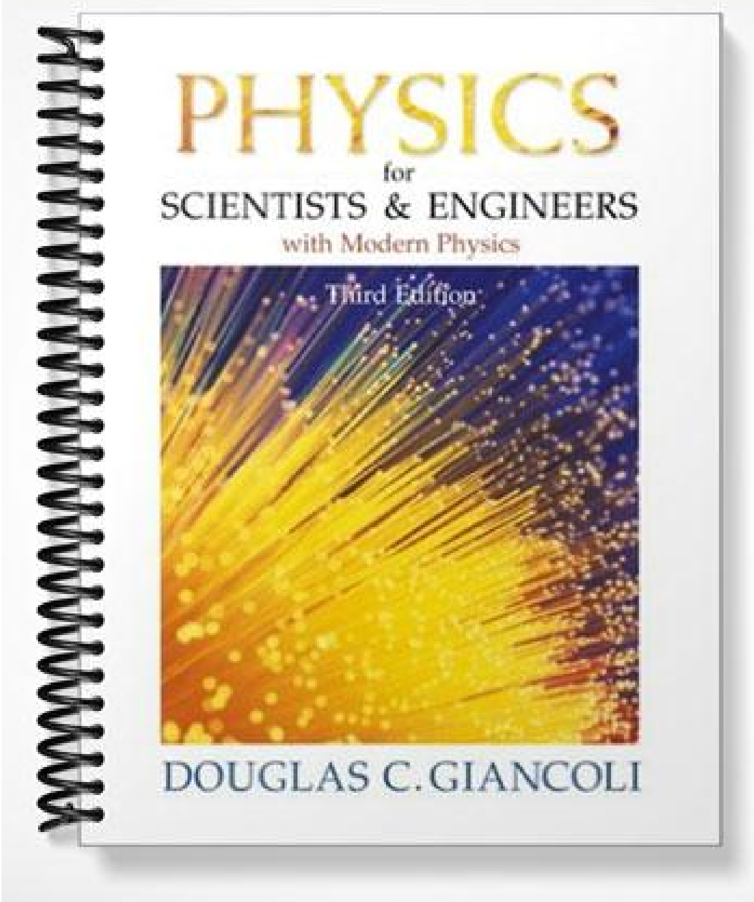
SOLUTIONS MANUAL



CHAPTER 2 - Describing Motion: Kinematics in One Dimension

1. We find the time from
   average speed = d/t;
   15 km/h = (75 km)/t , which gives t = 5.0 h.

2. We find the average speed from
   average speed = d/t = (280 km)/(3.2 h) = 88 km/h.

3. We find the distance traveled from
   average speed = d/t;
   (110 km/h)/(3600 s/h) = d/(2.0 s), which gives $d = 6.1 \times 10^{-2}$ km = 61 m.

4. We find the average velocity from
   æ = $(x_2 - x_1)/(t_2 - t_1)$ = (– 4.2 cm – 3.4 cm)/(6.1 s – 3.0 s) = – 2.5 cm/s (toward – x).

5. We find the average velocity from
   æ = $(x_2 - x_1)/(t_2 - t_1)$ = (8.5 cm – 3.4 cm)/[4.5 s – (– 2.0 s)] = 0.78 cm/s (toward + x).
   Because we do not know the total distance traveled, we cannot calculate the average speed.

6. (*a*) We find the elapsed time before the speed change from
   speed = d_1/t_1 ;
   65 mi/h = (130 mi)/t_1 , which gives t_1 = 2.0 h.
   Thus the time at the lower speed is
   $t_2 = T - t_1$ = 3.33 h – 2.0 h = 1.33 h.
   We find the distance traveled at the lower speed from
   speed = d_2/t_2;
   55 mi/h = d_2/(1.33 h), which gives d_2 = 73 mi.
   The total distance traveled is
   $D = d_1 + d_2$ = 130 mi + 73 mi = 203 mi.
   (*b*) We find the average speed from
   average speed = d/t = (203 mi)/(3.33 h) = 61 mi/h.
   Note that the average speed is <u>not</u> !(65 mi/h + 55 mi/h). The two speeds were not maintained for
   equal times.

7. Because there is no elapsed time when the light arrives, the sound travels one mile in 5 seconds.
   We find the speed of sound from
   speed = d/t = (1 mi)(1610 m/1 mi)/(5 s) ˜ 300 m/s.

8. (*a*) We find the average speed from
   average speed = d/t = 8(0.25 mi)(1.61×10^3 m/mi)/(12.5 min)(60 s/min) = 4.29 m/s.
   (*b*) Because the person finishes at the starting point, there is no displacement;
   thus the average velocity is
   æ = $\Delta x/\Delta t$ = 0.

9. (*a*) We find the average speed from
   average speed = d/t = (160 m + 80 m)/(17.0 s + 6.8 s) = 10.1 m/s.
   (*b*) The displacement away from the trainer is 160 m – 80 m = 80 m; thus the average velocity is
   æ = $\Delta x/\Delta t$ = (80 m)/(17.0 s + 6.8 s) = + 3.4 m/s, away from trainer.

10. Because the two locomotives are traveling with equal speeds in opposite directions, each locomotive will travel half the distance, 4.25 km. We find the elapsed time from

speed$_1$ = d_1/t ;

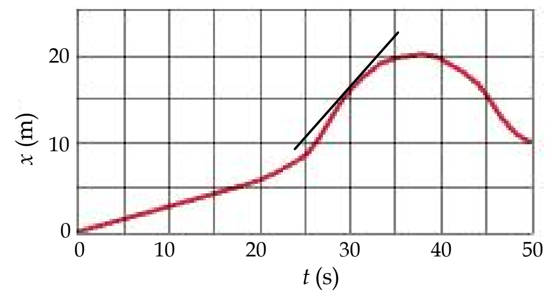
(95 km/h)/(60 min/h) = (4.25 km)/t, which gives t = 2.7 min.

11. (*a*) We find the instantaneous velocity from the slope of the straight line from t = 0 to t = 10.0 s:

v_{10} = ?x/?t = (2.8 m – 0)/(10.0 s – 0) = 0.28 m/s.

(*b*) We find the instantaneous velocity from the slope of a tangent to the line at t = 30.0 s:

v_{30} = ?x/?t = (22 m – 10 m)/(35 s – 25 s) = 1.2 m/s.



(*c*) The velocity is constant for the first 17 s (a straight line), so the velocity is the same as the velocity at t = 10 s:

æ$_{0\to5}$ = 0.28 m/s.

(*d*) For the average velocity we have

æ$_{25\to30}$ = ?x/?t = (16 m – 8 m)/(30.0 s – 25.0 s) = 1.6 m/s.

(*e*) For the average velocity we have

æ$_{40\to50}$ = ?x/?t = (10 m – 20 m)/(50.0 s – 40.0 s) = – 1.0 m/s.

12. (*a*) Constant velocity is indicated by a straight line, which occurs from t = 0 to 17 s.

(*b*) The maximum velocity is when the slope is greatest: t = 28 s.

(*c*) Zero velocity is indicated by a zero slope. The tangent is horizontal at t = 38 s.

(*d*) Because the curve has both positive and negative slopes, the motion is in both directions.

13. (*a*) We find the average speed from

average speed = d/t = (100 m + 50 m)/[8.4 s + @(8.4 s)] = 13.4 m/s.

(*b*) The displacement away from the trainer is 100 m – 50 m = 50 m; thus the average velocity is

æ = $\Delta x/\Delta t$ = (50 m)/[8.4 s + @(8.4 s)] = + 4.5 m/s, away from master.

14. (*a*) We find the position from the dependence of x on t: x = 2.0 m – (4.6 m/s)t + (1.1 m/s^2)t^2.

x_1 = 2.0 m – (4.6 m/s)(1.0 s) + (1.1 m/s^2)(1.0 s)^2 = – 1.5 m;

x_2 = 2.0 m – (4.6 m/s)(2.0 s) + (1.1 m/s^2)(2.0 s)^2 = – 2.8 m;

x_3 = 2.0 m – (4.6 m/s)(3.0 s) + (1.1 m/s^2)(3.0 s)^2 = – 1.9 m.

(*b*) For the average velocity we have

æ$_{1\to3}$ = ?x/?t = [(– 1.9 m) – (– 1.5 m)]/(3.0 s – 1.0 s) = – 0.2 m/s (toward – x).

(*c*) We find the instantaneous velocity by differentiating:

v = dx/dt = – (4.6 m/s) + (2.2 m/s^2)t;

v_2 = – (4.6 m/s) + (2.2 m/s^2)(2.0 s) = – 0.2 m/s (toward – x);

v_3 = – (4.6 m/s) + (2.2 m/s^2)(3.0 s) = + 2.0 m/s (toward + x).

15. Because the velocities are constant, we can use the relative speed of the car to find the time:

$t = d/v_{rel}$ = [(0.100 km)/(90 km/h – 75 km/h)](60 min/h) = 0.40 min = 24 s.

16. We find the total time for the trip by adding the times for each leg:

$T = t_1 + t_2 = (d_1/v_1) + (d_2/v_2)$

= [(2100 km)/(800 km/h)] + [(1800 km)/(1000 km/h)] = 4.43 h.

We find the average speed from

average speed = $(d_1 + d_2)/T$ = (2100 km + 1800 km)/(4.43 h) = 881 km/h.

Note that the average speed is <u>not</u> !(800 km/h + 1000 km/h). The two speeds were not maintained for
equal times.

17. We find the time for the outgoing 200 km from
$t_1 = d_1/v_1 = (200\text{ km})/(90\text{ km/h}) = 2.22\text{ h}.$
We find the time for the return 200 km from
$t_2 = d_2/v_2 = (200\text{ km})/(50\text{ km/h}) = 4.00\text{ h}.$
We find the average speed from
average speed $= (d_1 + d_2)/(t_1 + t_{\text{lunch}} + t_2)$
$= (200\text{ km} + 200\text{ km})/(2.22\text{ h} + 1.00\text{ h} + 4.00\text{ h}) =$ 55 km/h.
Because the trip finishes at the starting point, there is no displacement; thus the average velocity is
æ $= \Delta x/\Delta t =$ 0.

