8. ***Draining a Tank*** The number of gallons of water in a tank $t$ minutes after the tank has started to drain is $Q(t) = 200(30 - t)^2$. How fast is the water running out at the end of 10 min? What is the average rate at which the water flows out during the first 10 min?

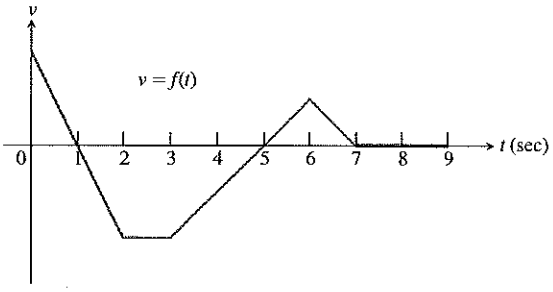
9. ***Particle Motion*** The accompanying figure shows the velocity $v = f(t)$ of a particle moving on a coordinate line.

(a) When does the particle move forward? move backward? speed up? slow down?

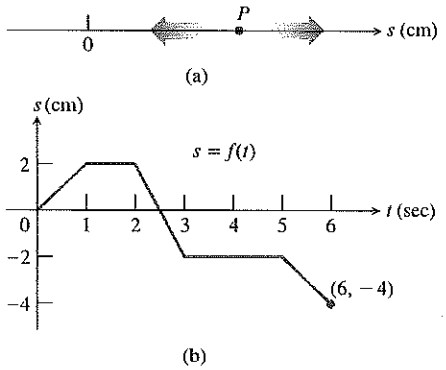
(b) When is the particle's acceleration positive? negative? zero?

(c) When does the particle move at its greatest speed?

(d) When does the particle stand still for more than an instant?



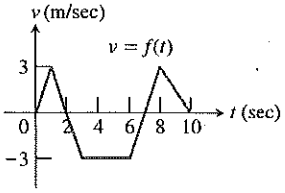

10. ***Particle Motion*** A particle $P$ moves on the number line shown in part (a) of the accompanying figure. Part (b) shows the position of $P$ as a function of time $t$.




(a) When is $P$ moving to the left? moving to the right? standing still?

(b) Graph the particle's velocity and speed (where defined).

11. ***Particle Motion*** The accompanying figure shows the velocity $v = ds/dt = f(t)$ (m/sec) of a body moving along a coordinate line.




(a) When does the body reverse direction?

(b) When (approximately) is the body moving at a constant speed?

(c) Graph the body's speed for $0 \le t \le 10$.

(d) Graph the acceleration, where defined.

12. ***Thoroughbred Racing*** A racehorse is running a 10-furlong race. (A furlong is 220 yards, although we will use furlongs and seconds as our units in this exercise.) As the horse passes each furlong marker ($F$), a steward records the time elapsed ($t$) since the beginning of the race, as shown in the table below:

| $F$ | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $t$ | 0 | 20 | 33 | 46 | 59 | 73 | 86 | 100 | 112 | 124 | 135 |

(a) How long does it take the horse to finish the race?

(b) What is the average speed of the horse over the first 5 furlongs?

(c) What is the approximate speed of the horse as it passes the 3-furlong marker?

(d) During which portion of the race is the horse running the fastest?

(e) During which portion of the race is the horse accelerating the fastest?

13. ***Lunar Projectile Motion*** A rock thrown vertically upward from the surface of the moon at a velocity of 24 m/sec (about 86 km/h) reaches a height of $s = 24t - 0.8t^2$ meters in $t$ seconds.

(a) Find the rock's velocity and acceleration as functions of time. (The acceleration in this case is the acceleration of gravity on the moon.)

(b) How long did it take the rock to reach its highest point?

(c) How high did the rock go?

(d) When did the rock reach half its maximum height?

(e) How long was the rock aloft?

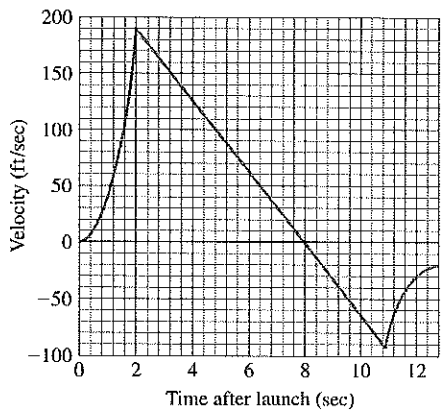
14. ***Free Fall*** The equations for free fall near the surfaces of Mars and Jupiter ($s$ in meters, $t$ in seconds) are: Mars, $s = 1.86t^2$; Jupiter, $s = 11.44t^2$. How long would it take a rock falling from rest to reach a velocity of 16.6 m/sec (about 60 km/h) on each planet?

