2 Kinematics in One Dimension

2.1 Uniform Motion

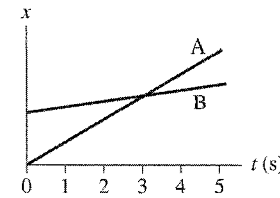
1. Sketch position-versus-time graphs (x versus t or y versus t) for the following motions. Include appropriate numerical scales along both axes. A small amount of computation may be necessary.

   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.

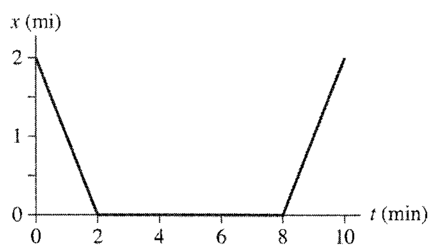


   a. At the instant $t = 1$ s, is the speed of A greater than, less than, or equal to the speed of B? Explain.

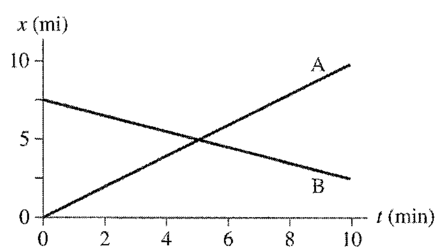
   b. Do objects A and B ever have the *same* speed? If so, at what time or times? Explain.

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.

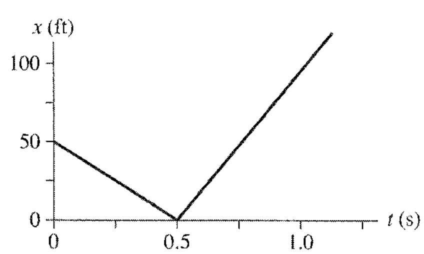
   a.



   b.

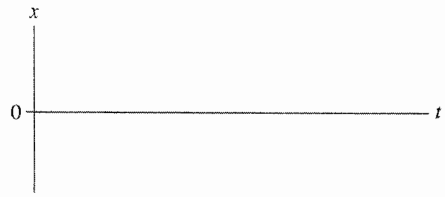


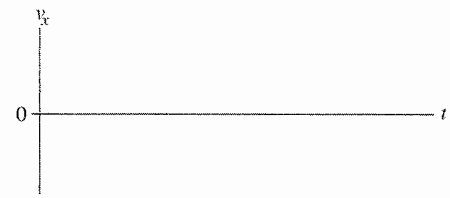
   c.



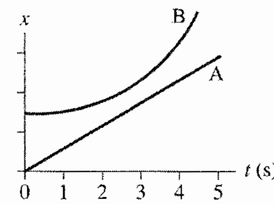
2.2 Instantaneous Velocity

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.

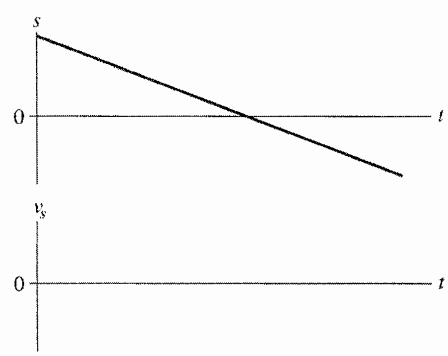


   a. At the instant $t = 1$ s, is the speed of A greater than, less than, or equal to the speed of B? Explain.

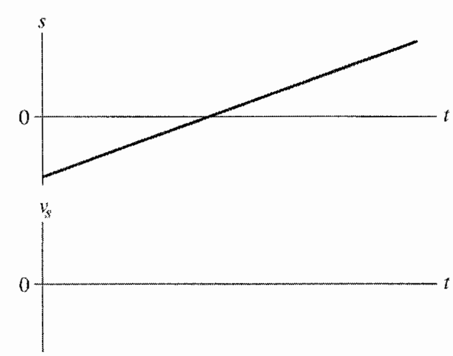
   b. Do objects A and B ever have the *same* speed? If so, at what time or times? Explain.

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.

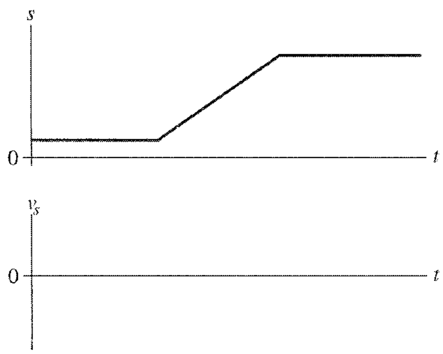
a.



