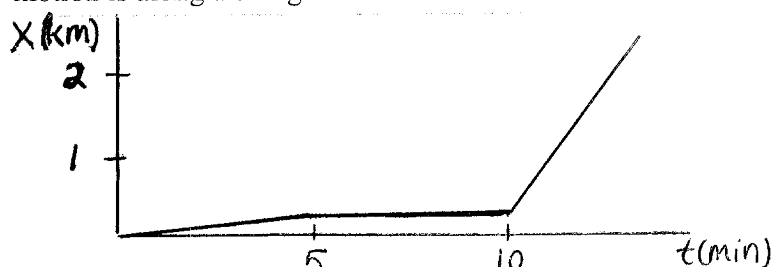
2 Motion in One Dimension

2.1 Describing Motion

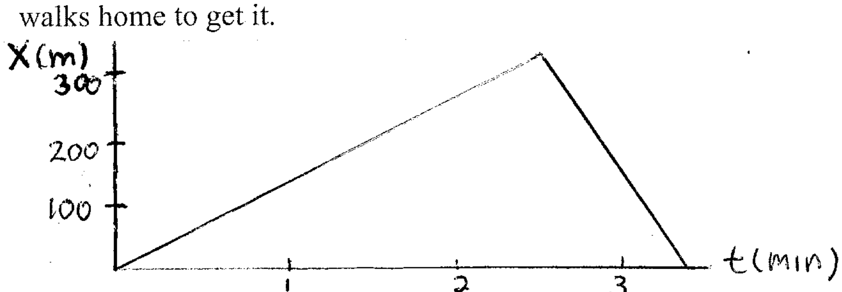
1. Sketch position-versus-time graphs for the following motions. Include a numerical scale on both axes with units that are *reasonable* for this motion. Some numerical information is given in the problem, but for other quantities make reasonable estimates.

   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.

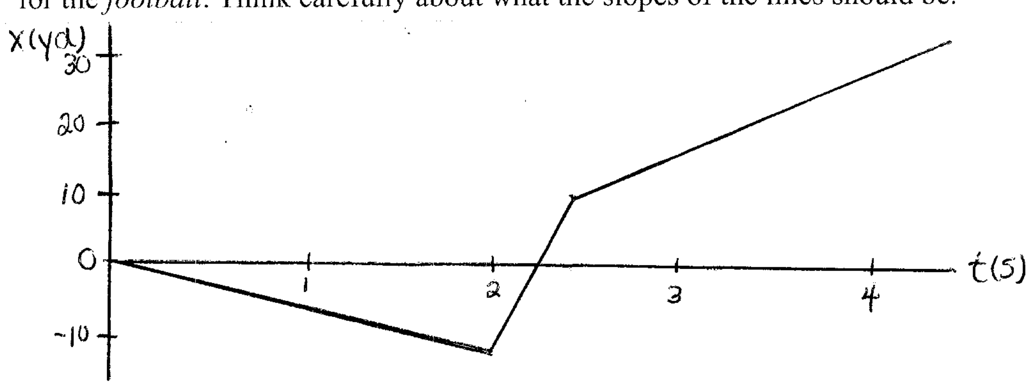
   a. A student walks to the bus stop, waits for the bus, then rides to campus. Assume that all the motion is along a straight street.



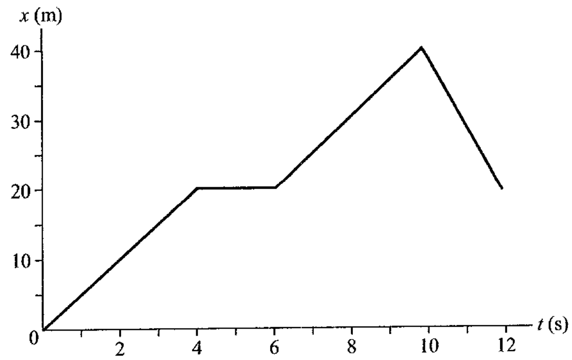
   b. A student walks slowly to the bus stop, realizes he forgot his paper that is due, and *quickly* walks home to get it.



   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.



2. The position-versus-time graph below shows the position of an object moving in a straight line for 12 seconds.



a. What is the position of the object at 2 s, 6 s, and 10 s after the start of the motion?

At 2 s: 10 m

At 6 s: 20 m

At 10 s: 40 m

b. What is the object's velocity during the first 4 s of motion?

$5\,\frac{m}{s}$ $\left(= \frac{20\,m}{4\,s}\right)$

c. What is the object's velocity during the interval from $t = 4$ s to $t = 6$ s?

$0\,\frac{m}{s}$

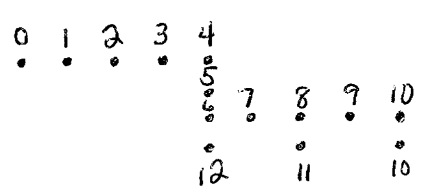
d. What is the object's velocity during the four seconds from $t = 6$ s to $t = 10$ s?

$5\,\frac{m}{s}$ $\left(= \frac{40\,m - 20\,m}{10\,s - 6\,s}\right)$

e. What is the object's velocity during the final two seconds from $t = 10$ s to $t = 12$ s?

