**CHAPTER 2**

1. We find the average speed from
   average speed = $d/t$ = (230 km)/(3.25 h) = 70.8 km/h.

2. We find the time from
   average speed = $d/t$;
   25 km/h = (15 km)/$t$ , which gives $t$ = 0.60 h (36 min).

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 × $10^{ñ2}$ km = 61 m.

4. (*a*) 65 mi/h = (65 mi/h)(1.61 km/1 mi)= 105 km/h.
   (*b*) 65 mi/h = (65 mi/h)(1610 m/1 mi)/(3600 s/1 h) = 29 m/s.
   (*c*) 65 mi/h = (65 mi/h)(5280 ft/1 mi)/(3600 s/1 h) = 95 ft/s.

5. (*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
   $t_2$ = $T$ ñ $t_1$ = 3.33 h ñ 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 not !(65 mi/h + 55 mi/h). The two speeds were not maintained for equal times.

6. 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.

7. (*a*) We find the average speed from
   average speed = $d/t$ = 8(0.25 mi)(1610 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.

8. (*a*) We find the average speed from
   average speed = $d/t$ = (130 m + 65 m)/(14.0 s + 4.8 s) = 10.4 m/s.
   (*b*) The displacement away from the trainer is 130 m ñ 65 m = 65 m; thus the average velocity is

æ = $\Delta x/\Delta t$ = (65 m)/(14.0 s + 4.8 s) = + 3.5 m/s.

9. 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 = $d_1/t_1$ ;
   (95 km/h)/(60 min/h) = (4.25 km)/$t$, which gives $t$ = 2.7 min.

10. 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.

11. We find the time for the outgoing 200 km from
    $t_1 = d_1/v_1$ = (200 km)/(90 km/h) = 2.22 h.
    We find the time for the return 200 km from
    $t_2 = d_2/v_2$ = (200 km)/(50 km/h) = 4.00 h.
    We find the average speed from
    average speed = $(d_1 + d_2)/(t_1 + t_{\text{lunch}} + t_2)$
    = (200 km + 200 km)/(2.22 h + 1.00 h + 4.00 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.

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

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

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

15. (*a*) We find the acceleration from
    Æ = $\Delta v/\Delta t$
    = (10 m/s ñ 0)/(1.35 s) = 7.41 m/s$^2$.
    (*b*) Æ = (7.41 m/s$^2$)(1 km/1000m)(3600 s/1h)$^2$ = $9.60 \times 10^4$ km/h$^2$.

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

$v^2 = v_0^2 + 2a(x_2$ ñ $x_1)$;

$0 = [(90\ \mathrm{km/h})/(3.6\ \mathrm{ks/h})]^2 + 2a(50\ \mathrm{m})$, which gives $a =$ ñ $6.3\ \mathrm{m/s^2}$.

The number of *g*ís is

$N = |a|/g = (6.3\ \mathrm{m/s^2})/(9.80\ \mathrm{m/s^2}) =$ 0.64.

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

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

Thus for the first interval we have

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

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

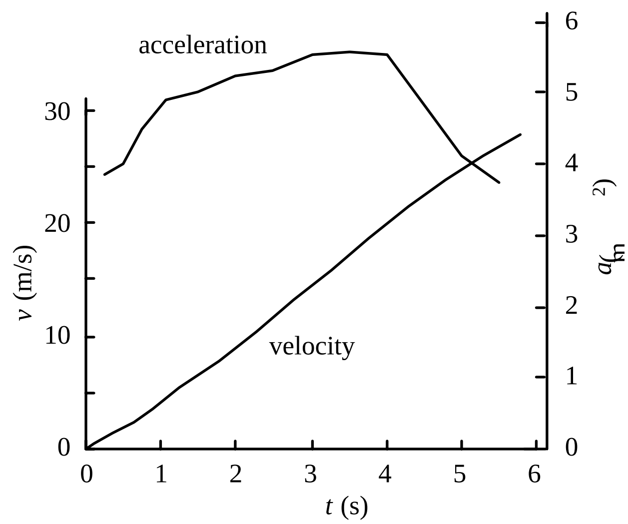
$a_{\mathrm{midpoint}}$ = Æ = $\Delta v/\Delta t$.

Thus for the first interval in the velocity column we have

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

The results are presented in the following table and graph.

| $t$(s) | $x$(m) | $t$(s) | $v$(m/s) | $t$(s) | $a$(m/s$^2$) |
|---|---|---|---|---|---|
| 0.0 | 0.0 | 0.0 | 0.0 | | |
| 0.25 | 0.11 | 0.125 | 0.44 | 0.25 | 3.8 |
| 0.50 | 0.46 | 0.375 | 1.4 | 0.50 | 4.0 |
| 0.75 | 1.06 | 0.625 | 2.4 | 0.75 | 4.5 |
| 1.00 | 1.94 | 0.875 | 3.5 | 1.06 | 4.9 |
| 1.50 | 4.62 | 1.25 | 5.36 | 1.50 | 5.0 |
| 2.00 | 8.55 | 1.75 | 7.85 | 2.00 | 5.2 |
| 2.50 | 13.79 | 2.25 | 10.5 | 2.50 | 5.3 |
| 3.00 | 20.36 | 2.75 | 13.1 | 3.00 | 5.5 |
| 3.50 | 28.31 | 3.25 | 15.9 | 3.50 | 5.6 |
| 4.00 | 37.65 | 3.75 | 18.7 | 4.00 | 5.5 |
| 4.50 | 48.37 | 4.25 | 21.4 | 4.50 | 4.8 |
| 5.00 | 60.30 | 4.75 | 23.9 | 5.00 | 4.1 |
| 5.50 | 73.26 | 5.25 | 25.9 | 5.50 | 3.8 |
| 6.00 | 87.16 | 5.75 | 27.8 | | |




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

18. When $x_0 = 0$ and $v_0 = 0$, we see that

$v = v_0 + at$ becomes $v = at$ ;

$x = x_0 + v_0 t +$ !$at^2$ becomes $x =$ !$at^2$;

$v^2 = v_0^2 + 2a(x$ ñ $x_0)$ becomes $v^2 = 2ax$ ; and

æ = !$(v + v_0)$ becomes æ = !$v$ .