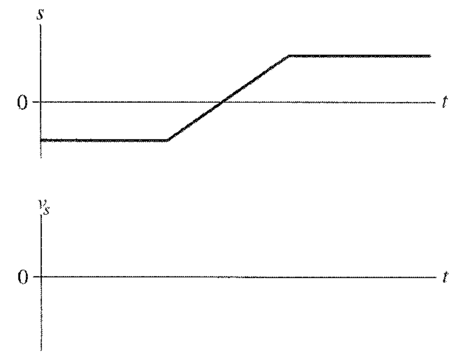
b.



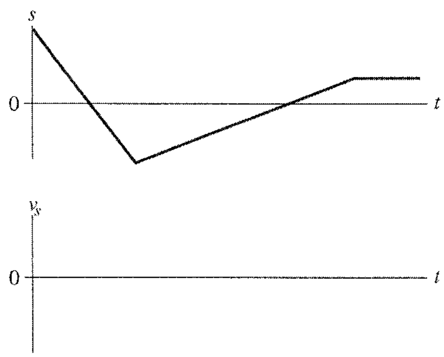
c.



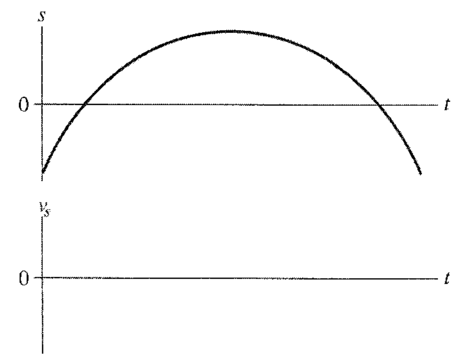
d.



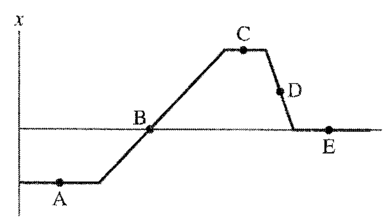
e.



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? ______

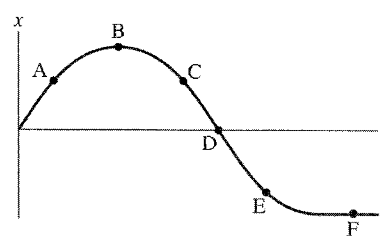
b. Is the object moving the fastest? ______

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? ______

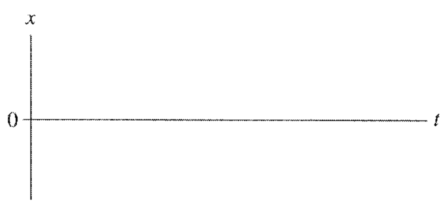
c. Is the object speeding up? ______

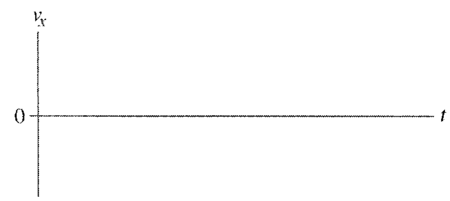
d. Is the object slowing down? ______

e. Is the object turning around? ______

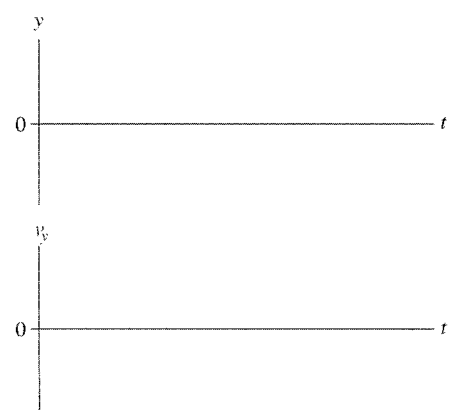
9. For each of the following motions, draw
   - A motion diagam,
   - A position-versus-time graph, and
   - A velocity-versus-time graph.

   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.

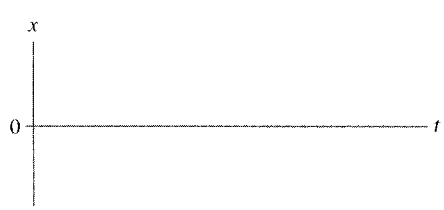


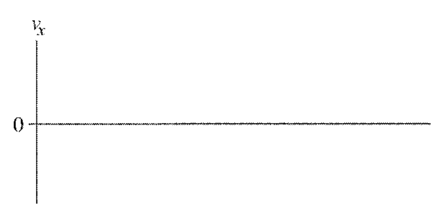


   b. A rock is dropped from a bridge and steadily speeds up as it falls. It is moving at 30 m/s when it hits the ground 3 s later. Think carefully about the signs.