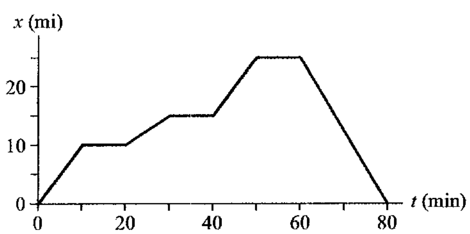
$-10\,\frac{m}{s}$ $\left(= \frac{20\,m - 40\,m}{12\,s - 10\,s}\right)$

f. Draw a motion diagram below to represent the entire 12 s of motion.



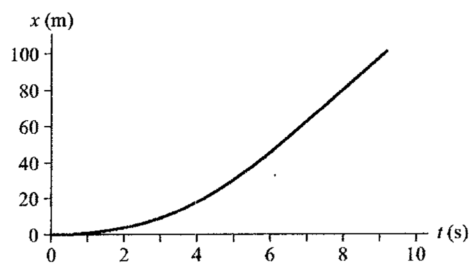
3. Interpret the following position-versus-time graphs by writing a very short "story" of what is happening. Be creative! Have characters and situations! Simply saying that "a car moves 100 meters to the right" doesn't qualify as a story. Your stories should make *specific reference* to information you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

a. Moving car



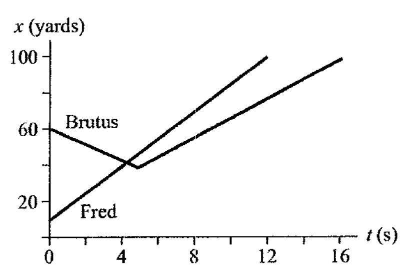
It was a typical summer day on the interstate. After driving for 10min at 60 mph, I stopped at a rest area for coffee. When I got back on the road 10min later, I was slowed to 30mph by a construction zone for 10min. Finally, back up to cruising speed, I got off at my exit 25mi from home. After searching my pockets and car for 10min I realized that I left my wallet at home so I drove back, without stops or construction delays, at 75mph!

b. Sprinter



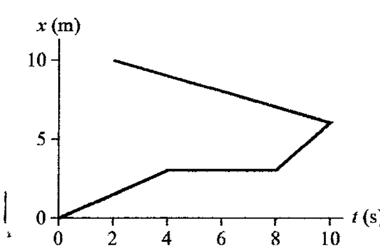
With a slow start out of the blocks, a super sprinter reached top speed in about 5 seconds, having gone only 30 meters. He still was able to finish his 100 meters in only just over 9 seconds. By running a world record pace for the rest of the race.

c. Two football players



At the kickoff, Fred receives the ball on the 10yd line and heads upfield at a sprint. Brutus runs towards Fred in an attempt to tackle him, but misses as Fred crosses the 50yd line. Brutus vainly tries to catch up, but Fred scores. Foolishly, Brutus continues to run after Fred has already scored.

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

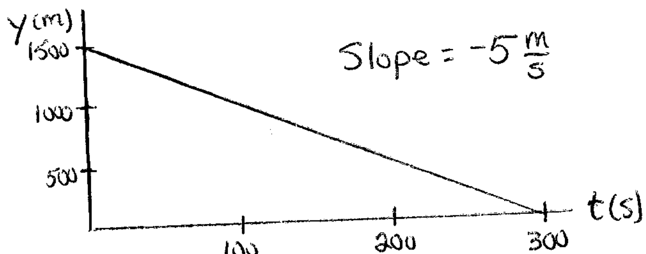


There is no sensible interpretation because the graph requires the object to be in two places at once!

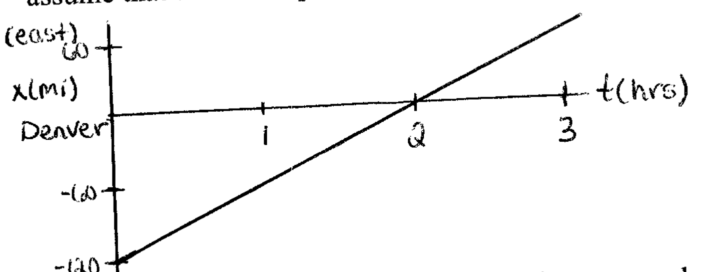
2.2 Uniform Motion

5. Sketch position-versus-time graphs for the following motions. Include appropriate numerical scales along both axes. A small amount of computation may be necessary.

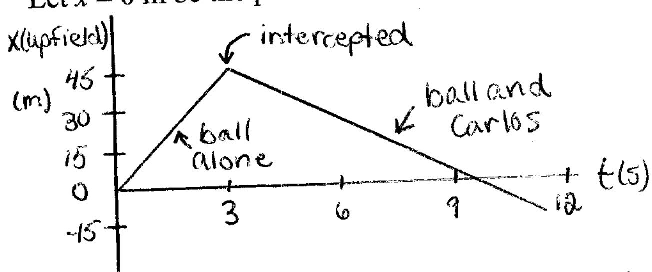
   a. A parachutist opens her parachute at an altitude of 1500 m. She then descends slowly to earth at a steady speed of 5 m/s. Start your graph as her parachute opens.



   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.

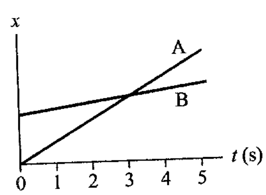


   c. Quarterback Bill throws the ball to the right at a speed of 15 m/s. It is intercepted 45 m away by Carlos, who is running to the left at 7.5 m/s. Carlos carries the ball 60 m to score. Let $x = 0$ m be the point where Bill throws the ball. Draw the graph for the *football.*



(Note: It can be shown that a ball thrown at 15 m/s cannot travel 45 m over a level surface.)