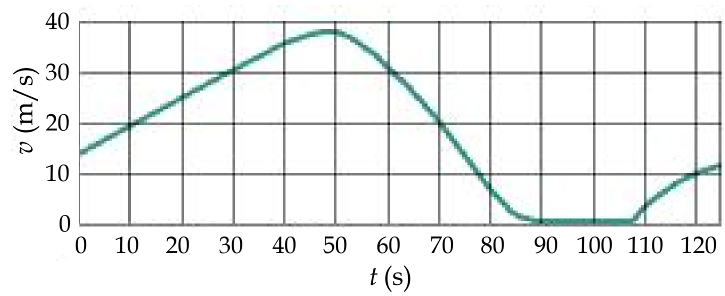
18. If $\mathbf{v}_{AG}$ is the velocity of the automobile with respect to the ground,
$\mathbf{v}_{TG}$ the velocity of the train with respect to the ground, and
$\mathbf{v}_{AT}$ the velocity of the automobile with respect to the train, then
$\mathbf{v}_{AT} = \mathbf{v}_{AG} - \mathbf{v}_{TG}$.
If we use a coordinate system in the reference frame of the train with the origin at the back of the train, we find the time to pass from
$x_1 = v_{AT}t_1;$
$1.10\text{ km} = (90\text{ km/h} - 80\text{ km/h})t_1$, which gives $t_1 = 0.11\text{ h} =$ 6.6 min.
With respect to the ground, the automobile will have traveled
$x_{1G} = v_{AG}t_1 = (90\text{ km/h})(0.11\text{ h}) =$ 9.9 km.
If the automobile is traveling toward the train, we find the time to pass from
$x_2 = v_{AT}t_2;$
$1.10\text{ km} = [90\text{ km/h} - (-\,80\text{ km/h})]t_2$, which gives $t_2 = 0.00647\text{ h} =$ 23.3 s.
With respect to the ground, the automobile will have traveled
$x_{2G} = v_{AG}t_2 = (90\text{ km/h})(0.00647\text{ h}) =$ 0.58 km.

19. We find the time for the sound to travel the length of the lane from
$t_{\text{sound}} = d/v_{\text{sound}} = (16.5\text{ m})/(340\text{ m/s}) = 0.0485\text{ s}.$
We find the speed of the ball from
$v = d/(T - t_{\text{sound}})$
$= (16.5\text{ m})/(2.50\text{ s} - 0.0485\text{ s}) =$ 6.73 m/s.

20. We find the average acceleration from
Æ $= \Delta v/\Delta t$
$= [(95\text{ km/h})(1\text{ h}/3.6\text{ ks}) - 0]/(6.2\text{ s}) =$ 4.3 m/s^2.

21. We find the time from
Æ $= \Delta v/\Delta t$;
$1.6\text{ m/s}^2 = (110\text{ km/h} - 80\text{ km/h})(1\text{ h}/3.6\text{ ks})/\Delta t$, which gives $\Delta t =$ 5.2 s.

22.



(a) The maximum velocity is indicated by the highest point, which occurs at $t = 50$ s.

(b) Constant velocity is indicated by a horizontal slope, which occurs from $t = 90$ s to 107 s.

(c) Constant acceleration is indicated by a straight line, which occurs from
$t = 0$ to 30 s, and $t = 90$ s to 107 s.

(d) The maximum acceleration is when the slope is greatest: $t = 75$ s.

23. We find the acceleration (assumed to be constant) from

$v^2 = v_0{}^2 + 2a(x_2 - x_1)$;

$0 = [(100 \text{ km/h})/(3.6 \text{ ks/h})]^2 + 2a(55 \text{ m})$, which gives $a = -7.0 \text{ m/s}^2$.

The number of g's is

$N = |a|/g = (7.0 \text{ m/s}^2)/(9.80 \text{ m/s}^2) =$ 0.72.

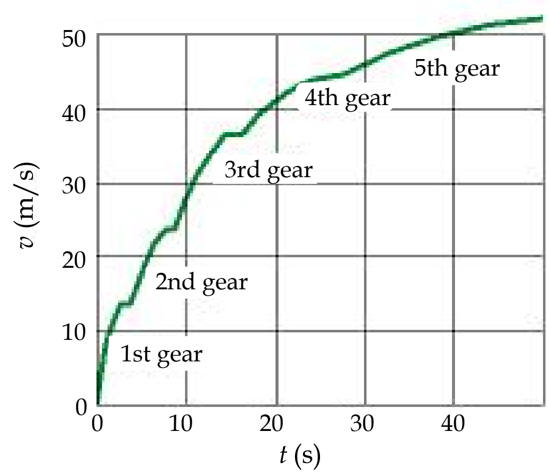
24. For the average acceleration we have

Æ$_2$ = ?v/?t = (24 m/s – 14 m/s)/(8 s – 4 s)

= 2.5 m/s^2;

Æ$_4$ = ?v/?t = (44 m/s – 37 m/s)/(27 s – 16 s)

= 0.6 m/s^2.



25. (*a*) For the average acceleration we have

$Æ_1 = ?v/?t = (14 \text{ m/s} - 0)/(3 \text{ s} - 0) =$ 4.7 m/s^2.

(*b*) For the average acceleration we have

$Æ_3 = ?v/?t = (37 \text{ m/s} - 24 \text{ m/s})/(14 \text{ s} - 8 \text{ s}) =$ 2.2 m/s^2.

(*c*) For the average acceleration we have

$Æ_5 = ?v/?t = (52 \text{ m/s} - 44 \text{ m/s})/(50 \text{ s} - 27 \text{ s}) =$ 0.3 m/s^2.

(*d*) For the average acceleration we have

$Æ_{1\to 4} = ?v/?t = (44 \text{ m/s} - 0)/(27 \text{ s} - 0) =$ 1.6 m/s^2.

Note that we cannot add the four average accelerations and divide by 4.

26. (*a*) We take the average velocity during a time interval as the instantaneous velocity at the midpoint of the time interval:

$v_{\text{midpoint}} = æ = \Delta x/\Delta t.$

Thus for the first interval we have

$v_{0.125 \text{ s}} = (0.11 \text{ m} - 0)/(0.25 \text{ s} - 0) = 0.44 \text{ m/s}.$

(*b*) We take the average acceleration during a time interval as the instantaneous acceleration at the midpoint of the time interval:

$a_{\text{midpoint}} = Æ = \Delta v/\Delta t.$

Thus for the first interval in the velocity column we have

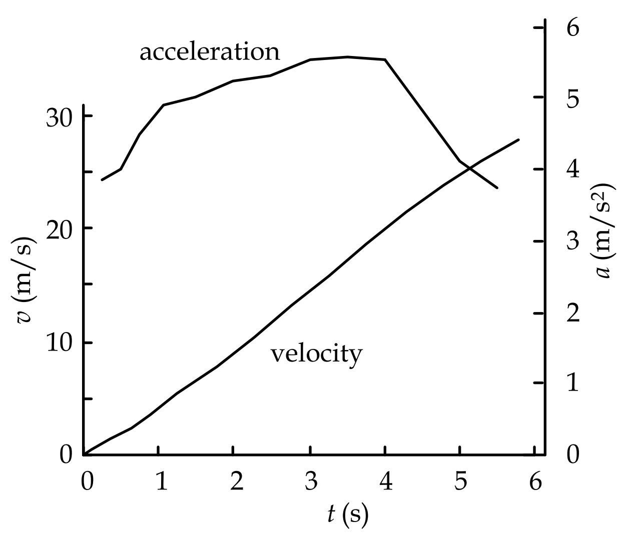
$a_{0.25 \text{ s}} = (1.4 \text{ m/s} - 0.44 \text{ m/s})/(0.375 \text{ s} - 0.125 \text{ s}) = 3.8 \text{ m/s}^2.$

The results are presented in the following table and graph.

t(s)	x(m)
0.0	0.0
0.25	0.11
0.50	0.46
0.75	1.06
1.00	1.94
1.50	4.62
2.00	8.55
2.50	13.79
3.00	20.36
3.50	28.31
4.00	37.65
4.50	48.37
5.00	60.30
5.50	73.26
6.00	87.16

t(s)	v(m/s)
0.0	0.0
0.125	0.44
0.375	1.4
0.625	2.4
0.875	3.5
1.25	5.36
1.75	7.85
2.25	10.5
2.75	13.1
3.25	15.9
3.75	18.7
4.25	21.4
4.75	23.9
5.25	25.9
5.75	27.8

t(s)	a(m/s^2)
0.25	3.8
0.50	4.0
0.75	4.5
1.06	4.9
1.50	5.0
2.00	5.2
2.50	5.3
3.00	5.5
3.50	5.6
4.00	5.5
4.50	4.8
5.00	4.1
5.50	3.8



Note that we do not know the acceleration at $t = 0$.

27. We find the velocity and acceleration by differentiating $x = (6.0\ \mathrm{m/s})t + (8.5\ \mathrm{m/s^2})t^2$:

$v = \mathrm{d}x/\mathrm{d}t = (6.0\ \mathrm{m/s}) + (17\ \mathrm{m/s^2})t$;

$a = \mathrm{d}v/\mathrm{d}t = 17\ \mathrm{m/s^2}$.

28. The position is given by $x = At + 6Bt^3$.

(*a*) All terms must give the same units, so we have

$A \sim x/t = \mathrm{m/s}$; and $B \sim x/t^3 = \mathrm{m/s^3}$.

(*b*) We find the velocity and acceleration by differentiating:

$v = \mathrm{d}x/\mathrm{d}t = A + 18Bt^2$;

$a = \mathrm{d}v/\mathrm{d}t = 36Bt$.

(*c*) For the given time we have

$v = \mathrm{d}x/\mathrm{d}t = A + 18Bt^2 = A + 18B(5.0\ \mathrm{s})^2 = A + (450\ \mathrm{s^2})B$;

$a = \mathrm{d}v/\mathrm{d}t = 36Bt = 36B(5.0\ \mathrm{s}) = (180\ \mathrm{s})B$.

(*d*) We find the velocity by differentiating:

$v = \mathrm{d}x/\mathrm{d}t = A - 3Bt^{-4}$.

29. We find the acceleration from

$v = v_0 + a(t - t_0)$;

$21\ \mathrm{m/s} = 12\ \mathrm{m/s} + a(6.0\ \mathrm{s})$, which gives $a = 1.5\ \mathrm{m/s^2}$.

We find the distance traveled from

$x = !(v + v_0)t$

$= !(21\ \mathrm{m/s} + 12\ \mathrm{m/s})(6.0\ \mathrm{s}) = 99\ \mathrm{m}$.

30. We find the acceleration (assumed constant) from

$v^2 = v_0^2 + 2a(x_2 - x_1)$;

$0 = (25\ \mathrm{m/s})^2 + 2a(75\ \mathrm{m})$, which gives $a = -4.2\ \mathrm{m/s^2}$.