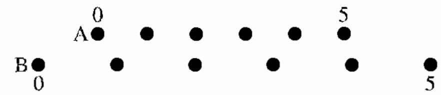


   c. A pitcher winds up and throws a baseball with a speed of 40 m/s. One-half second later the batter hits a line drive with a speed of 60 m/s. The ball is caught 1 s after it is hit. From where you are sitting, the batter is to the right of the pitcher. Draw your motion diagram and graph for the *horizontal*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

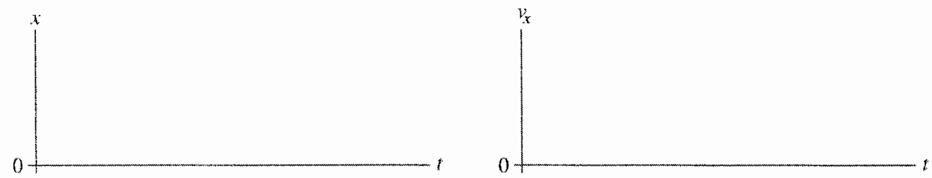




10. The figure shows six frames from the motion diagram of two moving cars, A and B.



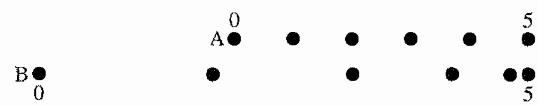
a. Draw both a position-versus-time graph and a velocity-versus-time graph. Show the motion of *both* cars on each graph. Label them A and B.



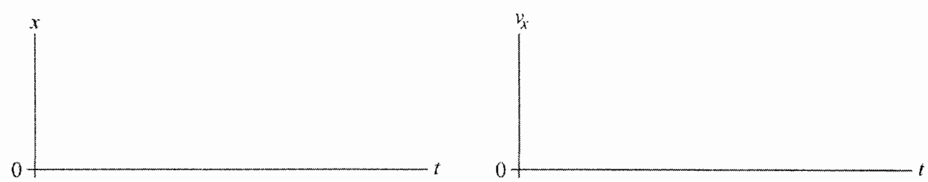
b. Do the two cars ever have the same position at one instant of time?
If so, in which frame number (or numbers)? ______________
Draw a vertical line through your graphs of part a to indicate this instant of time.

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.

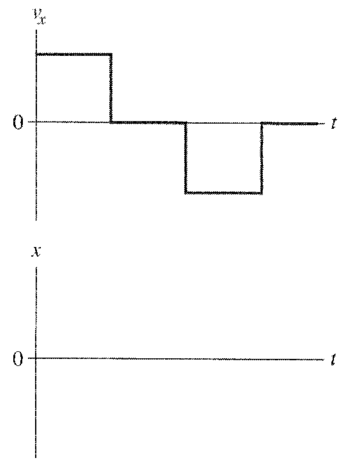
c. Do the two cars ever have the same velocity at one instant of time?
If so, between which two frames? ______________

2.3 Finding Position from Velocity

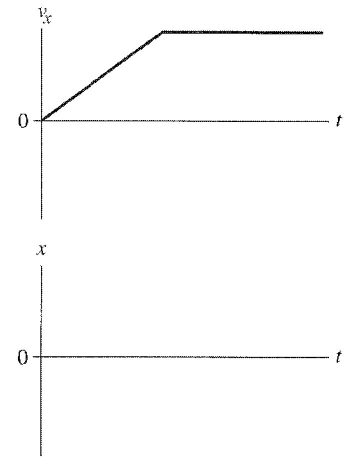
12. Below are shown four velocity-versus-time graphs. For each:
    - Draw the corresponding position-versus-time graph.
    - Give a written description of the motion.

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

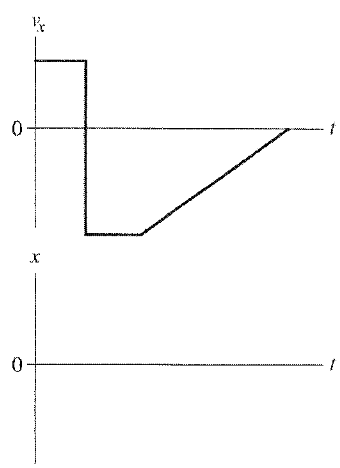
a.



