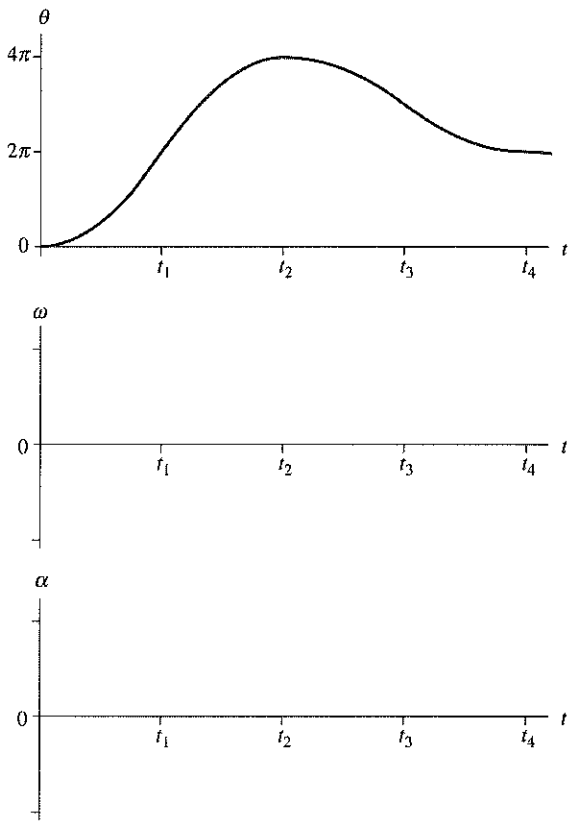


α = _____

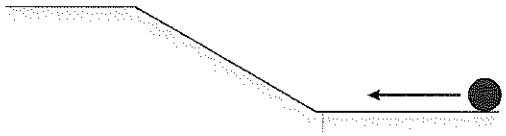
26. A pendulum swings from its end point on the left (point 1) to its end point on the right (point 5). At each of the labeled points:
    a. Use a **black** pen or pencil to draw and label the vectors $\vec{a}_r$ and $\vec{a}_t$ at each point. Make sure the length indicates the relative size of the vector.
    b. Use a **red** pen or pencil to draw and label the total acceleration vector $\vec{a}$.

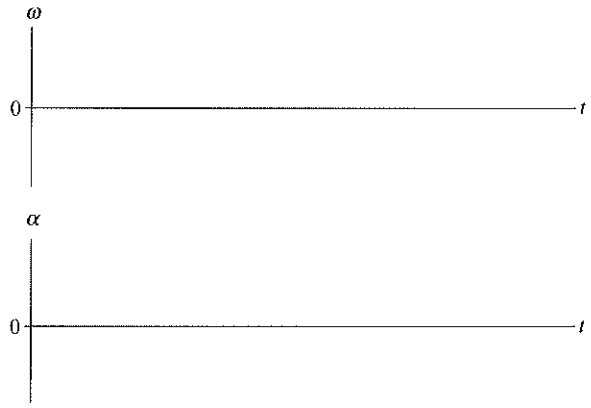


27. The figure shows the θ-versus-t graph for a particle moving in a circle. The curves are all sections of parabolas.
    a. Draw the corresponding ω-versus-t and α-versus-t graphs. Notice that the horizontal tick marks are equally spaced.
    b. Write a description of the particle's motion.



28. A wheel rolls to the left along a horizontal surface, up a ramp, then continues along the upper horizontal surface. Draw graphs for the wheel's angular velocity ω and angular acceleration α as functions of time.

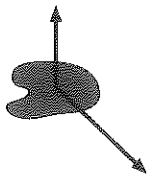




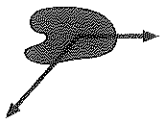
5 Force and Motion

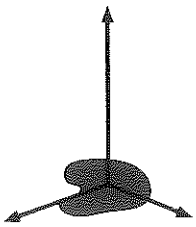
5.1 Force

1. Two or more forces are shown on the objects below. Draw and label the net force $\vec{F}_{\text{net}}$.



2. Two or more forces are shown on the objects below. Draw and label the net force $\vec{F}_{\text{net}}$.





5.2 A Short Catalog of Forces

5.3 Identifying Forces

Exercises 3–8: Follow the six-step procedure of Tactics Box 5.2 to identify and name all the forces acting on the object.