31. We find the length of the runway from

$v^2 = v_0^2 + 2aL$;

$(32\ \mathrm{m/s})^2 = 0 + 2(3.0\ \mathrm{m/s^2})L$, which gives $L = 1.7 \times 10^2\ \mathrm{m}$.

32. We find the average acceleration from

$v^2 = v_0^2 + 2Æ(x_2 - x_1)$;

$(44\ \mathrm{m/s})^2 = 0 + 2Æ(3.5\ \mathrm{m})$, which gives $Æ = 2.8 \times 10^2\ \mathrm{m/s^2}$.

33. We find the average acceleration from

$v^2 = v_0^2 + 2Æ(x_2 - x_1)$;

$(11.5\ \mathrm{m/s})^2 = 0 + 2Æ(15.0\ \mathrm{m})$, which gives $Æ = 4.41\ \mathrm{m/s^2}$.

We find the time required from

$x = !(v + v_0)t$;

$15.0\ \mathrm{m} = !(11.5\ \mathrm{m/s} + 0)$, which gives $t = 2.61\ \mathrm{s}$.

34. The average velocity is $æ = (x - x_0)/(t - t_0)$, so we must find the position as a function of time. Because the acceleration is a function of time, we find the velocity by integrating $a = \mathrm{d}v/\mathrm{d}t$:

$?\ \mathrm{d}v = ?\ a\ \mathrm{d}t = ?\ (A + Bt)\ \mathrm{d}t$;

$v = At + (Bt^2/2) + C$.

If $v = v_0$ when $t = 0$, $C = v_0$; so we have $v = At + (Bt^2/2) + v_0$.
We find the position by integrating $v = dx/dt$:

$$\int dx = \int v\,dt = \int [At + (Bt^2/2) + v_0]\,dt;$$

$$x = (At^2/2) + (Bt^3/6) + v_0 t + D.$$

If $x = x_0$ when $t = 0$, $D = x_0$; so we have $x = (At^2/2) + (Bt^3/6) + v_0 t + x_0$.
Thus the average velocity is

$$\bar{v} = (x - x_0)/(t - t_0) = \{[(At^2/2) + (Bt^3/6) + v_0 t + x_0] - x_0\}/(t - 0) = (At/2) + (Bt^2/6) + v_0.$$

If we evaluate $(v + v_0)/2$, we get

$$(v + v_0)/2 = \{[At + (Bt^2/2) + v_0] + v_0\}/2 = (At/2) + (Bt^2/4) + v_0,$$

which is not the average velocity.

35. For the constant acceleration the average speed is $\frac{1}{2}(v + v_0)$, thus

$$x = \tfrac{1}{2}(v + v_0)t:$$
$$= \tfrac{1}{2}(0 + 22.0\text{ m/s})(5.00\text{ s}) = \quad 55.0\text{ m}.$$

36. We find the speed of the car from

$$v^2 = v_0^2 + 2a(x_1 - x_0);$$
$$0 = v_0^2 + 2(-7.00\text{ m/s}^2)(75\text{ m}),\text{ which gives}\quad v_0 = 32\text{ m/s}.$$

37. We convert the units for the speed: $(55\text{ km/h})/(3.6\text{ ks/h}) = 15.3\text{ m/s}$.

(*a*) We find the distance the car travels before stopping from

$$v^2 = v_0^2 + 2a(x_1 - x_0);$$
$$0 = (15.3\text{ m/s})^2 + 2(-0.50\text{ m/s}^2)(x_1 - x_0),\text{ which gives}\quad x_1 - x_0 = 2.3 \times 10^2\text{ m}.$$

(*b*) We find the time it takes to stop the car from

$$v = v_0 + at\,;$$
$$0 = 15.3\text{ m/s} + (-0.50\text{ m/s}^2)t,\text{ which gives}\quad t = 31\text{ s}.$$

(*c*) With the origin at the beginning of the coast, we find the position at a time t from

$x = v_0 t + \frac{1}{2}at^2$. Thus we find

$$x_1 = (15.3\text{ m/s})(1.0\text{ s}) + \tfrac{1}{2}(-0.50\text{ m/s}^2)(1.0\text{ s})^2 = 15\text{ m};$$
$$x_4 = (15.3\text{ m/s})(4.0\text{ s}) + \tfrac{1}{2}(-0.50\text{ m/s}^2)(4.0\text{ s})^2 = 57\text{ m};$$
$$x_5 = (15.3\text{ m/s})(5.0\text{ s}) + \tfrac{1}{2}(-0.50\text{ m/s}^2)(5.0\text{ s})^2 = 70\text{ m}.$$

During the first second the car travels 15 m – 0 = 15 m.
During the fifth second the car travels 70 m – 57 m = 13 m.

38. We find the average acceleration from

$$v^2 = v_0^2 + 2\bar{a}(x_2 - x_1);$$
$$0 = [(95\text{ km/h})/(3.6\text{ ks/h})]^2 + 2\bar{a}(0.80\text{ m}),\text{ which gives}\quad \bar{a} = -4.4 \times 10^2\text{ m/s}^2.$$

The number of g's is

$$|\bar{a}| = (4.4 \times 10^2\text{ m/s}^2)/[(9.80\text{ m/s}^2)/g] = \quad 44g.$$

39. We convert the units for the speed: $(90\text{ km/h})/(3.6\text{ ks/h}) = 25\text{ m/s}$.
With the origin at the beginning of the reaction, the location when the brakes are applied is

$$x_0 = v_0 t = (25\text{ m/s})(1.0\text{ s}) = 25\text{ m}.$$

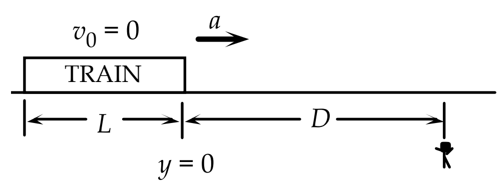
(*a*) We find the location of the car after the brakes are applied from

$$v^2 = v_0^2 + 2a_1(x_1 - x_0);$$
$$0 = (25\text{ m/s})^2 + 2(-4.0\text{ m/s}^2)(x_1 - 25\text{ m}), \text{ which gives} \quad x_1 = 103\text{ m}.$$

(*b*) We repeat the calculation for the new acceleration:
$$v^2 = v_0^2 + 2a_2(x_2 - x_0);$$
$$0 = (25\text{ m/s})^2 + 2(-8.0\text{ m/s}^2)(x_2 - 25\text{ m}), \text{ which gives} \quad x_2 = 64\text{ m}.$$

40. We find the acceleration of the space vehicle from
$$v = v_0 + at;$$
$$162\text{ m/s} = 65\text{ m/s} + a(10.0\text{ s} - 0.0\text{ s}), \text{ which gives } a = 9.7\text{ m/s}^2.$$
We find the positions at the two times from
$$x = x_0 + v_0t + \tfrac{1}{2}at^2;$$
$$x_2 = x_0 + (65\text{ m/s})(2.0\text{ s}) + \tfrac{1}{2}(9.7\text{ m/s}^2)(2.0\text{ s})^2 = x_0 + 149\text{ m};$$
$$x_6 = x_0 + (65\text{ m/s})(6.0\text{ s}) + \tfrac{1}{2}(9.7\text{ m/s}^2)(6.0\text{ s})^2 = x_0 + 565\text{ m}.$$
Thus the distance moved is
$$x_6 - x_2 = 565\text{ m} - 149\text{ m} = 416\text{ m} = \quad 4.2 \times 10^2\text{ m}.$$

41. We use a coordinate system with the origin at the initial position of the front of the train. We can find the acceleration of the train from the motion up to the point where the front of the train passes the worker:



$$v_1^2 = v_0^2 + 2a(D - 0);$$
$$(25\text{ m/s})^2 = 0 + 2a(140\text{ m} - 0),$$
which gives $a = 2.23\text{ m/s}^2$.
Now we consider the motion of the last car, which starts at $-L$, to the point where it passes the worker:
$$v_2^2 = v_0^2 + 2a[D - (-L)]$$
$$= 0 + 2(2.23\text{ m/s}^2)(140\text{ m} + 75\text{ m}), \text{ which gives } v_2 = \quad 31\text{ m/s}.$$

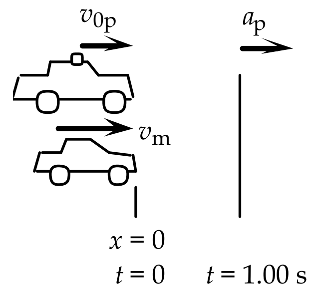
42. With the origin at the beginning of the reaction, the location when the brakes are applied is
$$d_0 = v_0t_R.$$
We find the location of the car after the brakes are applied, which is the total stopping distance, from
$$v^2 = 0 = v_0^2 + 2a(d_S - d_0), \text{ which gives} \quad d_S = v_0t_R - v_0^2/(2a).$$
Note that a is negative.

43. (*a*) We assume constant velocity of v_0 through the intersection. The time to travel at this speed is
$$t = (d_S + d_I)/v_0 = t_R - (v_0/2a) + (d_I/v_0).$$
(*b*) For the two speeds we have
$$t_1 = t_R - (v_{01}/2a) + (d_I/v_{01})$$
$$= 0.500\text{ s} - [(30.0\text{ km/h})/(3.60\text{ ks/h})2(-4.00\text{ m/s}^2)] + [(14.4\text{ m})(3.60\text{ ks/h})/(30.0\text{ km/h})]$$
$$= 3.27\text{ s}.$$
$$t_2 = t_R - (v_{02}/2a) + (d_I/v_{02})$$
$$= 0.500\text{ s} - [(60.0\text{ km/h})/(3.60\text{ ks/h})2(-4.00\text{ m/s}^2)] + [(14.4\text{ m})(3.60\text{ ks/h})/(60.0\text{ km/h})]$$
$$= 3.45\text{ s}.$$
Thus the chosen time is 3.45 s.

44. We convert the units:

$(95\ \text{km/h})/(3.6\ \text{ks/h}) = 26.4\ \text{m/s}.$

$(140\ \text{km/h/s})/(3.6\ \text{ks/h}) = 38.9\ \text{m/s}.$



We use a coordinate system with the origin where the motorist passes the police officer, as shown in the diagram.