19. We find the acceleration from
$v = v_0 + a(t \text{ ñ } t_0)$;
25 m/s = 12 m/s + $a$(6.0 s), which gives $a = 2.2\ \mathrm{m/s^2}$.
We find the distance traveled from
$x = !(v + v_0)t$
$= !(25\ \mathrm{m/s} + 12\ \mathrm{m/s})(6.0\ \mathrm{s}) =$ $1.1 \times 10^2$ m.

20. We find the acceleration (assumed constant) from
$v^2 = v_0^2 + 2a(x_2 \text{ ñ } x_1)$;
$0 = (20\ \mathrm{m/s})^2 + 2a(85\ \mathrm{m})$, which gives $a = \text{ñ } 2.4\ \mathrm{m/s^2}$.

21. We find the length of the runway from
$v^2 = v_0^2 + 2aL$;
$(30\ \mathrm{m/s})^2 = 0 + 2(3.0\ \mathrm{m/s^2})L$, which gives $L = 1.5 \times 10^2$ m.

22. We find the average acceleration from
$v^2 = v_0^2 + 2\text{Æ}(x_2 \text{ ñ } x_1)$;
$(11.5\ \mathrm{m/s})^2 = 0 + 2\text{Æ}(15.0\ \mathrm{m})$, which gives $\text{Æ} = 4.41\ \mathrm{m/s^2}$.
We find the time required from
$x = !(v + v_0)t$ ;
15.0 m = $!(11.5\ \mathrm{m/s} + 0)t$, which gives $t$ = 2.61 s.

23. For an assumed constant acceleration the average speed is $!(v + v_0)$, thus
$x = !(v + v_0)t$:
$= !(0 + 25.0\ \mathrm{m/s})(5.00\ \mathrm{s}) =$ 62.5 m.

24. We find the speed of the car from
$v^2 = v_0^2 + 2a(x_1 \text{ ñ } x_0)$;
$0 = v_0^2 + 2(\text{ñ } 7.00\ \mathrm{m/s^2})(80\ \mathrm{m})$, which gives $v_0 = 33$ m/s.

25. We convert the units for the speed: (45 km/h)/(3.6 ks/h) = 12.5 m/s.
(*a*) We find the distance the car travels before stopping from
$v^2 = v_0^2 + 2a(x_1 \text{ ñ } x_0)$;
$0 = (12.5\ \mathrm{m/s})^2 + 2(\text{ñ } 0.50\ \mathrm{m/s^2})(x_1 \text{ ñ } x_0)$, which gives $x_1 \text{ ñ } x_0 = 1.6 \times 10^2$ m.
(*b*) We find the time it takes to stop the car from
$v = v_0 + at$ ;
$0 = 12.5\ \mathrm{m/s} + (\text{ñ } 0.50\ \mathrm{m/s^2})t$, which gives $t = 25$ s.
(*c*) With the origin at the beginning of the coast, we find the position at a time $t$ from
$x = v_0t + !at^2$. Thus we find
$x_1 = (12.5\ \mathrm{m/s})(1.0\ \mathrm{s}) + !(\text{ñ } 0.50\ \mathrm{m/s^2})(1.0\ \mathrm{s})^2 = 12$ m;
$x_4 = (12.5\ \mathrm{m/s})(4.0\ \mathrm{s}) + !(\text{ñ } 0.50\ \mathrm{m/s^2})(4.0\ \mathrm{s})^2 = 46$ m;
$x_5 = (12.5\ \mathrm{m/s})(5.0\ \mathrm{s}) + !(\text{ñ } 0.50\ \mathrm{m/s^2})(5.0\ \mathrm{s})^2 = 56$ m.
During the first second the car travels 12 m ñ 0 = 12 m.

During the fifth second the car travels 56 m ñ 46 m = 10 m.

26. We find the average acceleration from

$v^2 = v_0^2 + 2\text{Æ}(x_2 \text{ ñ } x_1)$;

$0 = [(90 \text{ km/h})/(3.6 \text{ ks/h})]^2 + 2\text{Æ}(0.80 \text{ m})$, which gives $\text{Æ} = \text{ñ } 3.9 \times 10^2 \text{ m/s}^2$.

The number of *g*ís is

$|\text{Æ}| = (3.9 \times 10^2 \text{ m/s}^2)/[(9.80 \text{ m/s}^2)/g] =$ $40g$.

27. We convert the units for the speed: (90 km/h)/(3.6 ks/h) = 25 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

$v^2 = v_0^2 + 2a_1(x_1 \text{ ñ } x_0)$;

$0 = (25 \text{ m/s})^2 + 2(\text{ñ } 4.0 \text{ m/s}^2)(x_1 \text{ ñ } 25 \text{ m})$, which gives $x_1 = 103 \text{ m}$.

(*b*) We repeat the calculation for the new acceleration:

$v^2 = v_0^2 + 2a_2(x_2 \text{ ñ } x_0)$;

$0 = (25 \text{ m/s})^2 + 2(\text{ñ } 8.0 \text{ m/s}^2)(x_2 \text{ ñ } 25 \text{ m})$, which gives $x_2 = 64 \text{ m}$.

28. With the origin at the beginning of the reaction, the location when the brakes are applied is

$d_0 = v_0 t_R$.