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



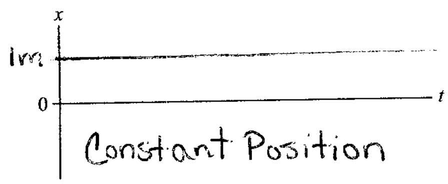
   a. At the instant $t = 1$ s, is the speed of A greater than, less than, or equal to the speed of B? Explain.

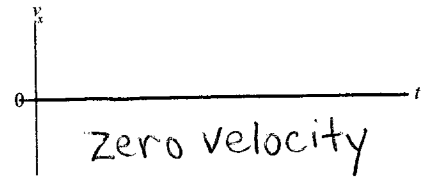
   At t = 1 s, the slope of the line for A is greater than that for object B. Therefore, object A's speed is greater. (Both are positive slopes.)

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

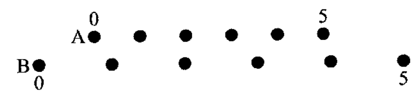
   No, the speeds are never the same. Each has a constant speed (constant slope) and A's speed is always greater.

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

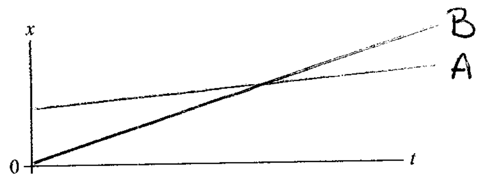


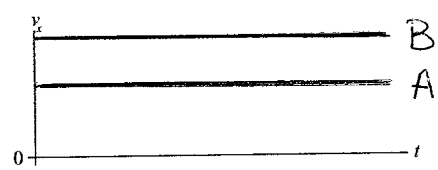


8. The figure shows six frames from the motion diagram of two moving cars, A and B.



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.

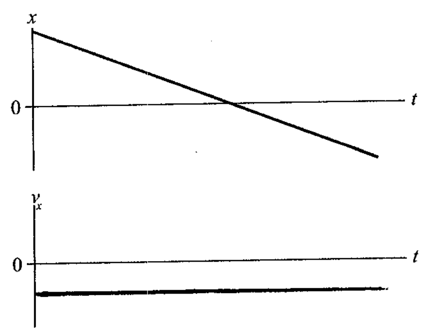




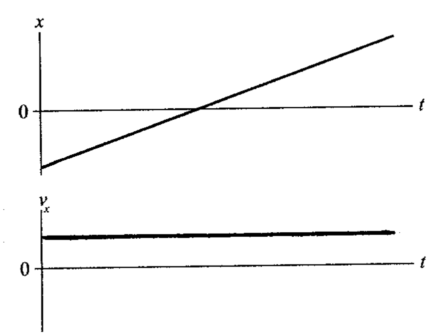
b. Do the two cars ever have the same position at one instant of time?
If so, in which frame number (or numbers)? yes, at 2
Draw a vertical line through your graphs of part a to indicate this instant of time.

9. Below are four 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_x 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.

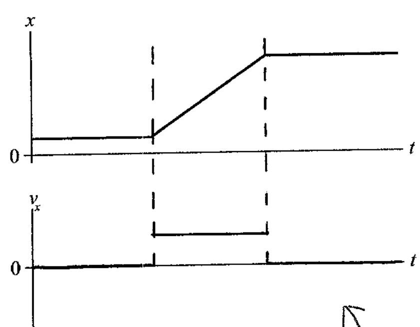
a.



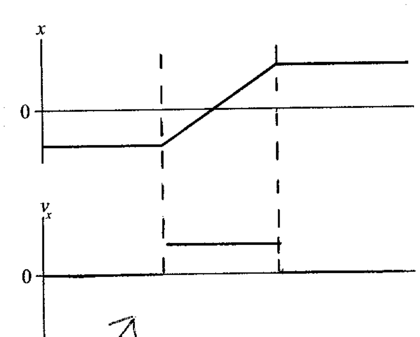
b.



c.



d.

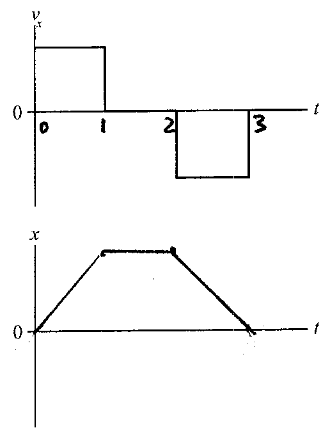


identical graphs

10. Below are two 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.

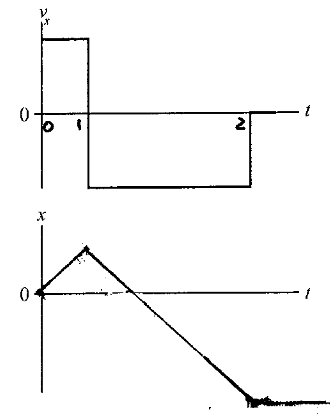


0 to 1 - moving forward at constant speed

1 to 2 - stationary

2 to 3 - moving backward at the same constant speed as from 0 to 1

b.