The location of the speeding motorist is given by

$x_m = x_0 + v_m t = 0 + (38.9\ \text{m/s})t.$

The location of the police officer is given by

$x_p = x_0 + v_{0p}(1.00\ \text{s}) + v_{0p}(t - 1.00\ \text{s}) + !a_p(t - 1.00\ \text{s})^2$

$= 0 + (26.4\ \text{m/s})t + !(2.00\ \text{m/s}^2)(t - 1.00\ \text{s})^2.$

The officer will reach the speeder when these locations coincide, so we have

$x_m = x_p;$

$(38.9\ \text{m/s})t = (26.4\ \text{m/s})t + !(2.00\ \text{m/s}^2)(t - 1.00\ \text{s})^2.$

The solutions to this quadratic equation are 0.07 s and 14.4 s.

Because the time must be greater than 1.00 s, the result is $t = 14.4$ s.

45. If the police car accelerates for 6.0 s, the time from when the speeder passed the police car is 7.0 s.

From the analysis of Problem 44 we have

$x_m = x_p;$

$v_m t = v_{0p}t + !a_p(t - 1.00\ \text{s})^2;$

$v_m(7.0\ \text{s}) = (26.4\ \text{m/s})(7.0\ \text{s}) + !(2.00\ \text{m/s}^2)(6.0\ \text{s})^2$, which gives $v_m =$ 32 m/s (110 km/h).

46. We find the assumed constant speed for the first 27.0 min from

$v_0 = ?x/?t = (10{,}000\ \text{m} - 1100\ \text{m})/(27.0\ \text{min})(60\ \text{s/min}) = 5.49\ \text{m/s}.$

The runner must cover the last 1100 m in 3.0 min (180 s). If the runner accelerates for t s, the new speed will be

$v = v_0 + at = 5.49\ \text{m/s} + (0.20\ \text{m/s}^2)t;$

and the distance covered during the acceleration will be

$x_1 = v_0 t + !at^2 = (5.49\ \text{m/s})t + !(0.20\ \text{m/s}^2)t^2.$

The remaining distance will be run at the new speed, so we have

$1100\ \text{m} - x_1 = v(180\ \text{s} - t);$ or

$1100\ \text{m} - (5.49\ \text{m/s})t - !(0.20\ \text{m/s}^2)t^2 = [5.49\ \text{m/s} + (0.20\ \text{m/s}^2)t](180\ \text{s} - t).$

This is a quadratic equation:

$0.10\ t^2 - 36\ t + 111.8 = 0$, with the solutions $t = +\ 363$ s, $+\ 3.1$ s.

Because we want a total time less than 3 minutes, the physical answer is $t = 3.1$ s.

47. We use a coordinate system with the origin at the top of the cliff and down positive.

To find the time for the object to acquire the velocity, we have

$v = v_0 + at;$

$(100\ \text{km/h})/(3.6\ \text{ks/h}) = 0 + (9.80\ \text{m/s}^2)t$, which gives $t = 2.83$ s.

48. We use a coordinate system with the origin at the top of the cliff and down positive.

To find the height of the cliff, we have

$y = y_0 + v_0 t + !at^2$

$= 0 + 0 + !(9.80\ \text{m/s}^2)(2.75\ \text{s})^2 =$ 37.1 m.

49. We use a coordinate system with the origin at the top of the building and down positive.

(*a*) To find the time of fall, we have

$y = y_0 + v_0 t + !at^2;$

$380 \text{ m} = 0 + 0 + \frac{1}{2}(9.80 \text{ m/s}^2)t^2$, which gives $t = 8.81 \text{ s}$.

(*b*) We find the velocity just before landing from

$v = v_0 + at$

$= 0 + (9.80 \text{ m/s}^2)(8.81 \text{ s}) =$ 86.3 m/s.

50. We use a coordinate system with the origin at the ground and up positive.

(*a*) At the top of the motion the velocity is zero, so we find the height h from

$v^2 = v_0^2 + 2ah;$

$0 = (20 \text{ m/s})^2 + 2(-9.80 \text{ m/s}^2)h$, which gives $h = 20 \text{ m}$.

(*b*) When the ball returns to the ground, its displacement is zero, so we have

$y = y_0 + v_0t + \frac{1}{2}at^2$

$0 = 0 + (20 \text{ m/s})t + \frac{1}{2}(-9.80 \text{ m/s}^2)t^2$,

which gives $t = 0$ (when the ball starts up), and $t = 4.1 \text{ s}$.

51. We use a coordinate system with the origin at the ground and up positive.

We can find the initial velocity from the maximum height (where the velocity is zero):

$v^2 = v_0^2 + 2ah;$

$0 = v_0^2 + 2(-9.80 \text{ m/s}^2)(2.55 \text{ m})$, which gives $v_0 = 7.07 \text{ m/s}$.

When the kangaroo returns to the ground, its displacement is zero. For the entire jump we have

$y = y_0 + v_0t + \frac{1}{2}at^2;$

$0 = 0 + (7.07 \text{ m/s})t + \frac{1}{2}(-9.80 \text{ m/s}^2)t^2$,

which gives $t = 0$ (when the kangaroo jumps), and $t = 1.44 \text{ s}$.

52. We use a coordinate system with the origin at the ground and up positive.

When the ball returns to the ground, its displacement is zero, so we have

$y = y_0 + v_0t + \frac{1}{2}at^2;$

$0 = 0 + v_0(3.1 \text{ s}) + \frac{1}{2}(-9.80 \text{ m/s}^2)(3.1 \text{ s})^2$, which gives $v_0 = 15 \text{ m/s}$.

At the top of the motion the velocity is zero, so we find the height h from

$v^2 = v_0^2 + 2ah;$

$0 = (15 \text{ m/s})^2 + 2(-9.80 \text{ m/s}^2)h$, which gives $h = 12 \text{ m}$.

53. We use a coordinate system with the origin at the ground and up positive. We assume you can throw the object 4 stories high, which is about 12 m.

We can find the initial speed from the maximum height (where the velocity is zero):

$v^2 = v_0^2 + 2ah;$

$0 = v_0^2 + 2(-9.80 \text{ m/s}^2)(12 \text{ m})$, which gives $v_0 =$ 15 m/s.

54. We use a coordinate system with the origin at the ground and up positive.

(*a*) We can find the initial velocity from the maximum height (where the velocity is zero):

$v^2 = v_0^2 + 2ah;$

$0 = v_0^2 + 2(-9.80 \text{ m/s}^2)(1.20 \text{ m})$, which gives $v_0 = 4.85 \text{ m/s}$.

(*b*) When the player returns to the ground, the displacement is zero. For the entire jump we have

$y = y_0 + v_0t + \frac{1}{2}at^2;$

$0 = 0 + (4.85 \text{ m/s})t + \frac{1}{2}(-9.80 \text{ m/s}^2)t^2$,

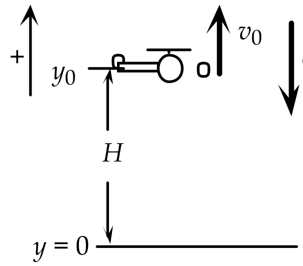
which gives $t = 0$ (when the player jumps), and $t = 0.990 \text{ s}$.

55. We use a coordinate system with the origin at the ground and up positive. When the package returns to the ground, its displacement is zero, so we have

$y = y_0 + v_0t + !at^2$;

$0 = 115\text{ m} + (5.60\text{ m/s})t + !(-\ 9.80\text{ m/s}^2)t^2$.

The solutions of this quadratic equation are $t = -\ 4.31$ s, and $t = 5.44$ s. Because the package is released at $t = 0$, the positive answer is the physical answer: 5.44 s.



56. We use a coordinate system with the origin at the release point and down positive. Because the object starts from rest, $v_0 = 0$. The position of the object is given by

$y = y_0 + v_0t + !at^2 = 0 + 0 + !gt^2$.

The positions at one-second intervals are

$y_0 = 0$;

$y_1 = !g(1\text{ s})^2 = (1\text{ s}^2)!g$;

$y_2 = !g(2\text{ s})^2 = (4\text{ s}^2)!g$;

$y_3 = !g(3\text{ s})^2 = (9\text{ s}^2)!g; \ldots$.

The distances traveled during each second are

$d_1 = y_1 - y_0 = (1\text{ s}^2)!g$;

$d_2 = y_2 - y_1 = (4\text{ s}^2 - 1\text{ s}^2)!g = (3\text{ s}^2)(!g) = 3\,d_1$;

$d_3 = y_3 - y_2 = (9\text{ s}^2 - 4\text{ s}^2)!g = (5\text{ s}^2)(!g) = 5\,d_1; \ldots$.

57. We use a coordinate system with the origin at the ground and up positive. Without air resistance, the acceleration is constant, so we have

$v^2 = v_0^2 + 2a(y - y_0)$;

$v^2 = v_0^2 + 2(-\ 9.8\text{ m/s}^2)(0 - 0) = v_0^2$, which gives $v = \pm\, v_0$.

The two signs represent the two directions of the velocity at the ground. The magnitudes, and thus the speeds, are the same.

58. We use a coordinate system with the origin at the ground and up positive.

(*a*) We find the velocity from

$v^2 = v_0^2 + 2a(y - y_0)$;

$v^2 = (23.0\text{ m/s})^2 + 2(-\ 9.8\text{ m/s}^2)(12.0\text{ m} - 0)$, which gives $v =$ $\pm\,17.1$ m/s.

The stone reaches this height on the way up (the positive sign) and on the way down (the negative sign).

(*b*) We find the time to reach the height from

$v = v_0 + at$;

$\pm\,17.1\text{ m/s} = 23.0\text{ m/s} + (-\ 9.80\text{ m/s}^2)t$, which gives $t = 0.602$ s, 4.09 s.

(*c*) There are two answers because the stone reaches this height on the way up ($t = 0.602$ s) and on the way down ($t = 4.09$ s).

59. We use a coordinate system with the origin at the release point and down positive. On paper the apple measures 8 mm, which we will call 8 mmp. If its true diameter is 10 cm, the conversion is 0.10 m/8 mmp.