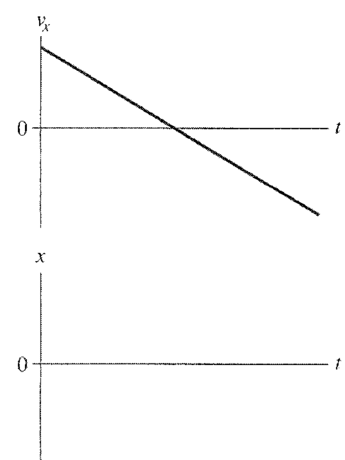
b.



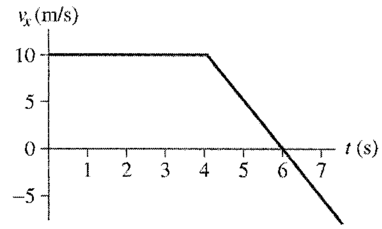
c.



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.

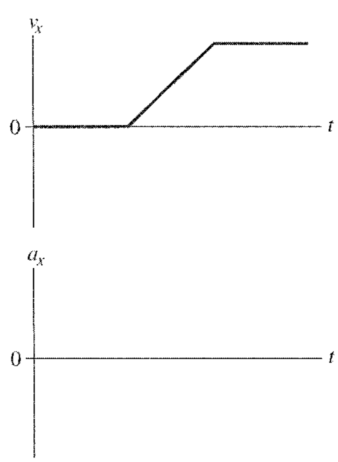
    a. $a_x = 0$ but $v_x \neq 0$.

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

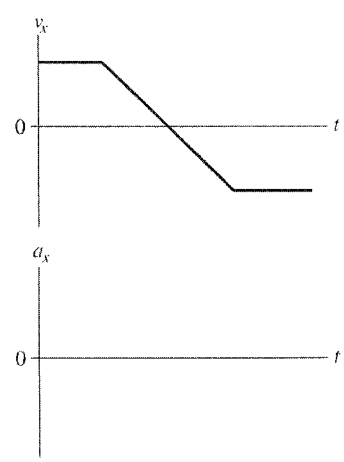
    c. $v_x < 0$ and $a_x > 0$.

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

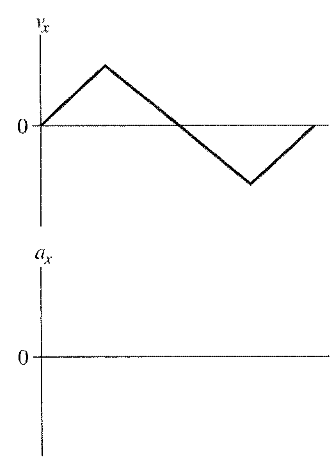
a.



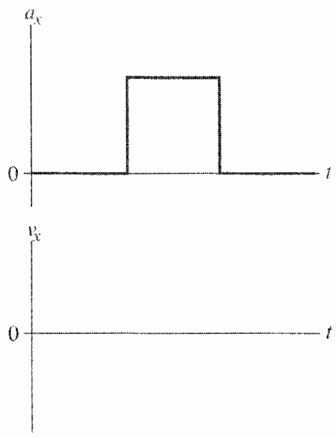
b.

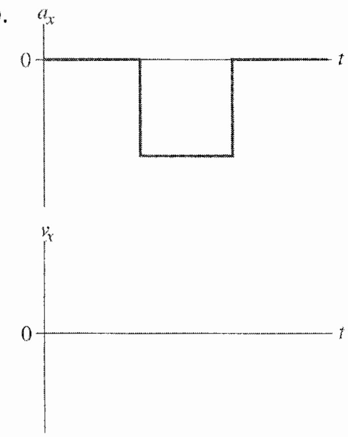


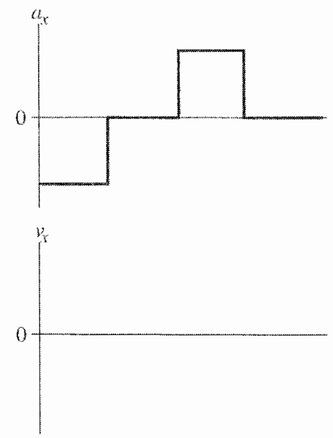
c.



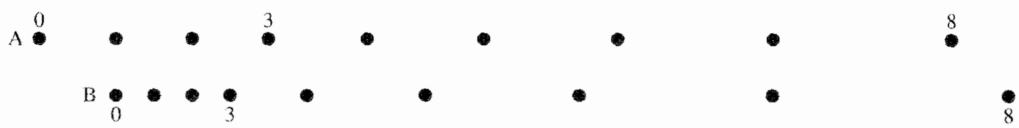
16. Below are three acceleration-versus-time graphs. For each, draw the corresponding velocity-versus-time graph. Assume that $v_{0x} = 0$.

a. 

b. 

c. 