We find the location of the car after the brakes are applied, which is the total stopping distance, from

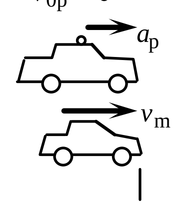
$v^2 = 0 = v_0^2 + 2a(d_S \text{ ñ } d_0)$, which gives $d_S = v_0 t_R \text{ ñ } v_0^2/(2a)$.

Note that *a* is negative.

29. We convert the units:

(120 km/h)/(3.6 ks/h) = 33.3 m/s.

(10.0 km/h/s)/(3.6 ks/h) = $2.78 \text{ m/s}^2$.




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

$x_m = x_0 + v_m t = 0 + (33.3 \text{ m/s})t$.

The location of the police officer is given by

$x_p = x_0 + v_{0p} t + \text{!} a_p t^2 = 0 + 0 + \text{!}(2.78 \text{ m/s}^2)t^2$.

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

$x_p = x_m$;

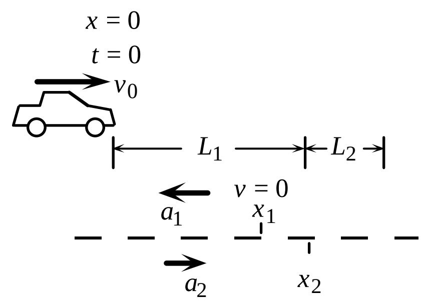
$(33.3 \text{ m/s})t = \text{!}(2.78 \text{ m/s}^2)t^2$, which gives $t = 0$ (the original passing) and $t = 24.0 \text{ s}$.

We find the speed of the officer from

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

$= 0 + (2.78 \text{ m/s}^2)(24.0 \text{ s}) = 66.7 \text{ m/s} =$ 240 km/h (about 150 mi/h!).

30. 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
$v_1^2 = v_0^2 + 2a_1(x_1$ ñ $x_0)$;
0 = (13.9 m/s)$^2$ + 2(ñ 6.0 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 m/s = 13.9 m/s + $a_2$(6.0 s), which gives $a_2$ = 0.917 m/s$^2$.
We find her location when the light turns red from
$x_2 = x_0 + v_0t_2$ + !$a_2t_2^2$ = 0 + (13.9 m/s)(2.0 s) + !(0.917 m/s$^2$)(2.0 s)$^2$ = 30 m.
Because this is L1, she is at the beginning of the intersection, but moving at high speed.
She should decide to stop!

31. We find the assumed constant speed for the first 27.0 min from
$v_0$ = Æ$x$/Æ$t$ = (10,000 m ñ 1100 m)/(27.0 min)(60 s/min) = 5.49 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 m/s + (0.20 m/s$^2$)$t$;
and the distance covered during the acceleration will be
$x_1 = v_0t$ + !$at^2$ = (5.49 m/s)$t$ + !(0.20 m/s$^2$)$t^2$.
The remaining distance will be run at the new speed, so we have
1100 m ñ $x_1 = v$(180 s ñ $t$); or
1100 m ñ (5.49 m/s)$t$ ñ !(0.20 m/s$^2$)$t^2$ = [5.49 m/s + (0.20 m/s$^2$)$t$](180 s ñ $t$).
This is a quadratic equation:
0.10 $t^2$ ñ 36 $t$ + 111.8 = 0, with the solutions $t$ = ñ 363 s, +3.1 s.
Because $t$ = 0 when the acceleration begins, the positive answer is the physical answer: $t$ = 3.1 s.

32. (280 m/s$^2$)(1 $g$/9.80 m/s$^2$) = 28.6 $g$.

33. 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
$v = v_0 + at$;
(90 km/h)/(3.6 ks/h) = 0 + (9.80 m/s$^2$)$t$, which gives $t$ = 2.6 s.

34. 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
$y = y_0 + v_0t$ + !$at^2$
= 0 + 0 + !(9.80 m/s$^2$)(3.50 s)$^2$ = 60.0 m.

35. 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

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

    380 m= 0 + 0 + !(9.80 m/s$^2$)$t^2$, which gives $t = 8.81$ s.

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

    $v = v_0 + at$

    = 0 + (9.80 m/s$^2$)(8.81 s) = 86.3 m/s (down).

36. 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 = (25 m/s)$^2$ + 2(ñ 9.80 m/s$^2$)$h$, which gives $h = 32$ m.

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

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

    0 = 0 + (25 m/s)$t$ + !(ñ 9.80 m/s$^2$)$t^2$,

    which gives $t = 0$ (when the ball starts up), and $t = 5.1$ s.

37. 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(ñ 9.80 m/s$^2$)(2.7 m), which gives $v_0 = 7.27$ m/s.

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

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

    0 = 0 + (7.27 m/s)$t$ + !(ñ 9.80 m/s$^2$)$t^2$,

    which gives $t = 0$ (when the kangaroo jumps), and $t = 1.5$ s.

38. 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

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

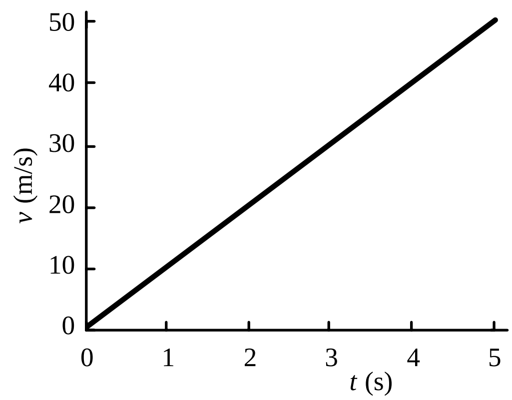
    0 = 0 + $v_0$(3.3 s) + !(ñ 9.80 m/s$^2$)(3.3 s)$^2$, which gives $v_0 = 16$ m/s.