The images of the apple immediately after release overlap. We will use the first clear image which is 10 mmp below the release point. The final image is 63 mmp below the release point, and there are 7

intervals between these two images.
The position of the apple is given by

$$y = y_0 + v_0t + !at^2 = 0 + 0 + !gt^2.$$

For the two selected images we have

$$y_1 = !gt_1^2; \quad (10 \text{ mmp})(0.10 \text{ m}/8 \text{ mmp}) = !(9.8 \text{ m/s}^2)t_1^2, \text{ which gives } t_1 = 0.159 \text{ s};$$

$$y_2 = !gt_2^2; \quad (63 \text{ mmp})(0.10 \text{ m}/8 \text{ mmp}) = !(9.8 \text{ m/s}^2)t_2^2, \text{ which gives } t_2 = 0.401 \text{ s}.$$

Thus the time interval between successive images is

$$?t = (t_2 - t_1)/7 = (0.401 \text{ s} - 0.159 \text{ s})/7 = \quad 0.035 \text{ s}.$$

60. We use a coordinate system with the origin at the ground and up positive.

(*a*) We find the velocity when the rocket runs out of fuel from

$$v_1^2 = v_0^2 + 2a(y_1 - y_0);$$

$$v_1^2 = 0 + 2(3.2 \text{ m/s}^2)(1200 \text{ m} - 0), \text{ which gives } v_1 = 87.6 \text{ m/s} = \quad 88 \text{ m/s}.$$

(*b*) We find the time to reach 1200 m from

$$v_1 = v_0 + at_1;$$

$$87.6 \text{ m/s} = 0 + (3.2 \text{ m/s}^2)t_1, \text{ which gives } t_1 = 27.4 \text{ s} = \quad 27 \text{ s}.$$

(*c*) After the rocket runs out of fuel, the acceleration is $- g$. We find the maximum altitude (where the velocity is zero) from

$$v_2^2 = v_1^2 + 2(- g)(h - y_1);$$

$$0 = (87.6 \text{ m/s})^2 + 2(- 9.80 \text{ m/s}^2)(h - 1200 \text{ m}), \text{ which gives } h = \quad 1590 \text{ m}.$$

(*d*) We find the time from

$$v_2 = v_1 + (- g)(t_2 - t_1)$$

$$0 = 87.6 \text{ m/s} + (- 9.80 \text{ m/s}^2)(t_2 - 27.4 \text{ s}), \text{ which gives } t_2 = \quad 36 \text{ s}.$$

(*e*) We consider the motion after the rocket runs out of fuel:

$$v_3^2 = v_1^2 + 2(- g)(y_3 - y_1);$$

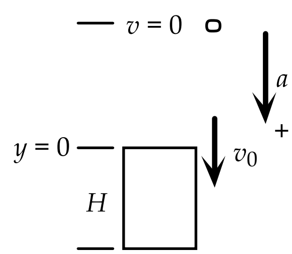
$$v_3^2 = (87.6 \text{ m/s})^2 + 2(- 9.80 \text{ m/s}^2)(0 - 1200 \text{ m}), \text{ which gives } v_3 = - 177 \text{ m/s} = \quad - 1.8 \times 10^2 \text{ m/s}.$$

(*f*) We find the time from

$$v_3 = v_1 + (- g)(t_3 - t_1)$$

$$- 177 \text{ m/s} = 87.6 \text{ m/s} + (- 9.80 \text{ m/s}^2)(t_3 - 27.4 \text{ s}), \text{ which gives } t_3 = \quad 54 \text{ s}.$$

61. We use a coordinate system with the origin at the top of the window and down positive.
We can find the velocity at the top of the window from the motion past the window:



$$y = y_0 + v_0t + !at^2;$$

$$2.2 \text{ m} = 0 + v_0(0.30 \text{ s}) + !(9.80 \text{ m/s}^2)(0.30 \text{ s})^2, \text{ which gives } v_0 = 5.86 \text{ m/s}.$$

For the motion from the release point to the top of the window, we have

$$v_0^2 = v_{\text{release}}^2 + 2g(y_0 - y_{\text{release}});$$

$$(5.86 \text{ m/s})^2 = 0 + 2(9.80 \text{ m/s}^2)(0 - y_{\text{release}}), \text{ which gives } y_{\text{release}} = - 1.8 \text{ m}.$$

The stone was released 1.8 m above the top of the window.

62. We use a coordinate system with the origin at the nozzle and up positive.
For the motion of the water from the nozzle to the ground, we have

$$y = y_0 + v_0t + !at^2;$$

$$- 1.5 \text{ m} = 0 + v_0(2.0 \text{ s}) + !(- 9.80 \text{ m/s}^2)(2.0 \text{ s})^2, \text{ which gives } \quad v_0 = 9.1 \text{ m/s}.$$

63. If the height of the cliff is H, the time for the sound to travel from the ocean to the top is

$t_{sound} = H/v_{sound}$.

The time of fall for the rock is $T - t_{sound}$. We use a coordinate system with the origin at the top of the cliff and down positive. For the falling motion we have

$y = y_0 + v_0t + !at^2$;

$H = 0 + 0 + !a(T - t_{sound})^2 = !(9.80\ m/s^2)[3.4\ s - H/(340\ m/s)]^2$.

This is a quadratic equation for H:

$4.24 \times 10^{-5} H^2 - 1.098H + 56.64 = 0$, with H in m; which has the solutions $H = 52$ m, 2.58×10^4 m.

The larger result corresponds to t_{sound} greater than 3.4 s, so the height of the cliff is 52 m.

64. We use a coordinate system with the origin at the ground, up positive, and $t = 0$ when the first object is thrown.

(*a*) For the motion of the rock we have

$y_1 = y_0 + v_{01}t + !at^2 = 0 + (12.0\ m/s)t + !(-9.80\ m/s^2)t^2$.

For the motion of the ball we have

$y_2 = y_0 + v_{02}(t - 1.00\ s) + !a(t - 1.00\ s)^2 = 0 + (20.0\ m/s)(t - 1.00\ s) + !(-9.80\ m/s^2)(t - 1.00\ s)^2$.

When the two meet we have

$y_1 = y_2$;

$(12.0\ m/s)t + !(-9.80\ m/s^2)t^2 = (20.0\ m/s)(t - 1.00\ s) + !(-9.80\ m/s^2)(t - 1.00\ s)^2$,

which gives $t =$ 1.40 s.

(*b*) We find the height from

$y_1 = y_0 + v_{01}t + !at^2 = 0 + (12.0\ m/s)(1.40\ s) + !(-9.80\ m/s^2)(1.40\ s)^2 =$ 7.18 m.

(*c*) If we reverse the order we have

$y_1 = y_2$;

$(20.0\ m/s)t + !(-9.80\ m/s^2)t^2 = (12.0\ m/s)(t - 1.00\ s) + !(-9.80\ m/s^2)(t - 1.00\ s)^2$,

which gives $t = 9.38$ s.

We find the height from

$y_1 = y_0 + v_{01}t + !at^2 = 0 + (20.0\ m/s)(9.38\ s) + !(-9.80\ m/s^2)(9.38\ s)^2 = -244$ m.

This means they never collide. The rock, thrown later, returns to the ground before the ball does. To confirm this we find the time when the rock strikes the ground:

$y_2 = y_0 + v_{02}(t - 1.00\ s) + !a(t - 1.00\ s)^2$

$0 = 0 + (12.0\ m/s)(t - 1.00\ s) + !(-9.80\ m/s^2)(t - 1.00\ s)^2$, which gives $t = 3.45$ s.

At this time the position of the ball is

$y_1 = y_0 + v_{01}t + !at^2 = 0 + (20.0\ m/s)(3.45\ s) + !(-9.80\ m/s^2)(3.45\ s)^2 = 10.7$ m.

65. We use a coordinate system with the origin at the ground, up positive, with t_1 the time when the rocket reaches the bottom of the window and $t_2 = t_1 + 0.15$ s the time when the rocket reaches the top of the window. A very quick burn means we can assume that the rocket has an initial velocity at the ground.

The position of the rocket is given by

$y = v_0t + !at^2$.

For the positions at the bottom and top of the window we have

$10.0\ m = v_0t_1 + !(-9.80\ m/s^2)t_1^2$;

$12.0\ m = v_0t_2 + !(-9.80\ m/s^2)t_2^2 = v_0(t_1 + 0.15\ s) + !(-9.80\ m/s^2)(t_1 + 0.15\ s)^2$.

Thus we have two equations for the two unknowns: v_0 and t_1. The results of combining the equations are

$t_1 = 0.590$ s (where we have taken the positive time) and $v_0 =$ 19.8 m/s.

We find the maximum height from

$v^2 = v_0^2 + 2ah;$

$0 = (19.8 \text{ m/s})^2 + 2(-9.80 \text{ m/s}^2)h$, which gives $h =$ 20.0 m.

66. We find the total displacement by integration:

$$x = \int_{t_1}^{t_2} v \, dt = \int_{t_1}^{t_2} \left[25 \text{ m/s} + \left(18 \text{ m/s}^2\right)t\right] dt = \left(25 \text{ m/s}\right)\left(t_2 - t_1\right) + \left(9.0 \text{ m/s}^2\right)\left(t_2^2 - t_1^2\right)$$

$$= \left(25 \text{ m/s}\right)\left(3.5 \text{ s} - 1.5 \text{ s}\right) + \left(9.0 \text{ m/s}^2\right)\left[\left(3.5 \text{ s}\right)^2 - \left(1.5 \text{ s}\right)^2\right] = 140 \text{ m}.$$

67. (*a*) If we make the suggested change of variable, we have

$u = g - kv$, and $du = -k\, dv$, and $a = g - kv = u$.

Thus from the definition of acceleration, we have

$a = dv/dt;$

$u = -du/k\, dt$, or $du/u = -k\, dt$.

When we integrate, we get

$$\int_g^{g-kv} \frac{du}{u} = \int_0^t -k\, dt, \text{ which gives } \ln\left(\frac{g-kv}{g}\right) = -kt, \text{ or } g - kv = ge^{-kt}.$$

Thus the velocity as a function of time is

$v = (g/k)(1 - e^{-kt})$.

(*b*) When the falling body reaches its terminal velocity, the acceleration will be zero, so we have

$a = g - kv_{\text{term}} = 0$, or $v_{\text{term}} = g/k$.

Note that this is the terminal velocity from the velocity expression because as $t \to 8$, $e^{-kt} \to 0$.