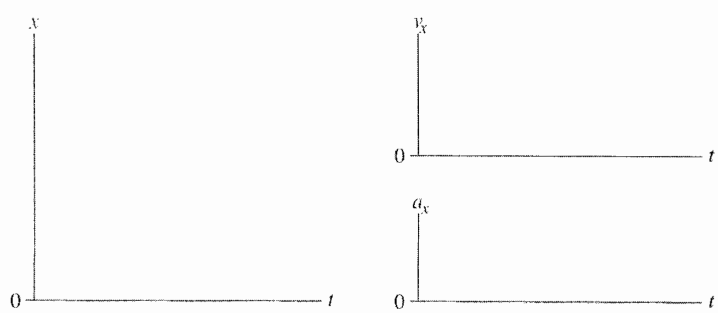
17. The figure below shows nine frames from the motion diagram of two cars. Both cars begin to accelerate, with constant acceleration, in frame 3.



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 Suppose you need to determine the maximum height reached by the rocket. We'll assume that air
2.1 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.

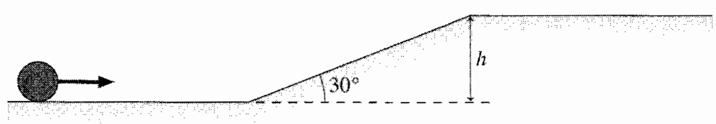
g. Now, substitute what you learned in part e into your equation of part f, do the algebra to solve for the unknown, and simplify the result as much as possible.

2.6 Motion on an Inclined Plane

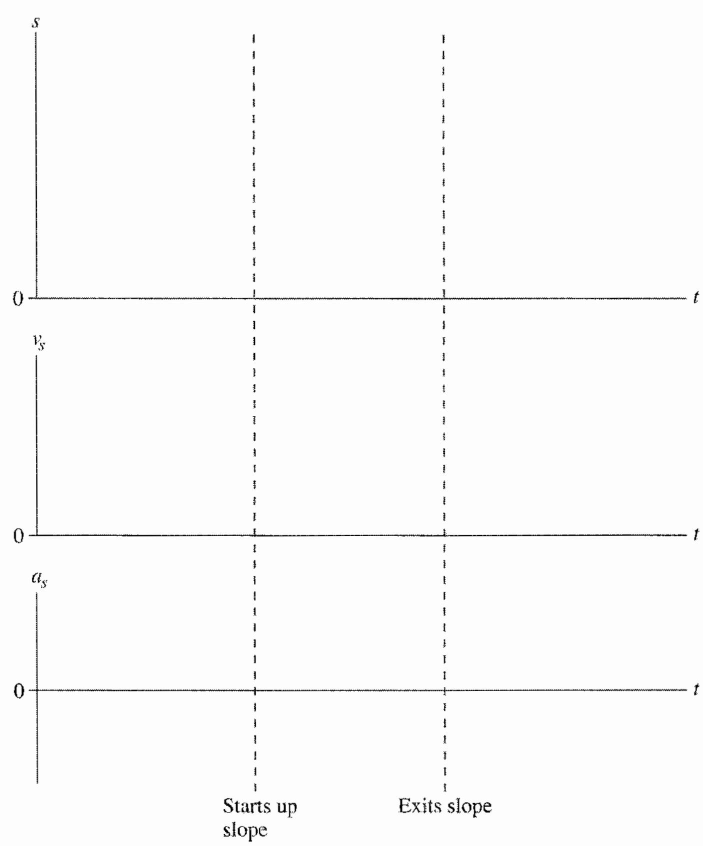
21. A ball released from rest on an inclined plane accelerates down the plane at 2 m/s^2. Complete the table below showing the ball's velocities at the times indicated. Do *not* use a calculator for this; this is a reasoning question, not a calculation problem.

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.



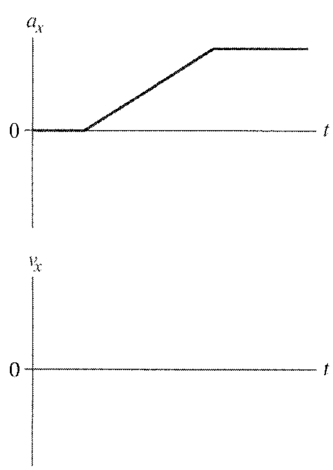
b. Suppose that the ball's initial speed is 5.0 m/s and its final speed is 1.0 m/s. Draw a pictorial representation that you would use to determine the height h of the slope. Establish a coordinate system, define all symbols, list known information, and identify desired unknowns.

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.