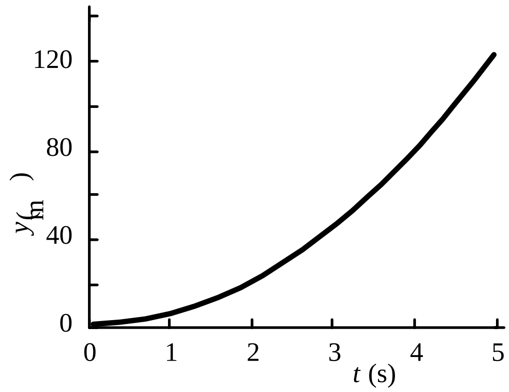
    At the top of the motion the velocity is zero, so we find the height $h$ from

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

    0 = (16 m/s)$^2$ + 2(ñ 9.80 m/s$^2$)$h$, which gives $h = 13$ m.

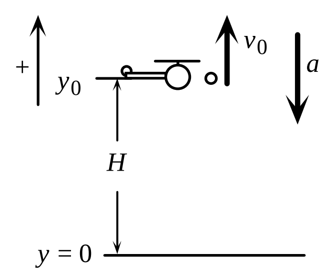
39. With the origin at the release point and the initial condition of $v_0 = 0$, we have
 (*a*) $v = v_0 + at = 0 + gt = (9.80\ \text{m/s}^2)t$;
 (*b*) $y = y_0 + v_0t + !at^2 = 0 + 0 + !gt^2 = (4.90\ \text{m/s}^2)t^2$.




40. 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):
 $v^2 = v_0^2 + 2ah$;
 $0 = v_0^2 + 2(ñ\ 9.80\ \text{m/s}^2)(1.20\ \text{m})$, 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
 $y = y_0 + v_0t + !at^2$;
 $0 = 0 + (4.85\ \text{m/s})t + !(ñ\ 9.80\ \text{m/s}^2)t^2$,
 which gives $t = 0$ (when the player jumps), and $t = 0.990$ s.

41. 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
 $y = y_0 + v_0t + !at^2$;
 $0 = 105\ \text{m} + (5.50\ \text{m/s})t + !(ñ\ 9.80\ \text{m/s}^2)t^2$.
 The solutions of this quadratic equation are $t = ñ\ 4.10$ s, and $t = 5.22$ s. Because the package is released at $t = 0$, the positive answer is the physical answer: 5.22 s.




42. 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
 $y_0 = 0$;
 $y_1 = !g(1\ \text{s})^2 = !g$;
 $y_2 = !g(2\ \text{s})^2 = (4)!g$;
 $y_3 = !g(3\ \text{s})^2 = (9)!g$; Ö .
 The distances traveled during each second are
 $d_1 = y_1\ ñ\ y_0 = !g$;
 $d_2 = y_2\ ñ\ y_1 = (4\ ñ\ 1)!g = 3(!g)$;
 $d_3 = y_3\ ñ\ y_2 = (9\ ñ\ 4)!g = 5(!g)$; Ö .

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

$v^2 = v_0^2 + 2a(y \text{ ñ } y_0)$;

$v^2 = v_0^2 + 2(\text{ñ } 9.80 \text{ m/s}^2)(0 \text{ ñ } 0) = v_0^2$, 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.

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

(*a*) We find the velocity from

$v^2 = v_0^2 + 2a(y \text{ ñ } y_0)$;

$v^2 = (20.0 \text{ m/s})^2 + 2(\text{ñ } 9.80 \text{ m/s}^2)(12.0 \text{ m ñ } 0)$, which gives $v =$ $\pm\, 12.8$ 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

$v = v_0 + at$;

$\pm\, 12.8 \text{ m/s} = 20.0 \text{ m/s} + (\text{ñ } 9.80 \text{ m/s}^2)t$, which gives $t = 0.735$ s, 3.35 s.

(*c*) There are two answers because the stone reaches this height on the way up ($t$ = 0.735 s) and on the way down ($t$ = 3.35 s).

45. We use a coordinate system with the origin at the release point and down positive. On paper the apple measures 7 mm, which we will call 7 mmp. If its true diameter is 10 cm, the conversion is 0.10 m/7 mmp.

The images of the apple immediately after release overlap. We will use the first clear image which is 8 mmp below the release point. The final image is 61 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

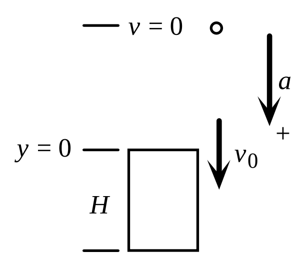
$y_1 = \,!gt_1^2$; (8 mmp)(0.10 m/7 mmp) = !(9.80 m/s²)$t_1^2$, which gives $t_1$ = 0.153 s;

$y_2 = \,!gt_2^2$; (61 mmp)(0.10 m/7 mmp) = !(9.80 m/s²)$t_2^2$, which gives $t_2$ = 0.422 s.

Thus the time interval between successive images is

Æ$t = (t_2 \text{ ñ } t_1)/7 = (0.422 \text{ s ñ } 0.153 \text{ s})/7 =$ 0.038 s.

46. 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:




$y = y_0 + v_0t + \,!at_A^2$;

2.2 m = 0 + $v_0$(0.30 s) + !(9.80 m/s²)(0.30 s)², which gives $v_0$ = 5.86 m/s.

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

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

(5.86 m/s)² = 0 + 2(9.80 m/s²)(0 ñ $y_{release}$), which gives $y_{release}$ = ñ 1.8 m.