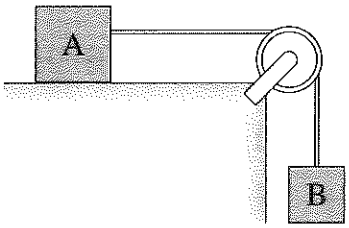
3. An elevator suspended by a cable is descending at constant velocity.

4. A car on a *very* slippery icy road is sliding headfirst into a snowbank, where it gently comes to rest with no one injured. (Question: What does "*very* slippery" imply?)

5. A compressed spring is pushing a block across a rough horizontal table.

6. A brick is falling from the roof of a three-story building.

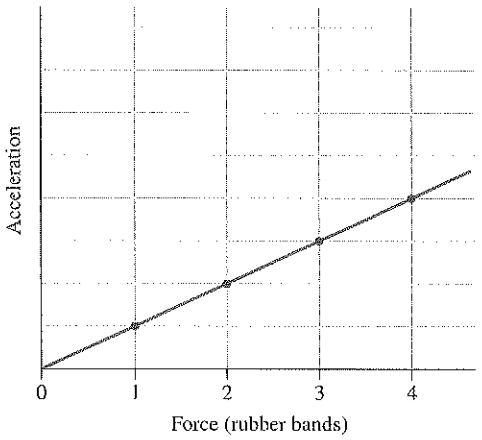
7. Blocks A and B are connected by a string passing over a pulley. Block B is falling and dragging block A across a frictionless table. Analyze block A.



8. A rocket is launched at a 30° angle. Air resistance is not negligible.

5.4 What Do Forces Do? A Virtual Experiment

9. The figure shows an acceleration-versus-force graph for an object of mass m. Data have been plotted as individual points, and a line has been drawn through the points.



Draw and label, directly on the figure, the acceleration-versus-force graphs for objects of mass

a. $2m$ b. $0.5m$

Use triangles ▲ to show four points for the object of mass $2m$, then draw a line through the points. Use squares ■ for the object of mass $0.5m$.

10. A constant force applied to object A causes A to accelerate at 5 m/s^2. The same force applied to object B causes an acceleration of 3 m/s^2. Applied to object C, it causes an acceleration of 8 m/s^2.

a. Which object has the largest mass?

b. Which object has the smallest mass?

c. What is the ratio of mass A to mass B? (m_A/m_B) = _____

11. A constant force applied to an object causes the object to accelerate at 10 m/s^2. What will the acceleration of this object be if

a. The force is doubled? b. The mass is doubled? _____

c. The force is doubled *and* the mass is doubled? _____

d. The force is doubled *and* the mass is halved? _____

12. A constant force applied to an object causes the object to accelerate at 8 m/s^2. What will the acceleration of this object be if

a. The force is halved? _____ b. The mass is halved? _____

c. The force is halved *and* the mass is halved?

d. The force is halved *and* the mass is doubled?

5.5 Newton's Second Law

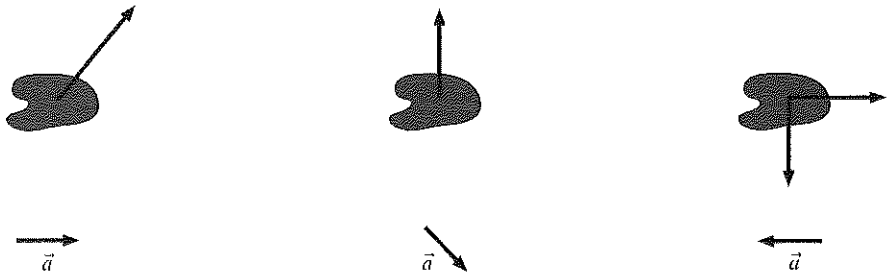
13. Forces are shown on two objects. For each:

a. Draw and label the net force vector. Do this right on the figure.

b. Below the figure, draw and label the object's acceleration vector.