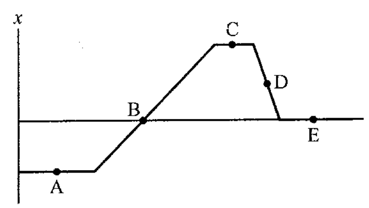


0 to 1 - moving forward at constant speed

1 to 2 - moving backward at the same constant speed

2 on - at rest

11. 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

   b. Is the object moving the fastest? D

   c. Is the object at rest? A, C, E

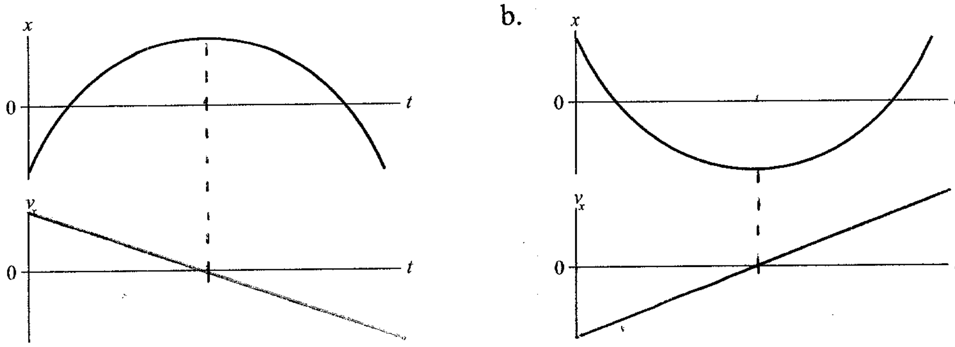
   d. Does the object have a constant nonzero velocity? B, D

   e. Is the object moving to the left? D

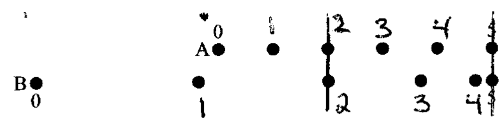
2.3 Motion with Changing Velocity

12. Below are two 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_x at time t with the position x at the *same* time t. There are no numbers, but your graphs should correctly indicate the *relative* speeds.

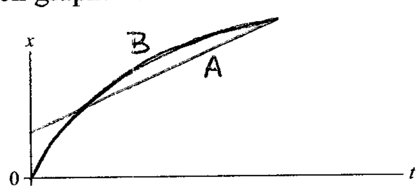
a. b.

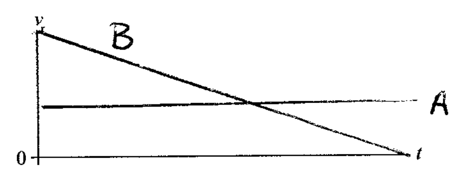


13. The figure shows six frames from the motion diagram of two moving cars, A and B.



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.



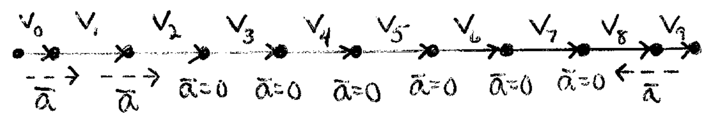


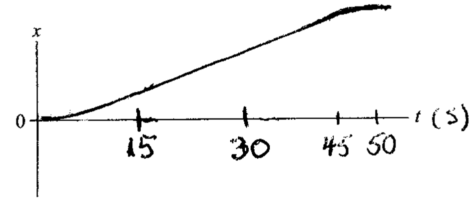
b. Do the two cars ever have the same position at one instant of time?
If so, in which frame number (or numbers)? yes, at 2 and 5
Draw a vertical line through your graphs of part a to indicate this instant of time.

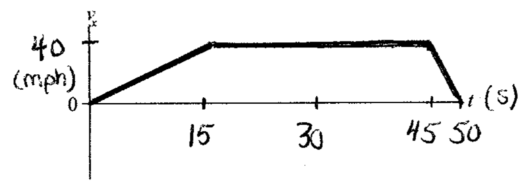
c. Do the two cars ever have the same velocity at one instant of time?
If so, between which two frames? yes, from 3 to 4

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

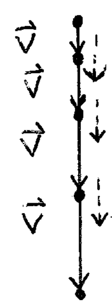
a. A car starts from rest, steadily speeds up to 40 mph in 15 s, moves at a constant speed for 30 s, then comes to a halt in 5 s.

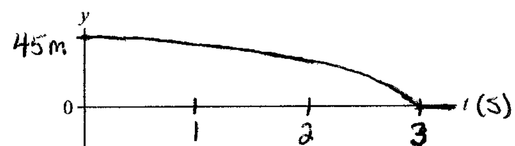


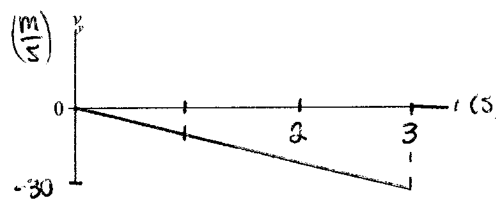




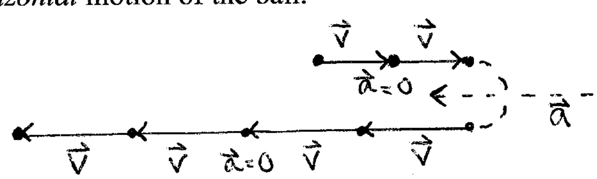
b. A rock is dropped from a bridge and steadily speeds up as it falls. It is moving at 30 m/s when it hits the ground 3 s later. Think carefully about the signs.