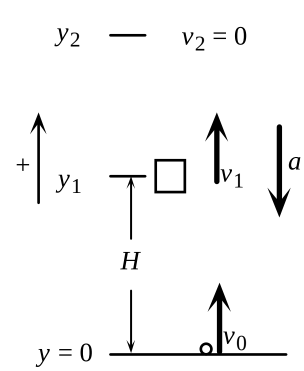
The stone was released 1.8 m above the top of the window.

47. 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 $T$ ñ $t_{sound}$. We use a coordinate system with the origin at the top of the cliff and down positive. For the falling motion we have
$y = y_0 + v_0t +$ !$at^2$;
$H = 0 + 0 +$ !$a(T$ ñ $t_{sound})^2 =$ !(9.80 m/s²)[3.4 s ñ $H$/(340 m/s)]² .
This is a quadratic equation for $H$:
$4.24 \times 10^{ñ5}$ $H^2$ ñ $1.098H + 56.64 = 0$, with $H$ in m; which has the solutions $H = 52$ m, $2.58 \times 10^4$ m.
The larger result corresponds to $t_{sound}$ greater than 3.4 s, so the height of the cliff is 52 m.

48. 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
$y = y_0 + v_0t +$ !$at^2$;
ñ 1.5 m = 0 + $v_0$(2.0 s) + !(ñ 9.80 m/s²)(2.0 s)², which gives $v_0 = 9.1$ m/s.

49. 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
$y = y_0 + v_0t +$ !$at^2$;
ñ 75.0 m = 0 + (12.0 m/s)$t$ + !(ñ 9.80 m/s²)$t^2$.
This is a quadratic equation for $t$, which has the solutions $t$ = ñ 2.88 s, 5.33 s.
Because the stone starts at $t = 0$, the time is 5.33 s.
(*b*) We find the speed from
$v = v_0 + at$
= 12.0 m/s + (ñ 9.80 m/s²)(5.33 s) = ñ 40.2 m/s.
The negative sign indicates the downward direction, so the speed is 40.2 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 = (12.0 m/s)² + 2(ñ 9.80 m/s²)$h$, which gives $h = 7.35$ m.
The total distance traveled is
$d$ = 7.35 m + 7.35 m + 75.0 m = 89.7 m.

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

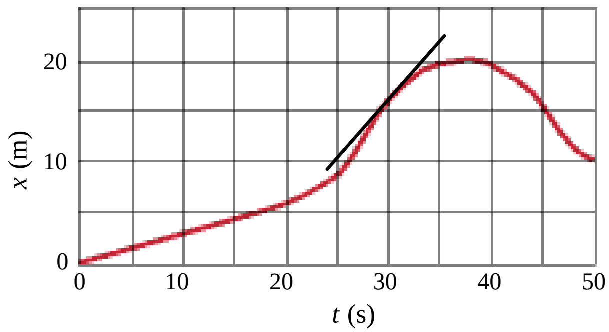



(*a*) We find the initial speed from the motion to the window:
$v_1^2 = v_0^2 + 2a(y_1$ ñ $y_0)$;
(12 m/s)² = $v_0^2$ + 2(ñ 9.80 m/s²)(25 m ñ 0), which gives $v_0 = 25$ m/s.
(*b*) We find the maximum altitude from
$v_2^2 = v_0^2 + 2a(y_2$ ñ $y_0)$;
0 = (25 m/s)² + 2(ñ 9.80 m/s²)($y_2$ ñ 0), which gives $y_2 =$ 32 m.
(*c*) We find the time from the motion to the window:
$v_1 = v_0 + at_1$
12 m/s = 25 m/s + (ñ 9.80 m/s²)$t_1$, which gives $t_1 =$ 1.3 s.
(*d*) We find the time to reach the street from
$y = y_0 + v_0t +$ !$at^2$;
0 = 0 + (25 m/s)$t$ + !(ñ 9.80 m/s²)$t^2$.

This is a quadratic equation for *t*, which has the solutions *t* = 0 (the initial throw), 5.1 s.
Thus the time after the baseball passed the window is 5.1 s ñ 1.3 s = 3.8 s.

51. (*a*) We find the instantaneous velocity from the slope of the straight line from *t* = 0 to *t* = 10 s:

$v_{10}$ = Æ*x*/Æ*t* = (2.8 m ñ 0)/(10.0 s ñ 0)
= 0.28 m/s.




(*b*) We find the instantaneous velocity from the slope of a tangent to the line at *t* = 30 s:

$v_{30}$ = Æ*x*/Æ*t* = (22 m ñ 10 m)/(35 s ñ 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:

$æ_{0\rightarrow5}$ = 0.28 m/s.

(*d*) For the average velocity we have

$æ_{25\rightarrow30}$ = Æ*x*/Æ*t* = (16 m ñ 8 m)/(30 s ñ 25 s) = 1.6 m/s.

(*e*) For the average velocity we have

$æ_{40\rightarrow50}$ = Æ*x*/Æ*t* = (10 m ñ 20 m)/(50 s ñ 40 s) = ñ 1.0 m/s.

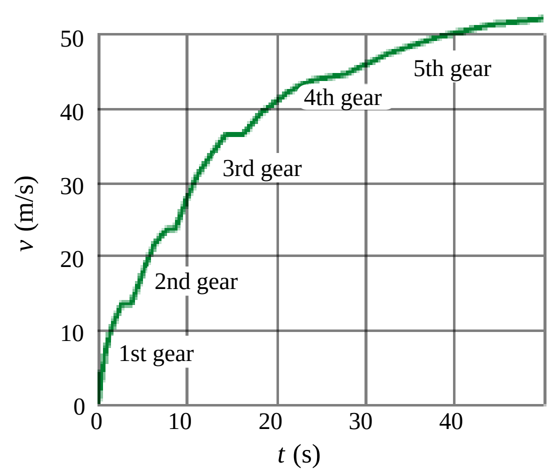
52. (*a*) Constant velocity is indicated by a straight line, which occurs from *t* = 0 to 17 s.
(*b*) The maximum velocity is when the slope is greatest: *t* = 28 s.
(*c*) Zero velocity is indicated by a zero slope. The tangent is horizontal at *t* = 38 s.
(*d*) Because the curve has both positive and negative slopes, the motion is in both directions.