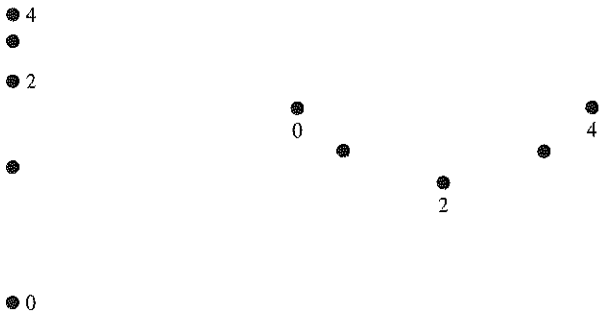
14. Forces are shown on two objects. For each:
    a. Draw and label the net force vector. Do this right on the figure.
    b. Below the figure, draw and label the object's acceleration vector.

15. In the figures below, one force is missing. Use the given direction of acceleration to determine the missing force and draw it on the object. Do all work directly on the figure.



16. Below are two motion diagrams for a particle. Draw and label the net force vector at point 2.

17. Below are two motion diagrams for a particle. Draw and label the net force vector at point 2.

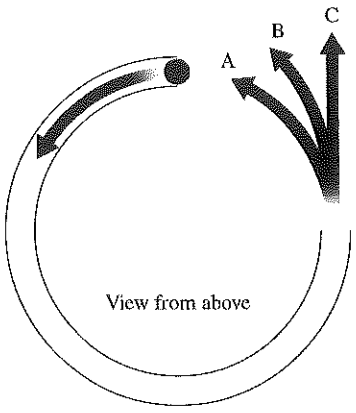


5.6 Newton's First Law

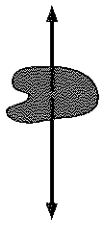
18. If an object is at rest, can you conclude that there are no forces acting on it? Explain.

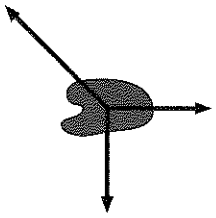
19. If a force is exerted on an object, is it possible for that object to be moving with constant velocity? Explain.

20. A hollow tube forms three-quarters of a circle. It is lying flat on a table. A ball is shot through the tube at high speed. As the ball emerges from the other end, does it follow path A, path B, or path C? Explain your reasoning.

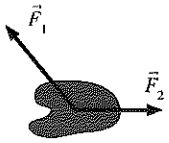


21. Which, if either, of the objects shown below is in equilibrium? Explain your reasoning.





22. Two forces are shown on the objects below. Add a third force $\vec{F}_3$ that will cause the object to be in equilibrium.



23. Are the following inertial reference frames? Answer Yes or No.

a. A car driving at steady speed on a straight and level road. _____

b. A car driving at steady speed up a 10° incline. _____

c. A car speeding up after leaving a stop sign. _____

d. A car driving at steady speed around a curve. _____

e. A hot air balloon rising straight up at steady speed. _____

f. A skydiver just after leaping out of a plane. _____

g. The space shuttle orbiting the earth. _____

5.7 Free-Body Diagrams

Exercises 24–29:

- Draw a picture and identify the forces, then
- Draw a complete free-body diagram for the object, following each of the steps given in Tactics Box 5.3. Be sure to think carefully about the direction of $\vec{F}_{\text{net}}$.

Note: Draw individual force vectors with a **black** or **blue** pencil or pen. Draw the *net* force vector $\vec{F}_{\text{net}}$ with a **red** pencil or pen.

24. A heavy crate is being lowered straight down at a constant speed by a steel cable.

25. A boy is pushing a box across the floor at a steadily increasing speed. Let the box be "the system" for analysis.

26. A bicycle is speeding up down a hill. Friction is negligible, but air resistance is not.

27. You've slammed on your car brakes while going down a hill. You're skidding to a halt.

28. You are going to toss a rock *straight up* into the air by placing it on the palm of your hand (you're not gripping it), then pushing your hand up very rapidly. You may want to toss an object into the air this way to help you think about the situation. The rock is "the system" of interest.

a. As you hold the rock at rest on your palm, before moving your hand.

b. As your hand is moving up but before the rock leaves your hand.

c. One-tenth of a second after the rock leaves your hand.

d. After the rock has reached its highest point and is now falling straight down.

29. Block B has just been released and is beginning to fall. The table has friction. Analyze block A.