8. Recognizing that the gap between the trains is closing at a constant rate of 60 km/h, the total time which elapses before they crash is $t = (60\,\mathrm{km})/(60\,\mathrm{km/h}) = 1.0$ h. During this time, the bird travels a distance of $x = vt = (60\,\mathrm{km/h})(1.0\,\mathrm{h}) = 60$ km.

19. In this solution, we make use of the notation $x(t)$ for the value of x at a particular t. Thus, $x(t) = 50t + 10t^2$ with SI units (meters and seconds) understood.

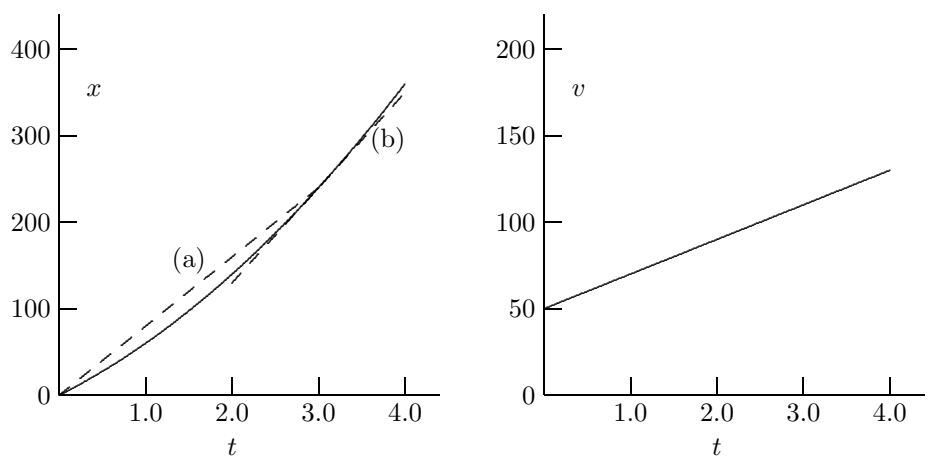
(a) The average velocity during the first 3 s is given by

$$v_{\text{avg}} = \frac{x(3) - x(0)}{\Delta t} = \frac{(50)(3) + (10)(3)^2 - 0}{3} = 80 \text{ m/s} .$$

(b) The instantaneous velocity at time t is given by $v = dx/dt = 50 + 20t$, in SI units. At $t = 3.0$ s, $v = 50 + (20)(3.0) = 110$ m/s.

(c) The instantaneous acceleration at time t is given by $a = dv/dt = 20 \text{ m/s}^2$. It is constant, so the acceleration at any time is $20\,\text{m/s}^2$.

(d) and (e) The graphs below show the coordinate x and velocity v as functions of time, with SI units understood. The dotted line marked (a) in the first graph runs from $t = 0$, $x = 0$ to $t = 3.0$ s, $x = 240$ m. Its slope is the average velocity during the first 3 s of motion. The dotted line marked (b) is tangent to the x curve at $t = 3.0$ s. Its slope is the instantaneous velocity at $t = 3.0$ s.



31. We choose the positive direction to be that of the initial velocity of the car (implying that $a < 0$ since it is slowing down). We assume the acceleration is constant and use Table 2-1.

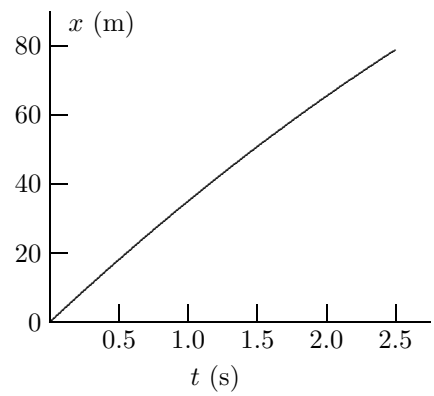
(a) Substituting $v_0 = 137\,\text{km/h} = 38.1\,\text{m/s}$, $v = 90\,\text{km/h} = 25\,\text{m/s}$, and $a = -5.2\,\text{m/s}^2$ into $v = v_0 + at$, we obtain

$$t = \frac{25\,\text{m/s} - 38\,\text{m/s}}{-5.2\,\text{m/s}^2} = 2.5\ \text{s}\ .$$

(b) We take the car to be at $x = 0$ when the brakes are applied (at time $t = 0$). Thus, the coordinate of the car as a function of time is given by

$$x = (38)t + \frac{1}{2}(-5.2)t^2$$

in SI units. This function is plotted from $t = 0$ to $t = 2.5\,\text{s}$ on the graph to the right. We have not shown the v-vs-t graph here; it is a descending straight line from v_0 to v.



56. The graph shows $y = 25$ m to be the highest point (where the speed momentarily vanishes). The neglect of "air friction" (or whatever passes for that on the distant planet) is certainly reasonable due to the symmetry of the graph.

(a) To find the acceleration due to gravity g_p on that planet, we use Eq. 2-15 (with $+y$ up)

$$y - y_0 = vt + \frac{1}{2}g_p t^2 \quad \Longrightarrow \quad 25 - 0 = (0)(2.5) + \frac{1}{2}g_p(2.5)^2$$

so that $g_p = 8.0$ m/s^2.

(b) That same (max) point on the graph can be used to find the initial velocity.

$$y - y_0 = \frac{1}{2}(v_0 + v)\,t \quad \Longrightarrow \quad 25 - 0 = \frac{1}{2}(v_0 + 0)\,(2.5)$$

Therefore, $v_0 = 20$ m/s.

81. During T_r the velocity v_0 is constant (in the direction we choose as $+x$) and obeys $v_0 = D_r/T_r$ where we note that in SI units the velocity is $v_0 = 200(1000/3600) = 55.6$ m/s. During T_b the acceleration is opposite to the direction of v_0 (hence, for us, $a < 0$) until the car is stopped ($v = 0$).

(a) Using Eq. 2-16 (with $\Delta x_b = 170$ m) we find

$$v^2 = v_0^2 + 2a\Delta x_b \quad \Longrightarrow \quad a = -\frac{v_0^2}{2\Delta x_b}$$

which yields $|a| = 9.08$ m/s^2.

(b) We express this as a multiple of g by setting up a ratio:

$$a = \left(\frac{9.08}{9.8}\right) 9 = 0.926g \ .$$

(c) We use Eq. 2-17 to obtain the braking time:

$$\Delta x_b = \frac{1}{2}\left(v_0 + v\right) T_b \quad \Longrightarrow \quad T_b = \frac{2(170)}{55.6} = 6.12 \text{ s} \ .$$

(d) We express our result for T_b as a multiple of the reaction time T_r by setting up a ratio:

$$T_b = \left(\frac{6.12}{400 \times 10^{-3}}\right) T_r = 15.3T_r \quad .$$

(e) We are only asked what the *increase* in distance D is, due to $\Delta T_r = 0.100$ s, so we simply have

$$\Delta D = v_0 \Delta T_r = (55.6)(0.100) = 5.56 \text{ m} \ .$$