53. (*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 20 s, and *t* = 90 s to 107 s.
(*d*) The maximum acceleration is when the slope is greatest: *t* = 75 s.

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

$Æ_2$ = Æ*v*/Æ*t*
= (24 m/s ñ 14 m/s)/(8 s ñ 4 s)
= 2.5 m/s$^2$;

$Æ_4$ = Æ*v*/Æ*t*
= (44 m/s ñ 37 m/s)/(27 s ñ 16 s)
= 0.7 m/s$^2$.




(*b*) The distance traveled is represented by the area under the curve, which we approximate as a rectangle with a height equal to the mean velocity:

*d* = $v_{mean}$Æ*t*
= !(44 m/s + 37 m/s)(27 s ñ 16 s)
= 450 m.

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

Æ$_1$ = Æ*v*/Æ*t* = (14 m/s ñ 0)/(3 s ñ 0) = 4.7 m/s$^2$.

(*b*) For the average acceleration we have

Æ$_3$ = Æ*v*/Æ*t* = (37 m/s ñ 24 m/s)/(14 s ñ 8 s) = 2.2 m/s$^2$.

(*c*) For the average acceleration we have

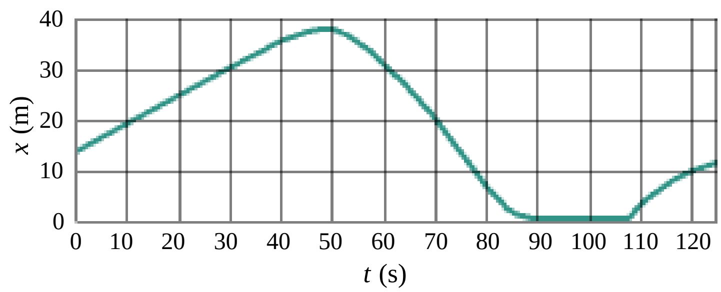
Æ$_5$ = Æ*v*/Æ*t* = (52 m/s ñ 44 m/s)/(50 s ñ 27 s) = 0.3 m/s$^2$.

(*d*) For the average acceleration we have

Æ$_{1\to4}$ = Æ*v*/Æ*t* = (44 m/s ñ 0)/(27 s ñ 0) = 1.6 m/s$^2$.

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

56. The distance is represented by the area under the curve. We will estimate it by counting the number of blocks, each of which represents (10 m/s)(10 s) = 100 m.




(*a*) For the first minute we have about 17 squares, so

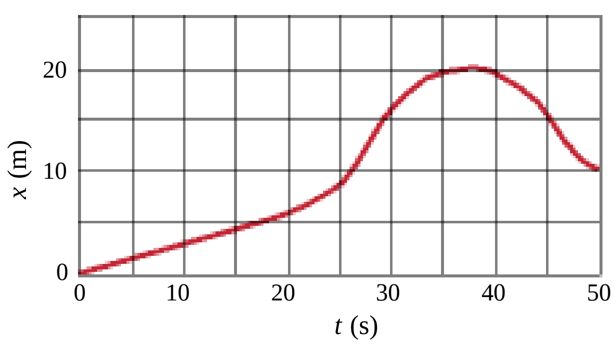
$d \approx$ (17 squares)(100 m)

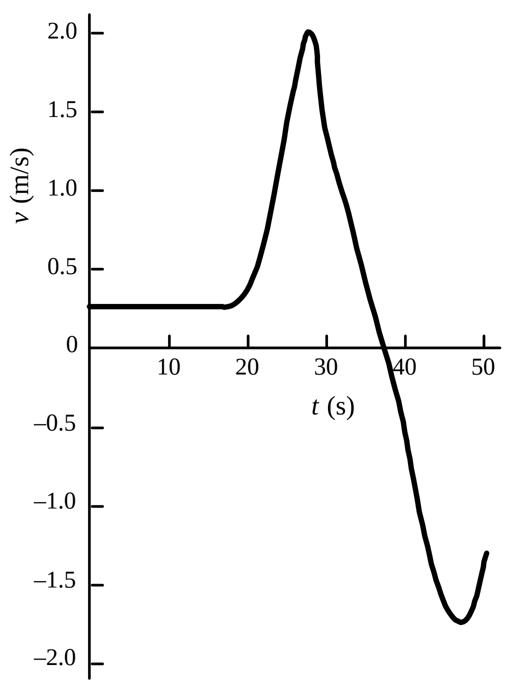
$\approx 1.7 \times 10^3$ m.

(*b*) For the second minute we have about 5 squares, so

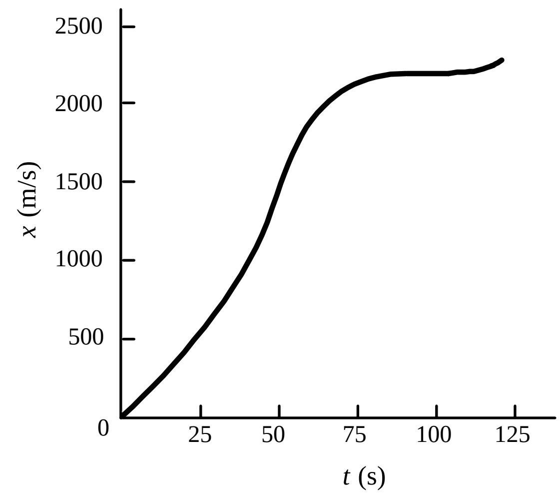
$d \approx$ (5 squares)(100 m) $\approx 5 \times 10^2$ m.