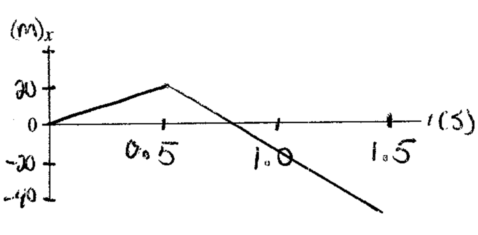


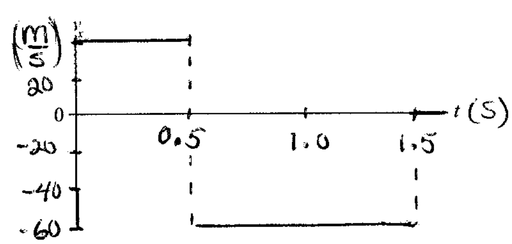




c. A pitcher winds up and throws a baseball with a speed of 40 m/s. One-half second later the batter hits a line drive with a speed of 60 m/s. The ball is caught 1 s after it is hit. From where you are sitting, the batter is to the right of the pitcher. Draw your motion diagram and graph for the *horizontal*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



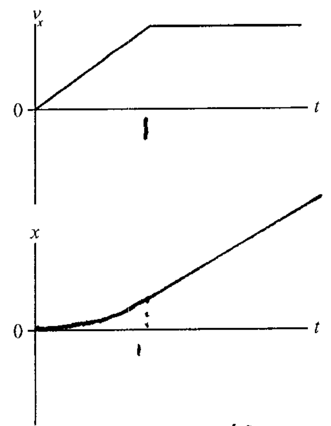




15. Below are shown four velocity-versus-time graphs. For each:
 - Draw the corresponding position-versus-time graph.
 - Give a written description of the motion.

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

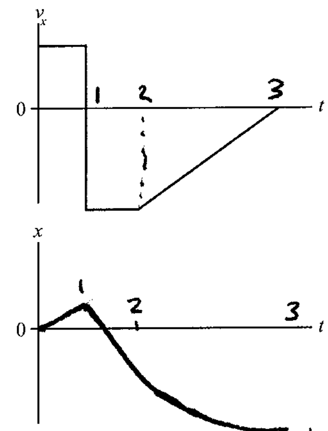
a.



0 to 1 - speeding up at a constant rate

After 1 - constant speed

b.

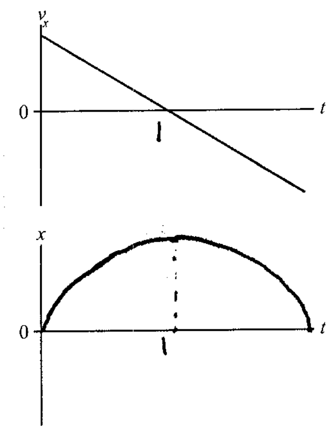


0 to 1 - constant forward speed

1 to 2 - a greater constant speed backwards

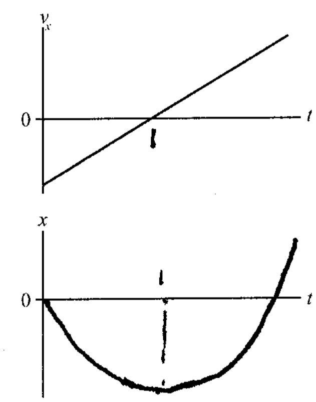
2 to 3 - slowing down while moving backwards, stopping at 3

c.



Constant negative acceleration, slowing down until 1, then speeding up in the negative direction

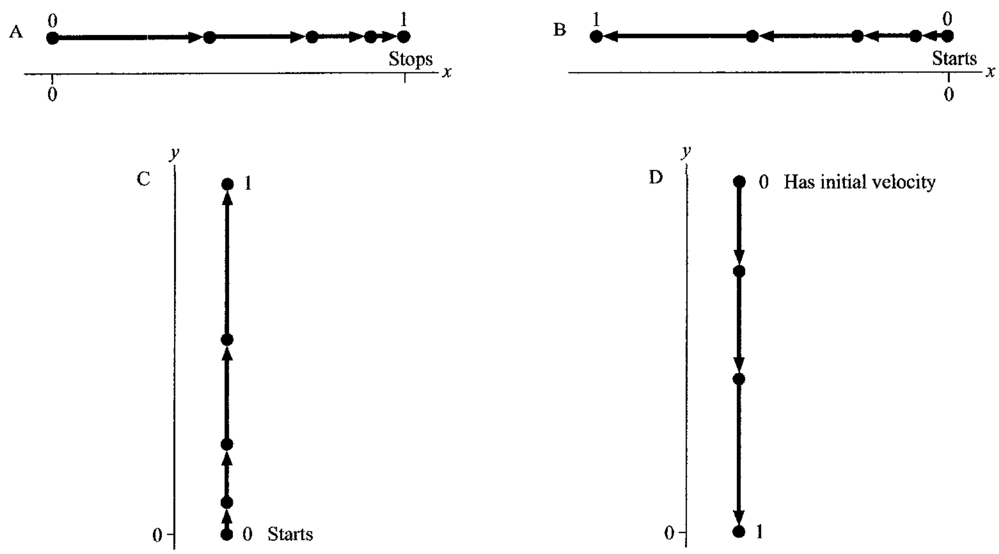
d.