15. ***Projectile Motion*** On Earth, in the absence of air, the rock in Exercise 13 would reach a height of $s = 24t - 4.9t^2$ meters in $t$ seconds. How high would the rock go?

16. ***Speeding Bullet*** A bullet fired straight up from the moon's surface would reach a height of $s = 832t - 2.6t^2$ ft after $t$ sec. On Earth, in the absence of air, its height would be $s = 832t - 16t^2$ ft after $t$ sec. How long would it take the bullet to get back down in each case?

17. ***Parametric Graphing*** Devise a grapher simulation of the problem situation in Exercise 16. Use it to support the answers obtained analytically.

**18.** ***Launching a Rocket*** When a model rocket is launched, the propellant burns for a few seconds, accelerating the rocket upward. After burnout, the rocket coasts upward for a while and then begins to fall. A small explosive charge pops out a parachute shortly after the rocket starts downward. The parachute slows the rocket to keep it from breaking when it lands. This graph shows velocity data from the flight.




Use the graph to answer the following.

**(a)** How fast was the rocket climbing when the engine stopped?

**(b)** For how many seconds did the engine burn?

**(c)** When did the rocket reach its highest point? What was its velocity then?

**(d)** When did the parachute pop out? How fast was the rocket falling then?

**(e)** How long did the rocket fall before the parachute opened?

**(f)** When was the rocket's acceleration greatest? When was the acceleration constant?

**19.** ***Particle Motion*** A particle moves along a line so that its position at any time $t \geq 0$ is given by the function

$$s(t) = t^2 - 3t + 2,$$

where $s$ is measured in meters and $t$ is measured in seconds.

**(a)** Find the displacement during the first 5 seconds.

**(b)** Find the average velocity during the first 5 seconds.

**(c)** Find the instantaneous velocity when $t = 4$.

**(d)** Find the acceleration of the particle when $t = 4$.

**(e)** At what values of $t$ does the particle change direction?

**(f)** Where is the particle when $s$ is a minimum?

**20.** ***Particle Motion*** A particle moves along a line so that its position at any time $t \geq 0$ is given by the function $s(t) = -t^3 + 7t^2 - 14t + 8$ where $s$ is measured in meters and $t$ is measured in seconds.

**(a)** Find the instantaneous velocity at any time $t$.

**(b)** Find the acceleration of the particle at any time $t$.

**(c)** When is the particle at rest?

**(d)** Describe the motion of the particle. At what values of $t$ does the particle change directions?

**21.** ***Particle Motion*** A particle moves along a line so that its position at any time $t \geq 0$ is given by the function $s(t) = (t - 2)^2(t - 4)$ where $s$ is measured in meters and $t$ is measured in seconds.

**(a)** Find the instantaneous velocity at any time $t$.

**(b)** Find the acceleration of the particle at any time $t$.

**(c)** When is the particle at rest?

**(d)** Describe the motion of the particle. At what values of $t$ does the particle change directions?

**22.** ***Particle Motion*** A particle moves along a line so that its position at any time $t \geq 0$ is given by the function $s(t) = t^3 - 6t^2 + 8t + 2$ where $s$ is measured in meters and $t$ is measured in seconds.

**(a)** Find the instantaneous velocity at any time $t$.

**(b)** Find the acceleration of the particle at any time $t$.

**(c)** When is the particle at rest?

**(d)** Describe the motion of the particle. At what values of $t$ does the particle change directions?

**23.** ***Particle Motion*** The position of a body at time $t$ sec is $s = t^3 - 6t^2 + 9t$ m. Find the body's acceleration each time the velocity is zero.

**24.** ***Finding Speed*** A body's velocity at time $t$ sec is $v = 2t^3 - 9t^2 + 12t - 5$ m/sec. Find the body's speed each time the acceleration is zero.

**25.** ***Draining a Tank*** It takes 12 hours to drain a storage tank by opening the valve at the bottom. The depth $y$ of fluid in the tank $t$ hours after the valve is opened is given by the formula

$$y = 6\left(1 - \frac{t}{12}\right)^2 \text{ m}.$$

**(a)** Find the rate $dy/dt$ (m/h) at which the water level is changing at time $t$.

**(b)** When is the fluid level in the tank falling fastest? slowest? What are the values of $dy/dt$ at these times?

**(c)** Graph $y$ and $dy/dt$ together and discuss the behavior of $y$ in relation to the signs and values of $dy/dt$.