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

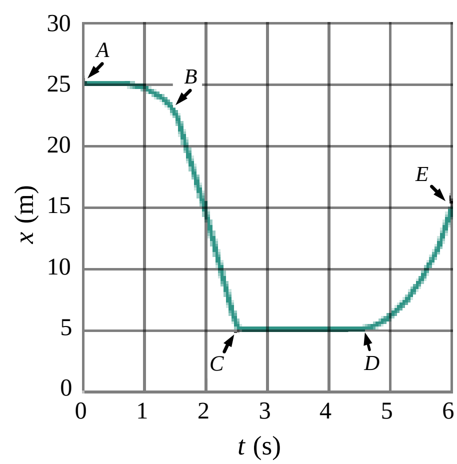


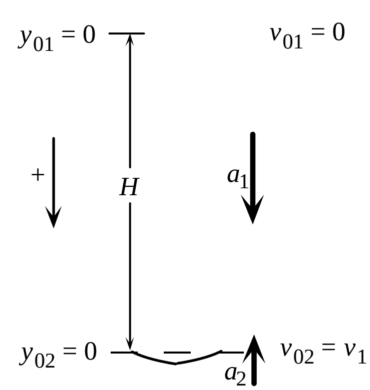
58. The displacement is the area under the $v$ vs. $t$ graph:




59. 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.




60. 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:
  $v_{02}^2 = v_{01}^2 + 2a_1(y_1$ ñ $y_{01}) = 0 + 2(9.80\text{ m/s}^2)(15.0\text{ m}$ ñ $0)$,
  which gives $v_{02} = 17.1$ m/s.
  We find the acceleration during the stretching of the net from
  $v_2^2 = v_{02}^2 + 2a_2(y_2$ ñ $y_{02})$;
  $0 = (17.1\text{ m/s})^2 + 2a_2(1.0\text{ m}$ ñ $0)$,
  which gives $a_2 =$ ñ $1.5 \times 10^2$ m/s$^2$.
  (*b*) To produce the same velocity change with a smaller acceleration requires a greater displacement. Thus the net should be loosened.



61. 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

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

$0 = v_0^2 + 2(ñ\, g)h$, so we get

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

62. 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

$v^2 = v_0^2 + 2a(x\ ñ\ x_0)$;

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

63. 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.

64. 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

$v^2 = v_0^2 + 2a(x\ ñ\ x_0)$

$= 0 + 2g(Hñ\ 0)$, which gives $v = (2gH)^{1/2}$.

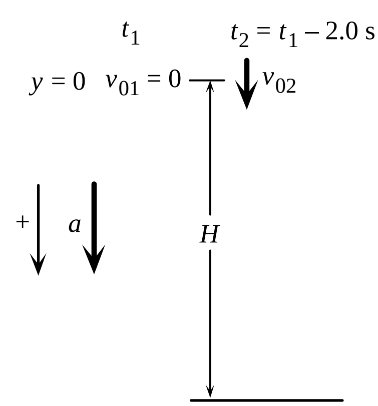
(*b*) To achieve a speed of 50 km/h, we have

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

65. 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

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

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

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

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

When we eliminate $H$ from the two equations, we get

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

$t_1 = 3.88$ s.

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

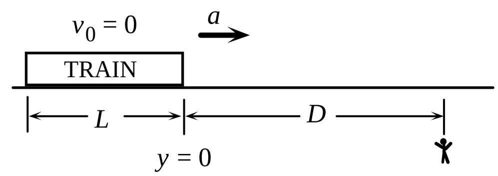
$H = !gt_1^2 = !(9.80 \text{ m/s}^2)(3.88 \text{ s})^2 =$ 73.9 m.

(*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 m/s + (9.80 m/s$^2$)(3.88 s ñ 2.00 s) = 48.4 m/s.

66. 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:




$v_1^2 = v_0^2 + 2a(D$ ñ 0);

(20 m/s)$^2$ = 0 + 2$a$(180 m ñ 0), which gives $a$ = 1.11 m/s$^2$.

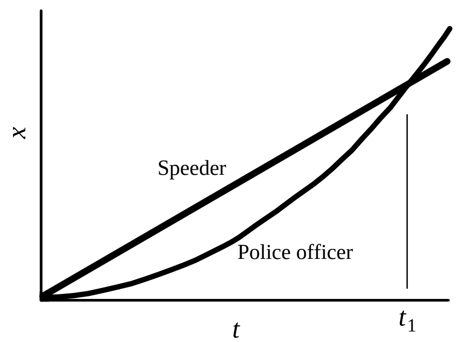
Now we consider the motion of the last car, which starts at ñ $L$, to the point where it passes the worker:

$v_2^2 = v_0^2 + 2a[D$ ñ (ñ $L$)]

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

67. We convert the units: (110 km/h)/(3.6 ks/h) = 30.6 m/s. We use a coordinate system with the origin where the motorist passes the police officer, as shown in the diagram.

(*a*)




(*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 s)$^2$, which gives $a_p$ = 2.67 m/s$^2$.

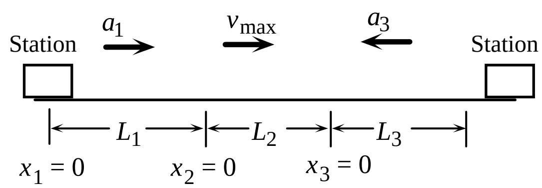
(*d*) We find the speed of the officer from

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

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

68. 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 m/s$^2$)(22.7 s)$^2$ = 284 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 m/s + (ñ 2.0 m/s$^2$)$t_3$ , which gives $t_3$ = 12.5 s.