68. (*a*) We find the speed by integration:

$$\int_{v_0}^{v} dv = \int_0^t a\, dt = \int_0^t At^{1/2}\, dt, \text{ whichgives}$$

$$v - v_0 = \tfrac{2}{3}At^{3/2} - 0, \text{ or } v = v_0 + \tfrac{2}{3}At^{3/2} = \left(10 \text{ m/s}\right) + \tfrac{2}{3}\left(2.0 \text{ m/s}^{5/2}\right)t^{3/2}.$$

(*b*) We find the displacement by integration:

$$\int_0^x dx = \int_0^t v\, dt = \int_0^t \left(v_0 + \tfrac{2}{3}At^{3/2}\right) dt, \text{ whichgives}$$

$$x = v_0 t + \tfrac{2}{3}\left(\tfrac{2}{5}\right)A\, t^{5/2}, \text{ or } x = v_0 t + \tfrac{4}{15}A\, t^{5/2} = \left(10 \text{ m/s}\right)t + \tfrac{4}{15}\left(2.0 \text{ m/s}^{5/2}\right)t^{5/2}.$$

(*c*) For the given time we have

$a = (2.0 \text{ m/s}^{5/2})(5.0 \text{ s})^{1/2} =$ 4.5 m/s^2;

$v = (10 \text{ m/s}) + \%(2.0 \text{ m/s}^{5/2})(5.0 \text{ s})^{3/2} =$ 25 m/s;

$x = (10 \text{ m/s})(5.0 \text{ s}) + (4/15)(2.0 \text{ m/s}^{5/2})(5.0 \text{ s})^{5/2} =$ 80 m.

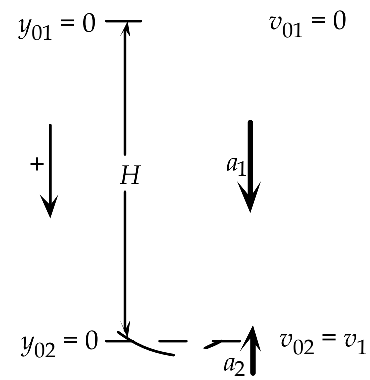
69. The height reached is determined by the initial velocity. We assume the same initial velocity of the object on the Moon and Earth. With a vertical velocity of 0 at the highest point, we have

$v^2 = v_0^2 + 2ah;$

$0 = v_0^2 + 2(-g)h$, so we get

$v_0^2 = 2g_{\text{Earth}}h_{\text{Earth}} = 2g_{\text{Moon}}h_{\text{Moon}}$, or $h_{\text{Moon}} = (g_{\text{Earth}}/g_{\text{Moon}})h_{\text{Earth}} =$ $6h_{\text{Earth}}$.

70. For the falling motion, we use a coordinate system with the origin at the fourth-story window and down positive. For the stopping motion in the net, we use a coordinate system with the origin at the original position of the net and down positive.



(*a*) We find the velocity of the person at the unstretched net (which is the initial velocity for the stretching of the net) from the free fall:

$$v_{02}^2 = v_{01}^2 + 2a_1(y_1 - y_{01}) = 0 + 2(9.80 \text{ m/s}^2)(15.0 \text{ m} - 0),$$

which gives $v_{02} = 17.1$ m/s.

We find the acceleration during the stretching of the net from

$$v_2^2 = v_{02}^2 + 2a_2(y_2 - y_{02});$$

$$0 = (17.1 \text{ m/s})^2 + 2a_2(1.0 \text{ m} - 0),$$

which gives $a_2 =$ $-\,1.5 \times 10^2 \text{ m/s}^2$.

(*b*) To produce the same velocity change with a smaller acceleration requires a greater displacement. Thus the net should be loosened.

71. We assume that the seat belt keeps the occupant fixed with respect to the car. The distance the occupant moves with respect to the front end is the distance the front end collapses, so we have

$$v^2 = v_0^2 + 2a(x - x_0);$$

$$0 = [(100 \text{ km/h})/(3.6 \text{ ks/h})]^2 + 2(-\,30)(9.80 \text{ m/s}^2)(x - 0),$$ which gives $x =$ 1.3 m.

72. If the lap distance is D, the time for the first 9 laps is

$t_1 = 9D/(199 \text{ km/h})$, the time for the last lap is

$t_2 = D/$æ, and the time for the entire trial is

$T = 10D/(200 \text{ km/h})$.

Thus we have

$T = t_1 + t_2$;

$10D/(200 \text{ km/h}) = 9D/(199 \text{ km/h}) + D/$æ, which gives æ = 209.5 km/h.

73. We use a coordinate system with the origin at the release point and down positive.

(*a*) The speed at the end of the fall is found from

$$v^2 = v_0^2 + 2a(x - x_0)$$
$$= 0 + 2g(H - 0), \text{ which gives } v = (2gH)^{1/2}.$$

(*b*) To achieve a speed of 50 km/h, we have

$v = (2gH)^{1/2}$; $(50 \text{ km/h})/(3.6 \text{ ks/h}) = [2(9.80 \text{ m/s}^2)H_{50}]^{1/2}$, which gives $H_{50} = 9.8$ m.

(*c*) To achieve a speed of 100 km/h, we have

$v = (2gH)^{1/2}$; $(100 \text{ km/h})/(3.6 \text{ ks/h}) = [2(9.80 \text{ m/s}^2)H_{100}]^{1/2}$, which gives $H_{100} = 39$ m.

74. For the motion from A to B,

(*a*) The object is moving in the negative direction.
The slope (the instantaneous velocity) is negative; the x-value is decreasing.

(*b*) Because the slope is becoming more negative (greater magnitude of the velocity), the object is speeding up.

(*c*) Because the velocity is becoming more negative, the acceleration is negative.

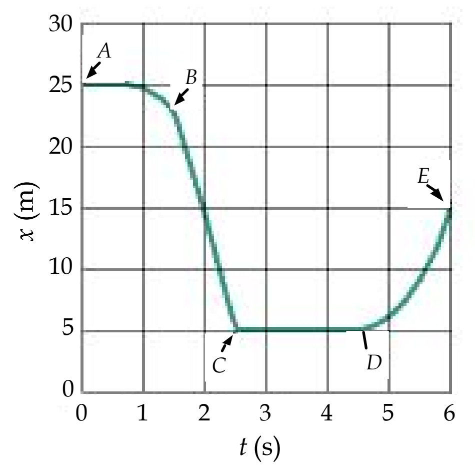
For the motion from D to E,

(*d*) The object is moving in the positive direction.
The slope (the instantaneous velocity) is positive; the x-value is increasing.

(*e*) Because the slope is becoming more positive (greater magnitude of the velocity), the object is speeding up.

(*f*) Because the velocity is becoming more positive, the acceleration is positive.

(*g*) The position is constant, so the object is not moving, the velocity and the acceleration are zero.



75. (*a*) At the top of the motion the velocity is zero, so we find the maximum height of the second child from

$v^2 = v_{02}^2 + 2ah_2$;

$0 = (5.0\ \text{m/s})^2 + 2(-\ 9.80\ \text{m/s}^2)h_2$, which gives $h_2 = 1.28\ \text{m} =$ 1.3 m.

(*b*) If the first child reaches a height $h_1 = 1.5h_2$, we find the initial speed from

$v^2 = v_{01}^2 + 2ah_1 = v_{01}^2 + 2a(1.5h_2) = v_{01}^2 - 1.5v_{02}^2 = 0$;

$v_{01}^2 = (1.5)(5.0\ \text{m/s})^2$, which gives $v_{01} =$ 6.1 m/s.

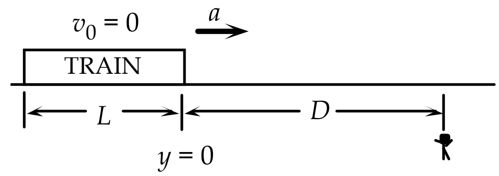
(*c*) We find the time for the first child from

$y = y_0 + v_0t + !at^2$

$0 = 0 + (6.1\ \text{m/s})t + !(-\ 9.80\ \text{m/s}^2)t^2$,

which gives $t = 0$ (when the child starts up), and $t = 1.2$ s.

76. We use a coordinate system with the origin at the initial position of the front of the train. We can find the acceleration of the train from the motion up to the point where the front of the train passes the worker:



$v_1^2 = v_0^2 + 2a(D - 0)$;

$(20 \text{ m/s})^2 = 0 + 2a(180 \text{ m} - 0)$,

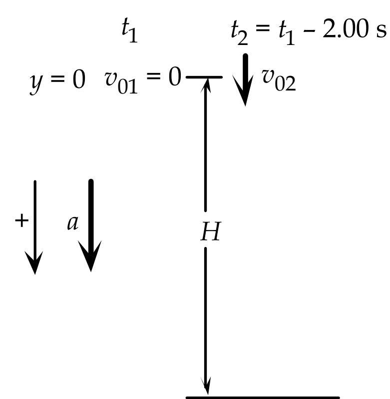
which gives $a = 1.11 \text{ m/s}^2$.

Now we consider the motion of the last car, which starts at $- L$, to the point where it passes the worker:

$v_2^2 = v_0^2 + 2a[D - (- L)]$

$= 0 + 2(1.11 \text{ m/s}^2)(180 \text{ m} + 90 \text{ m})$, which gives $v_2 =$ 24 m/s.

77. We use a coordinate system with the origin at the roof of the building and down positive, and call the height of the building H.



(*a*) For the first stone, we have

$y_1 = y_{01} + v_{01}t_1 + !at_1^2$;

$H = 0 + 0 + !(g)t_1^2$, or $H = !gt_1^2$.

For the second stone, we have

$y_2 = y_{02} + v_{02}t_2 + !at_2^2$;

$H = 0 + (30.0 \text{ m/s})t_2 + !(g)t_2^2$

$= (30.0 \text{ m/s})(t_1 - 2.00 \text{ s}) + !(g)(t_1 - 2.00 \text{ s})^2$

$= (30.0 \text{ m/s})t_1 - 60.0 \text{ m} + !gt_1^2 - (2.00 \text{ s})gt_1 + (2.00 \text{ s}^2)g$.

When we eliminate H from the two equations, we get

$0 = (30.0 \text{ m/s})t_1 - 60.0 \text{ m} - (2.00 \text{ s})gt_1 + (2.00 \text{ s}^2)g$, which gives

$t_1 = 3.88$ s.

(*b*) We use the motion of the first stone to find the height of the building:

$H = !gt_1^2 = !(9.80 \text{ m/s}^2)(3.88 \text{ s})^2 =$ 73.9 m.

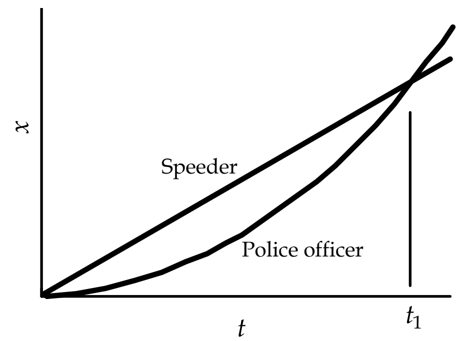
(*c*) We find the speeds from

$v_1 = v_{01} + at_1 = 0 + (9.80 \text{ m/s}^2)(3.88 \text{ s}) =$ 38.0 m/s;

$v_2 = v_{02} + at_2 = 30.0 \text{ m/s} + (9.80 \text{ m/s}^2)(3.88 \text{ s} - 2.00 \text{ s}) =$ 48.4 m/s.