Constant positive acceleration. Moving initially backwards and slowing down until turning around at 1 and speeding up thereafter in the forward direction

2.4 Acceleration

16. 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	0	0	0	+
x_1 or y_1	+	–	+	0
v_{0x} or v_{0y}	+	0	0	–
v_{1x} or v_{1x}	0	–	+	–
a_x or a_y	–	–	+	–

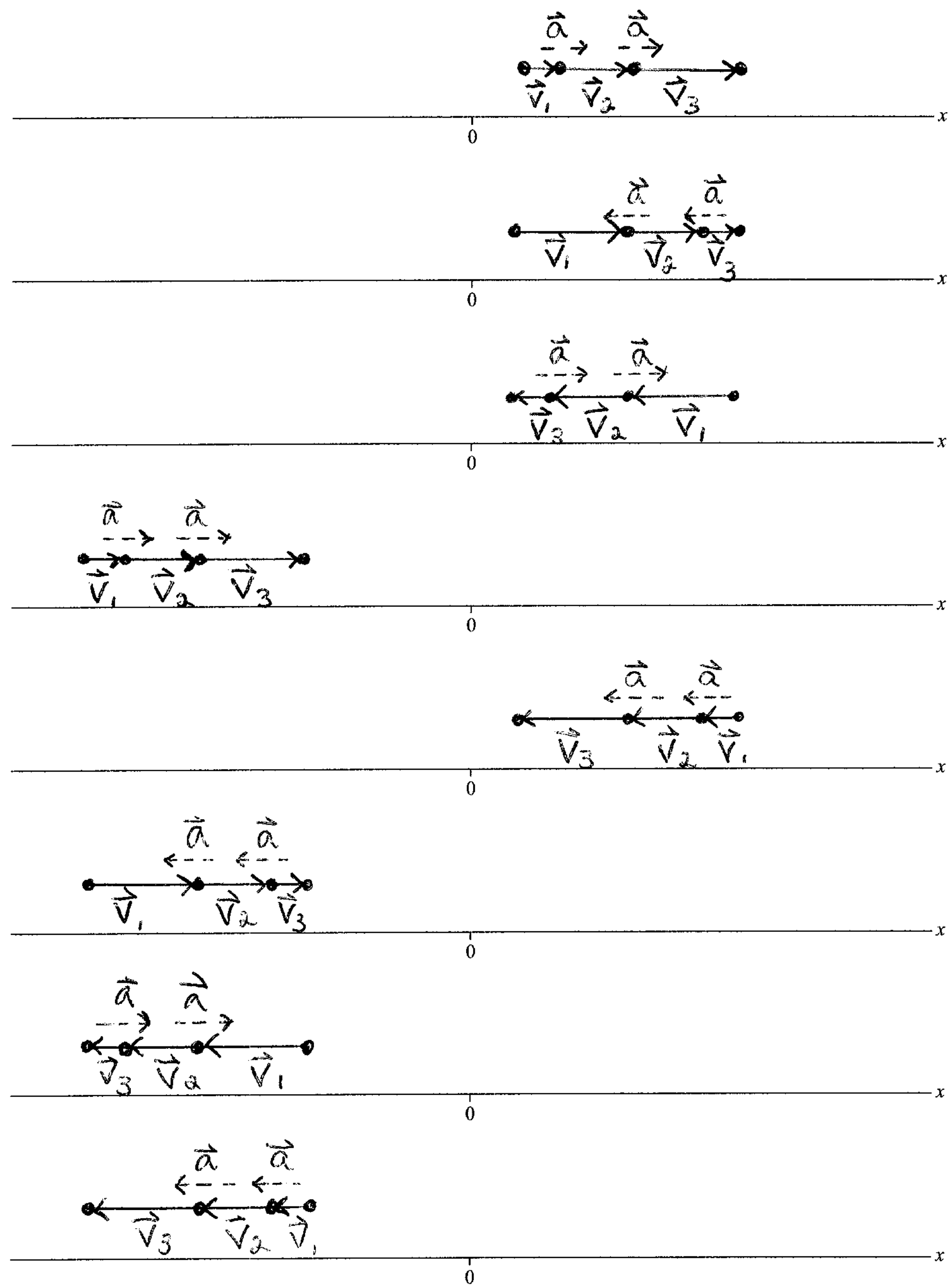
17. The three symbols x, v_x, and a_x have eight possible combinations of *signs*. For example, one combination is $(x, v_x, a_x) = (+, -, +)$.

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.

—— Black
- - - Red



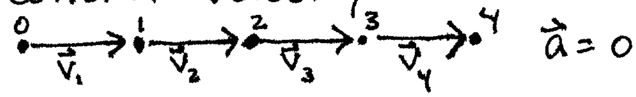
	X	V_x	a_x
1.	+	+	+
2.	+	+	−
3.	+	−	+
4.	−	+	+
5.	+	−	−
6.	−	+	−
7.	−	−	+
8.	−	−	−

2.5 Motion with Constant Acceleration

18. For each of the following situations, provide a description and a motion diagram.

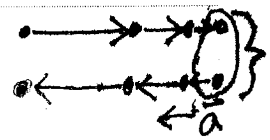
a. $a_x = 0$ but $v_x \neq 0$.