We find the distance for this motion from

$x_3 = x_{03} + v_{max}t$ + !$a_3 t_3^2$ ;

$L_3$ = 0 + (25 m/s)(12.5s) + !(ñ 2.0 m/s$^2$)(12.5 s)$^2$ = 156 m.

The distance for Motion 2 is

$L_2$ = 800 m ñ $L_1$ ñ $L_3$ = 800 m ñ 284 m ñ 156 m = 360 m, so the time for Motion 2 is

$t_2 = L_2/v_{max}$ = (360 m)/(25 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 s) = 45(22.7 s + 14.4 s + 12.5 s) + 44(20 s) = 3112 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 m ñ $L_1$ ñ $L_3$ = 3000 m ñ 284 m ñ 156 m = 2560 m, so the time for Motion 2 is

$t_2 = L_2/v_{max}$ = (2560 m)/(25 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 s) = 12(22.7 s + 102 s + 12.5 s) + 11(20 s) = 1870 s = 31 min.

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

69. We use a coordinate system with the origin at the start of the pelicanís dive and down positive.

We find the time for the pelican to reach the water from

$y_1 = y_0 + v_0 t$ + !$a t_1^2$;

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

This means that the fish must spot the pelican 1.81 s ñ 0.20 s = 1.61 s after the pelican starts its dive.

We find the distance the pelican has fallen at this time from

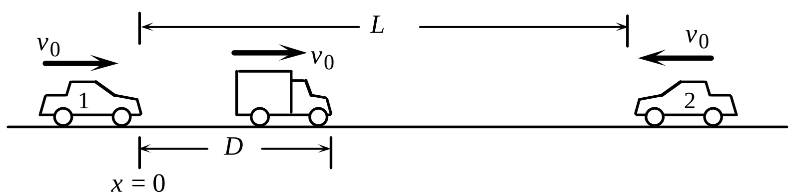
$y_2 = y_0 + v_0 t$ + !$a t_2^2$;

= 0 + 0 +(9.80 m/s$^2$)(1.61 s)$^2$ = 12.7 m.

Therefore the fish must spot the pelican at a height of 16.0 m ñ 12.7 m = 3.3 m.

70. 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 m < $x$ < 8.0 m.
For the downhill putt we have:
$v^2 = v_{0down}{}^2 + 2a_{down}(x$ ñ $x_0)$;
$0 = v_{0down}{}^2 + 2($ñ $2.0\ m/s^2)x$.
When we use the limits for $x$, we get 4.9 m/s < $v_{0down}$ < 5.7 m/s, or Æ$v_{0down}$ = 0.8 m/s.
For the uphill putt we have:
$v^2 = v_{0up}{}^2 + 2a_{up}(x$ ñ $x_0)$;
$0 = v_{0up}{}^2 + 2($ñ $3.0\ m/s^2)x$.
When we use the limits for $x$, we get 6.0 m/s < $v_{0up}$ < 6.9 m/s, or Æ$v_{0up}$ = 0.9 m/s.
The smaller spread in allowable initial velocities makes the downhill putt more difficult.

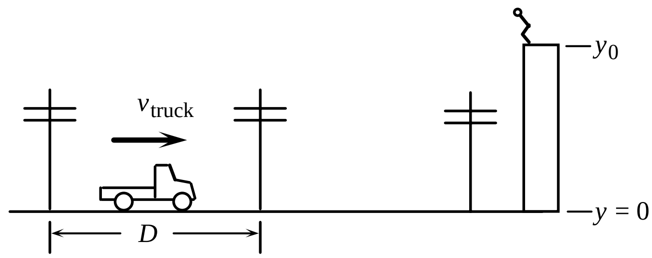
71. We use a coordinate system with the origin at the initial position of the car. The passing carís position is given by




$x_1 = x_{01} + v_0t$ + !$a_1t^2$
= 0 + $v_0t$ + !$a_1t^2$.
The truckís position is given by
$x_{truck} = x_{0truck} + v_0t = D + v_0t$.
The oncoming carís position is given by
$x_2 = x_{02}$ ñ $v_0t = L$ ñ $v_0t$.
For the car to be safely past the truck, we must have
$x_1$ ñ $x_{truck}$ = 10 m;
$v_0t$ + !$a_1t^2$ ñ $(D + v_0t)$ = !$a_1t^2$ ñ $D$ = 10 m,
which allows us to find the time required for passing:
!(1.0 m/s²)$t^2$ ñ 30 m = 10 m, which gives $t$ = 8.94 s.
At this time the carís location will be
$x_1 = v_0t$ + !$a_1t^2$ = (25 m/s)(8.94 s) + !(1.0 m/s²)(8.94 s)² = 264 m from the origin.
At this time the oncoming carís location will be
$x_2 = L$ ñ $v_0t$ = 400 m ñ (25 m/s)(8.94 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.

72. 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 m/s = 0 + (9.80 m/s²)$t_2$, 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 m/s²)(1.22 s)² = 7.29 m.
The time of fall for the first stone is
$t_1 = t_2$ + 1.50 s = 1.22 s + 1.50 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 m/s²)(2.72 s)² = 36.3 m.
Thus the distance between the two stones is
$y_1$ ñ $y_2$ = 36.3 m ñ 7.29 m = 29.0 m.

73. 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 m = 10 m + 0 + !(ñ 9.80 m/s$^2$)$t^2$,

which gives $t$ = 1.32 s.

During this time the distance the truck will travel is

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