78. We convert the units: (110 km/h)/(3.6 ks/h) = 30.6 m/s. (*a*)

We use a coordinate system with the origin where the motorist passes the police officer, as shown in the diagram.



(*b*) The location of the speeding motorist is given by

$x_m = x_0 + v_m t,$

which we use to find the time required:

700 m = (30.6 m/s)t, which gives t = 22.9 s.

(*c*) The location of the police car is given by

$x_p = x_0 + v_{0p}t + !a_p t^2 = 0 + 0 + !a_p t^2,$

which we use to find the acceleration:

700 m = $!a_p(22.9\ \text{s})^2$, which gives $a_p = 2.67\ \text{m/s}^2$.

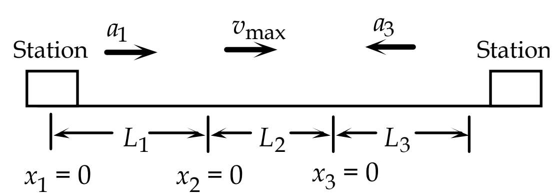
(*d*) We find the speed of the officer from

$v_p = v_{0p} + a_p t;$

$= 0 + (2.67\ \text{m/s}^2)(22.9\ \text{s}) =$ 61.1 m/s = 220 km/h (about 135 mi/h!).

79. We convert the maximum speed units: v_{max} = (90 km/h)/(3.6 ks/h) = 25 m/s.

(*a*) There are (36 km)/0.80 km) = 45 trip segments, which means 46 stations (with 44 intermediate stations). In each segment there are three motions.



Motion 1 is the acceleration to v_{max}.

We find the time for this motion from

$v_{max} = v_{01} + a_1 t_1;$

25 m/s = 0 + (1.1 m/s^2)t_1, which gives t_1 = 22.7 s.

We find the distance for this motion from

$x_1 = x_{01} + v_{01}t + !a_1 t_1^2;$

$L_1 = 0 + 0 + !(1.1\ \text{m/s}^2)(22.7\ \text{s})^2 = 284\ \text{m}.$

Motion 2 is the constant speed of v_{max},

for which we have

$x_2 = x_{02} + v_{max}t_2;$

$L_2 = 0 + v_{max}t_2.$

Motion 3 is the acceleration from v_{max} to 0.

We find the time for this motion from

$0 = v_{max} + a_3 t_3;$

$0 = 25 \text{ m/s} + (-2.0 \text{ m/s}^2)t_3$, which gives $t_3 = 12.5$ s.

We find the distance for this motion from

$x_3 = x_{03} + v_{max}t + \frac{1}{2}a_3t_3^2$;

$L_3 = 0 + (25 \text{ m/s})(12.5 \text{ s}) + \frac{1}{2}(-2.0 \text{ m/s}^2)(12.5 \text{ s})^2 = 156$ m.

The distance for Motion 2 is

$L_2 = 800 \text{ m} - L_1 - L_3 = 800 \text{ m} - 284 \text{ m} - 156 \text{ m} = 360$ m, so the time for Motion 2 is

$t_2 = L_2/v_{max} = (360 \text{ m})/(25 \text{ m/s}) = 14.4$ s.

Thus the total time for the 45 segments and 44 stops is

$T = 45(t_1 + t_2 + t_3) + 44(20 \text{ s}) = 45(22.7 \text{ s} + 14.4 \text{ s} + 12.5 \text{ s}) + 44(20 \text{ s}) = 3112 \text{ s} =$ 52 min.

(*b*) There are (36 km)/3.0 km) = 12 trip segments, which means 13 stations (with 11 intermediate stations.)

The results for Motion 1 and Motion 3 are the same:

$t_1 = 22.7$ s, $L_1 = 284$ m, $t_3 = 12.5$ s, $L_3 = 156$ m.

The distance for Motion 2 is

$L_2 = 3000 \text{ m} - L_1 - L_3 = 3000 \text{ m} - 284 \text{ m} - 156 \text{ m} = 2560$ m, so the time for Motion 2 is

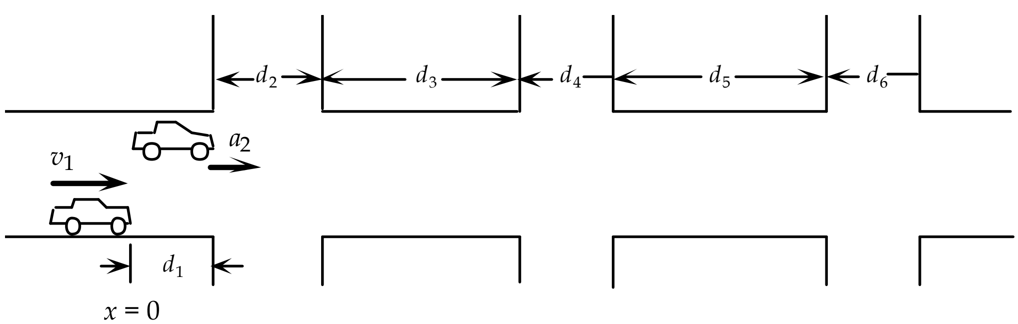
$t_2 = L_2/v_{max} = (2560 \text{ m})/(25 \text{ m/s}) = 102$ s.

Thus the total time for the 12 segments and 11 stops is

$T = 12(t_1 + t_2 + t_3) + 11(20 \text{ s}) = 12(22.7 \text{ s} + 102 \text{ s} + 12.5 \text{ s}) + 11(20 \text{ s}) = 1870 \text{ s} =$ 31 min.

This means there is a higher average speed for stations farther apart.

80.



We convert the units for the speed limit: (50 km/h)/(3.6 ks/h) = 13.9 m/s.

(*a*) If we assume that we are traveling at the speed limit, the time to pass through the farthest intersection is

$t_1 = (d_1 + d_2 + d_3 + d_4 + d_5 + d_6)/v_1 = (10\text{ m} + 15\text{ m} + 50\text{ m} + 15\text{ m} + 70\text{ m} + 15\text{ m})/(13.9\text{ m/s}) =$ 12.6 s.

Because this is less than the time while the lights are green, yes, you can make it through.

(*b*) We find the time required for the second car to reach the speed limit:

$v_{max} = v_{02} + a_2 t_{2a};$

$13.9\text{ m/s} = 0 + (2.0\text{ m/s}^2)t_{2a}$, which gives $t_{2a} = 6.95$ s.

In this time the second car will have traveled

$x_{2a} = v_{02}t_1 + !a_2 t_{2a}^2 = 0 + !(2.0\text{ m/s}^2)(6.95\text{ s})^2 = 48\text{ m}.$

The time to travel the remaining distance at constant speed is

$t_{2b} = (d_2 + d_3 + d_4 + d_5 + d_6 - x_{2a})/v_{max}$

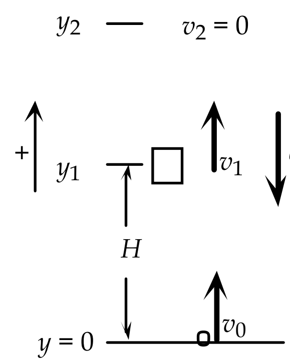
$= (15\text{ m} + 50\text{ m} + 15\text{ m} + 70\text{ m} + 15\text{ m} - 48\text{ m})/(13.9\text{ m/s}) = 8.42\text{ s}.$

Thus the total time is

$t_{total} = t_{2a} + t_{2b} = 6.95\text{ s} + 8.42\text{ s} = 15.4\text{ s}.$

No, the second car will not clear all the lights.

81. We use a coordinate system with the origin at the ground and up positive.



(*a*) We find the initial speed from the motion to the window:

$v_1^2 = v_0^2 + 2a(y_1 - y_0);$

$(14\text{ m/s})^2 = v_0^2 + 2(-9.80\text{ m/s}^2)(25\text{ m} - 0)$, which gives $v_0 = 26\text{ m/s}$.

(*b*) We find the maximum altitude from

$v_2^2 = v_0^2 + 2a(y_2 - y_0);$

$0 = (26.2\text{ m/s})^2 + 2(-9.80\text{ m/s}^2)(y_2 - 0)$, which gives $y_2 =$ 35 m.

(*c*) We find the time from the motion to the window:

$v_1 = v_0 + at_1$

$14\text{ m/s} = 26.2\text{ m/s} + (-9.80\text{ m/s}^2)t_1$, which gives $t_1 = 1.2$ s.

Thus it was thrown 1.2 s before passing the window.

(*d*) We find the time to reach the street from

$y = y_0 + v_0 t + !at^2;$

$0 = 0 + (26.2\text{ m/s})t + !(-9.80\text{ m/s}^2)t^2.$

This is a quadratic equation for t, which has the solutions $t = 0$ (the initial throw), 5.3 s.

Thus the time after the baseball passed the window is 5.3 s – 1.2 s = 4.1 s.

82. (*a*) We find the time required for the fugitive to reach his maximum speed:

$v_{max} = v_{0f} + a_f t_{f1};$

$8.0\text{ m/s} = 0 + (4.0\text{ m/s}^2)t_{f1}$, which gives $t_{f1} = 2.0$ s.

In this time the fugitive will have traveled

$x_{f1} = v_{0f}t_{f1} + !a_f t_{f1}^2 = 0 + !(4.0\text{ m/s}^2)(2.0\text{ s})^2 = 8.0\text{ m}.$

From this time the fugitive will run at constant speed. When he reaches the box car, we have

$x_{train} = x_f;$

$v_{train}t = x_{f1} + v_{max}(t - t_{f1});$

$(6.0\text{ m/s})t = 8.0\text{ m} + (8.0\text{ m/s})(t - 2.0\text{ s})$, which gives $t =$ 4.0 s.

(*b*) We can find the distance from the motion of the train:

$x_{train} = v_{train}t = (6.0\ \mathrm{m/s})(4.0\ \mathrm{s}) =$ 24 m.

83. We use a coordinate system with the origin at the top of the cliff and up positive.

(*a*) For the motion of the stone from the top of the cliff to the ground, we have

$y = y_0 + v_0t + \frac{1}{2}at^2$;

$-65.0\ \mathrm{m} = 0 + (10.0\ \mathrm{m/s})t + \frac{1}{2}(-9.80\ \mathrm{m/s^2})t^2$.