Moving at constant velocity



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

Turning around

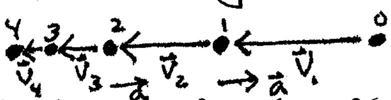


Only these two dots of the diagram signify $v_x = 0$

$a_x < 0$

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

Slowing down while moving in the negative direction



19. The quantity y is proportional to the square of x, and $y = 36$ when $x = 3$.

a. Write an equation to represent this quadratic relationship for all y and x.

$y = kx^2$ so $k = y/x^2 = \frac{36}{3^2} = 4$ or $y = 4x^2$

b. Find y if $x = 5$. 100

c. Find x if $y = 16$. 2

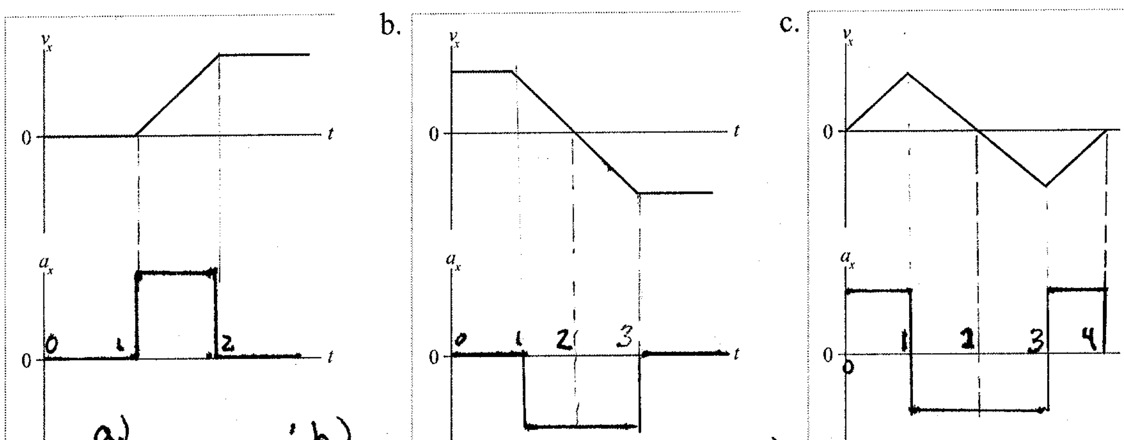
d. By what factor must x change for the value of y to double? $\sqrt{2}$

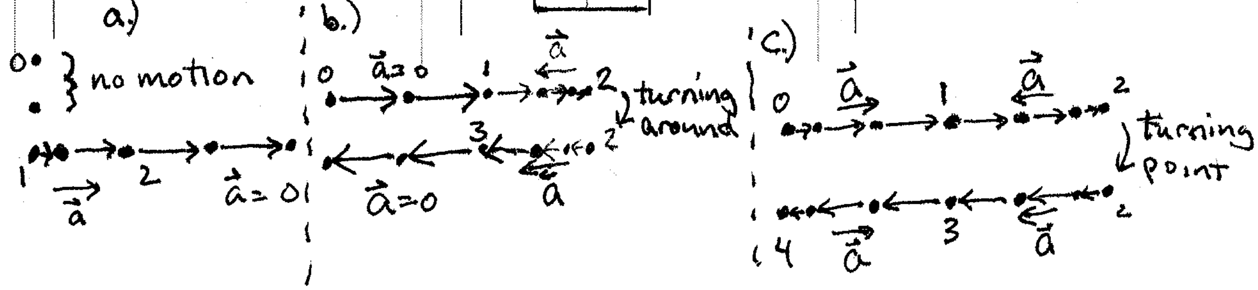
e. Compare your equation in part a to the equation from your text relating Δx and Δt, $\Delta x = \frac{1}{2}a_x\Delta t^2$. Which quantity assumes the role of x? Which quantity assumes the role of y? What is the constant of proportionality relating Δx and Δt?

$x \to \Delta t$, $y \to \Delta x$, $k \to \frac{1}{2}a_x$

20. Below are three velocity-versus-time graphs. For each, draw the corresponding acceleration-versus-time graph and draw a motion diagram below the graphs.

a. b. c.





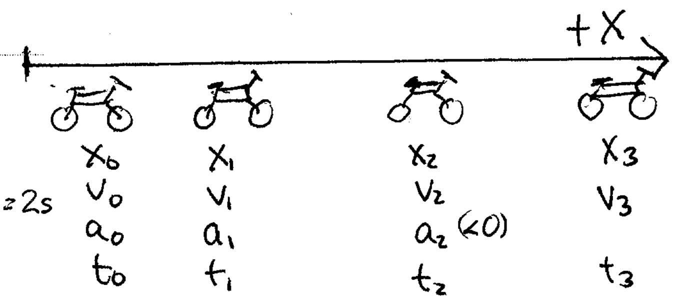
2.6 Solving One-Dimensional Motion Problems

21. Draw a pictorial representation of each situation described below. That is, (i) sketch the situation, showing appropriate points in the motion, (ii) establish a coordinate system on your sketch, and (iii) define appropriate symbols for the known and unknown quantities. **Do not solve.**

a. A bicyclist starts from rest and accelerates at 4.0 m/s^2 for 3.0 s. The cyclist then travels for 20 s at a constant speed before slowing to a stop in just 2.0 s. How far does the cyclist travel?

Known

$x_0 = 0$
$v_0 = 0$ $v_1 =$ const $v_2 = v_1$ $v_3 = 0$
$a_0 = 4 \frac{m}{s^2}$ $a_1 = 0$ $a_2 < 0$
$t_0 = 0$ $t_1 = 3s$ $t_2 - t_1 = 20s$ $t_3 - t_2 = 2s$



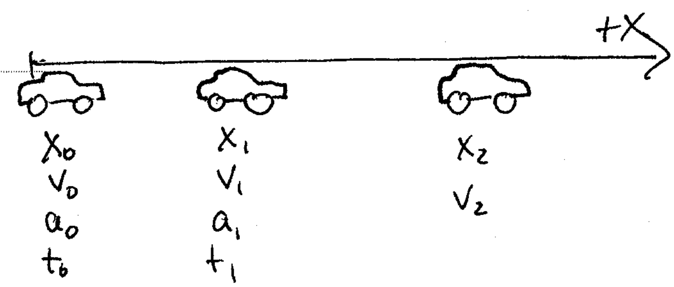
Find

x_3

b. You are driving your car at 12 m/s when a deer jumps in front of your car. What is the shortest stopping distance for your car if your reaction time is 0.80 s and your car brakes at 6.0 m/s^2?

Known

$v_0 = 12 \frac{m}{s}$ $v_2 = 0$
$a_0 = 0$ $a_1 = -6.0 \frac{m}{s^2}$
$x_0 = 0$
$t_0 = 0$ $t_1 = 0.80s$



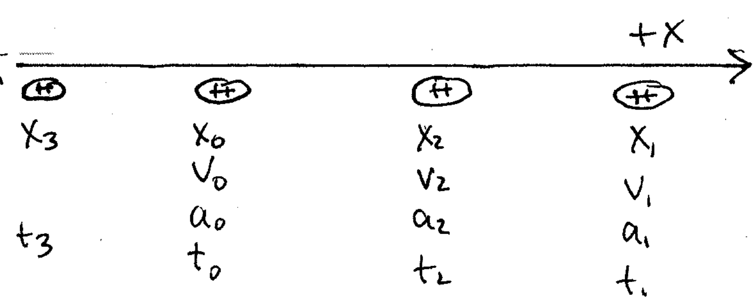
Find

x_2

c. At the snap, Quarterback Bill throws the football to the right at a speed of 15 m/s. It is intercepted 45 m away by Carlos, who accelerates at 2.5 m/s from rest to a speed of 7.5 m/s to the left and carries the ball for a total distance of 60 m to score. How much time has elapsed on the game clock?

Known

$x_0 = 0$ $x_1 = 45m$ $x_3 - x_1 = -60m$
$v_0 = 15 \frac{m}{s}$ $v_1 = 0$ $v_2 = -7.5 \frac{m}{s}$
$a_0 = 0$ $a_1 = -2.5 \frac{m}{s^2}$ $a_2 = 0$



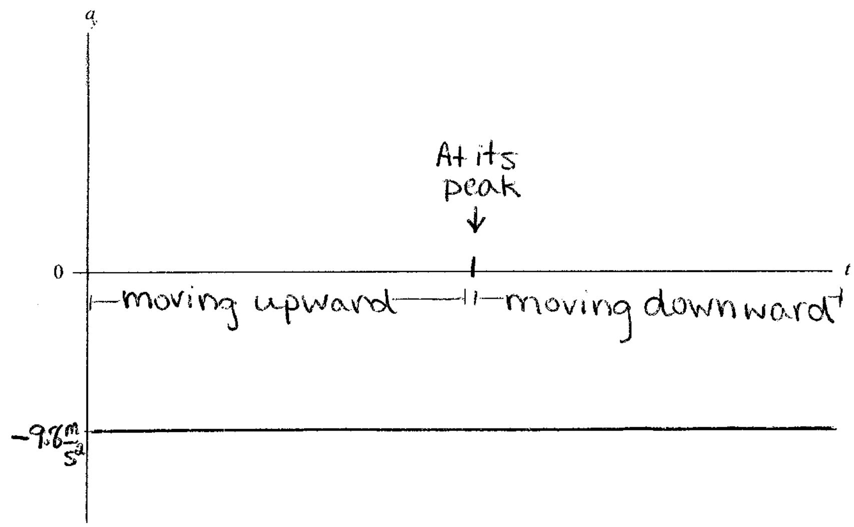
Find

t_3

2.7 Free Fall

22. A ball is thrown straight up into the air. At each of the following instants, is the ball's acceleration g, $-g$, 0, $< g$, or $> g$?
    a. Just after leaving your hand? $-g$
    b. At the very top (maximum height)? $-g$
    c. Just before hitting the ground? $-g$

23. A ball is thrown straight up into the air. It reaches height h, then falls back down to the ground. On the axes below, graph the ball's acceleration from an instant after it leaves the thrower's hand until an instant before it hits the ground. Indicate on your graph the times during which the ball is moving upwards, at its peak, and moving downwards.



24. On a single graph, using the axes below, graph
    a. the acceleration of a rock dropped from a bridge into the river below, and
    b. the acceleration of a rock thrown (not dropped) from a bridge into the river below.
    Be sure to label your graphs.