This is a quadratic equation for t, which has the solutions $t = -2.76$ s, 4.80 s.

Because the stone starts at $t = 0$, the time is 4.80 s.

(*b*) We find the speed from

$v = v_0 + at$

$= 10.0\ \mathrm{m/s} + (-9.80\ \mathrm{m/s^2})(4.80\ \mathrm{s}) = -37.0\ \mathrm{m/s}$.

The negative sign indicates the downward direction, so the speed is 37.0 m/s.

(*c*) The total distance includes the distance up to the maximum height, down to the top of the cliff, and down to the bottom. We find the maximum height from

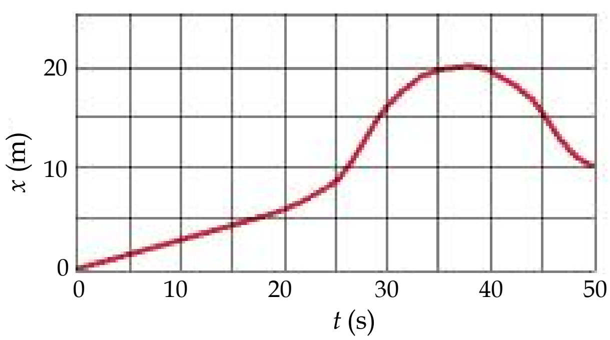
$v^2 = v_0^2 + 2ah$;

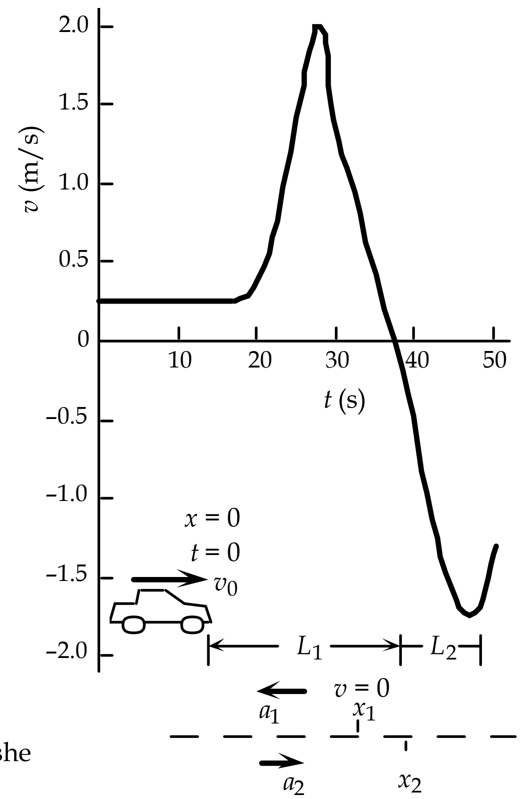
$0 = (10.0\ \mathrm{m/s})^2 + 2(-9.80\ \mathrm{m/s^2})h$, which gives $h = 5.10$ m.

The total distance traveled is

$d = 5.10\ \mathrm{m} + 5.10\ \mathrm{m} + 65.0\ \mathrm{m} =$ 75.2 m.

84. The instantaneous velocity is the slope of the x vs. t graph:





85. We use a coordinate system with the origin where the initial action takes place, as shown in the diagram.

The initial speed is (50 km/h)/(3.6 ks/h) = 13.9 m/s.

If she decides to stop, we find the minimum stopping distance from

$v_1^2 = v_0^2 + 2a_1(x_1 - x_0)$;

$0 = (13.9\ \mathrm{m/s})^2 + 2(-6.0\ \mathrm{m/s^2})x_1$, which gives $x_1 = 16$ m.

Because this is less than L_1, the distance to the intersection, she can safely stop in time.

If she decides to increase her speed, we find the acceleration from the time to go from 50 km/h to 70 km/h (19.4 m/s):

$v = v_0 + a_2t$;

$19.4\ \mathrm{m/s} = 13.9\ \mathrm{m/s} + a_2(6.0\ \mathrm{s})$, which gives $a_2 = 0.917\ \mathrm{m/s^2}$.

We find her location when the light turns red from

$x_2 = x_0 + v_0t_2 + \frac{1}{2}a_2t_2^2 = 0 + (13.9\ \mathrm{m/s})(2.0\ \mathrm{s}) + \frac{1}{2}(0.917\ \mathrm{m/s^2})(2.0\ \mathrm{s})^2 = 30$ m.

Because this is L_1, she is at the beginning of the intersection, but moving at high speed.
She should decide to stop!

86. We use a coordinate system with the origin at the water and up positive.
We find the time for the pelican to reach the water from

$y_1 = y_0 + v_0t + !at_1^2$;

$0 = 16.0 \text{ m} + 0 + ! (-9.80 \text{ m/s}^2)t^2$, which gives $t_1 = 1.81$ s.

This means that the fish must spot the pelican 1.81 s – 0.20 s = 1.61 s after the pelican starts its dive.
We find the height of the pelican at this time from

$y_2 = y_0 + v_0t + !at_2^2$;

$= 16.0 + 0 + !(-9.80 \text{ m/s}^2)(1.61 \text{ s})^2 =$ 3.3 m.

87. In each case we use a coordinate system with the origin at the beginning of the putt and the positive direction in the direction of the putt. The limits on the putting distance are $6.0 \text{ m} < x < 8.0 \text{ m}$.
For the downhill putt we have:

$v^2 = v_{0\text{down}}^2 + 2a_{\text{down}}(x - x_0)$;

$0 = v_{0\text{down}}^2 + 2(-2.0 \text{ m/s}^2)x$.

When we use the limits for x, we get $4.9 \text{ m/s} < v_{0\text{down}} < 5.7 \text{ m/s}$, or $?v_{0\text{down}} = 0.8 \text{ m/s}$.
For the uphill putt we have:

$v^2 = v_{0\text{up}}^2 + 2a_{\text{up}}(x - x_0)$;

$0 = v_{0\text{up}}^2 + 2(-3.0 \text{ m/s}^2)x$.

When we use the limits for x, we get $6.0 \text{ m/s} < v_{0\text{up}} < 6.9 \text{ m/s}$, or $?v_{0\text{up}} = 0.9 \text{ m/s}$.
The smaller spread in allowable initial velocities makes the downhill putt more difficult.

88. We use a coordinate system with the origin at the initial position of the car.
The passing car's position is given by

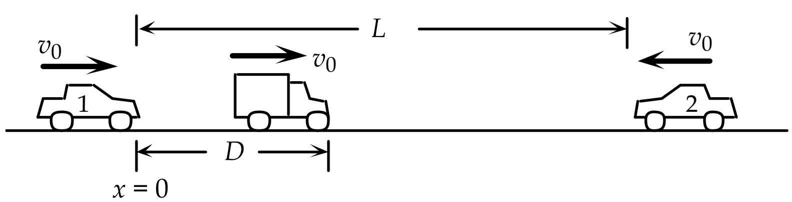
$x_1 = x_{01} + v_0t + !a_1t^2 = 0 + v_0t + !a_1t^2$.

The truck's position is given by

$x_{\text{truck}} = x_{0\text{truck}} + v_0t = D + v_0t$.

The oncoming car's position is given by

$x_2 = x_{02} - v_0t = L - v_0t$.



For the car to be safely past the truck, we must have

$x_1 - x_{\text{truck}} = 10$ m;

$v_0t + !a_1t^2 - (D + v_0t) = !a_1t^2 - D = 10$ m, which allows us to find the time required for passing:

$!(1.0\ \text{m/s}^2)t^2 - 30\ \text{m} = 10\ \text{m}$, which gives $t = 8.94$ s.

At this time the car's location will be

$x_1 = v_0t + !a_1t^2 = (25\ \text{m/s})(8.94\ \text{s}) + !(1.0\ \text{m/s}^2)(8.94\ \text{s})^2 = 264$ m from the origin.

At this time the oncoming car's location will be

$x_2 = L - v_0t = 400\ \text{m} - (25\ \text{m/s})(8.94\ \text{s}) = 176$ m from the origin.

Because this is closer to the origin, the two cars will have collided,

so the passing attempt should not be made.

89. We use a coordinate system with the origin at the roof of the building and down positive.

We find the time of fall for the second stone from

$v_2 = v_{02} + at_2$;

$12.0\ \text{m/s} = 0 + (9.80\ \text{m/s}^2)t_2$, which gives $t_2 = 1.22$ s.

During this time, the second stone fell

$y_2 = y_{02} + v_{02}t_2 + !at_2^2 = 0 + 0 + !(9.80\ \text{m/s}^2)(1.22\ \text{s})^2 = 7.29$ m.

The time of fall for the first stone is

$t_1 = t_2 + 1.50\ \text{s} = 1.22\ \text{s} + 1.50\ \text{s} = 2.72$ s.

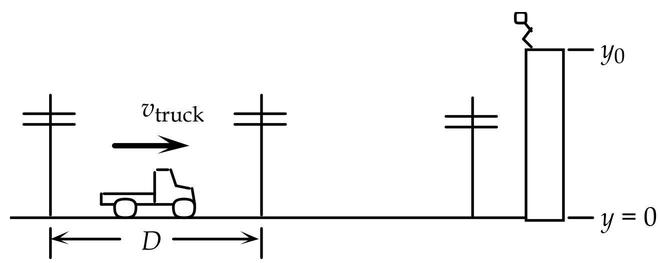
During this time, the first stone fell

$y_1 = y_{01} + v_{01}t_1 + !at_1^2 = 0 + 0 + !(9.80\ \text{m/s}^2)(2.72\ \text{s})^2 = 36.3$ m.

Thus the distance between the two stones is

$y_1 - y_2 = 36.3\ \text{m} - 7.29\ \text{m} =$ 29.0 m.

90. For the vertical motion of James Bond we use a coordinate system with the origin at the ground and up positive. We can find the time for his fall to the level of the truck bed from



$y = y_0 + v_0t + !at^2$;

$1.5\ \text{m} = 10\ \text{m} + 0 + !(-\,9.80\ \text{m/s}^2)t^2$,

which gives $t = 1.32$ s.

During this time the distance the truck will travel is

$x = x_0 + v_{\text{truck}}t = 0 + (30\ \text{m/s})(1.32\ \text{s}) = 39.6$ m.

Because the poles are 20 m apart, he should jump when the truck is 2 poles away, assuming that there is a pole at the bridge.