## Chapter 2 Problems

**2.1** During a hard sneeze, your eyes might shut for 0.5s. If you are driving a car at 90km/h during such a sneeze, how far does the car move during that time

$$s = \frac{90km}{h} \cdot \frac{1000m}{1km} \cdot \frac{1h}{3600s} = 25m/s$$
$$d = s \cdot t = 25m/s \cdot 0.5s = 12.5m$$

**2.5** The position of an object moving in a straight line is given by $x = 3t - 4t^2 + t^3$, where x is in meters and t in seconds (a). What is the position of the object at t=1,2,3, and 4s? (b) What is the object's displacement between t = 0 and t = 4s. (c) What is the average velocity for the time interval from t=2 s to t = 4s? (d) Graph x vs t for $0 \le t \le 4s$ and indicate how the answer for c can be found from the graph.

(a-d) We plug in to calculate positions.

$$x(1) = 0m$$
$$x(2) = -2.0m$$
$$x(3) = 0m$$
$$x(4) = 12m$$

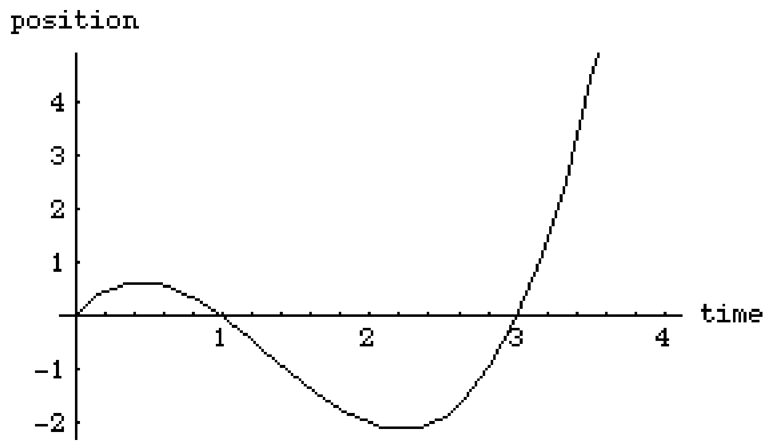
e) We can calculate the displacement from the positions.

$$\begin{aligned}\Delta x &= x(4) - x(0) \\ &= 12m - 0m \\ &= 12m\end{aligned}$$

(f) We calculate the average velocity using the displacements and time interval.

$$v = \frac{x(4) - x(2)}{4s - 2s} = \frac{12m - (-2m)}{2s} = 7m/s$$

(g) A graph of x vs t.. The average velocity can be computed by connecting x(4) and x(2) with a straight line and computing the slope. Note: Graph done with Mathematica.




**2.6** The 1992 world speed record for bicycle (human-powered vehicle) was set by Chris Huber. His time through the measured 200m stretch was sizzling 6.509 s, at which he commented "Cogito ergo zoom!" (I think, therefore I go fast!) In 2001 Sam Whittingham beat Huber's record by 19.0 km/hr What was whittingham's time through the 200m?

We begin by computing Huber's speed in km/hr.

$$v = \frac{d}{t} = 30.727 m / s$$

$$v = \frac{30.722m}{s} \cdot \frac{1km}{1000m} \cdot \frac{3600s}{1hr} = 110.62 km / hr$$

We can now compute Whittingham's speed, first in km/hr and then in m/s. We'll then use that speed to find the time.

$$v = 110.62 km / hr + 19 km / hr = 129.62 km / hr$$

$$v = \frac{129.62km}{hr} \cdot \frac{1hr}{3600s} \cdot \frac{1000m}{1km} = 36.004 m / s$$

$$t = \frac{d}{v} = \frac{200m}{36.004 m / s} = 5.555 s$$

**2.7** Two trains, each having a speed of 30km/h, are headed at each other on the same straight track. A bird that can fly 60km/h flies off the front of one train when they are 60 km apart and heads directly for the other train. On reaching the other train, the bird flies directly bact to the first train, and so forth. (We have no idea why a bird would behave in this way.) What is the total distance the bird travels before the trains collide?

The easiest way to think about and do this problem is to note that the bird flies at a constant speed for the entire time that the trains travel until colliding. The distance the bird travels is thus

$$d = v\,t = 60\frac{km}{h}\,t$$

We need to compute the time that the trains run before colliding. By symmetry, we can argue that the trains will collide in the middle, at 30 km. The time to collision is easy to compute--it's just the time for either time to travel 30 km, which is 1 hour. Now that we know how long the trains will run, we can see that the distance the bird will travel is 60 km.

**2.11** You are to drive to an interview in another town at a distance of 300 km on an expressway. The interview is at 11:15 AM. You plan to drive 100 km/h, so you eave at 8:00 AM to allow some extra time. You drive at that speed for the first 100 km, but then construction work forces you to slow to 40 km/h for 40 km. What would be the least speed needed for the rest of the trip to arrive in time for the interview?

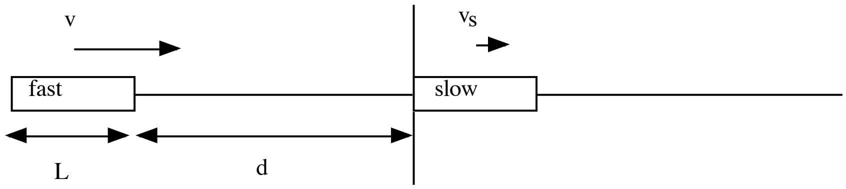
We need to compute how much time has passed and how far you have gone. If you drive at 100 km/h for 100 km, you spend 1 hour driving that segment. The next segment is 40 km at 40 km/h. This takes 1 hour as well. So you have driven 2 hours and covered 140 km. You allowed 3.25 hours for the entire 300km trip and you now have 1.25 hours left to cover the remaining 160km. This means that you need to drive at

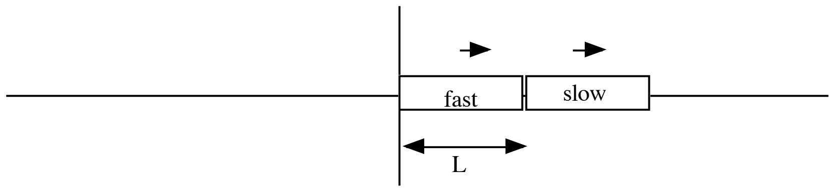
$$v = \frac{160km}{1.25h} = 128\,\frac{km}{h}$$

to complete the trip on time.

**2.12** Traffic Shock wave. An abrupt slowdown in concentrated traffic can travel as a pulse, termed a shock wave, along the line of cars, either downstream (in the traffic direction) or upstream, or it can be stationary. Figure 2-23 shows a uniformly spaced line of cars moving at speed $v = 25m/s$ toward a uniformly spaced line of slow cars, moving at speed $v_s = 5m/s$. Assume that each faster car adds length $L = 12m$ (car length plus buffer zone) to the line of cars when it joins the line, and assume it slows abruptly at the last instant. (a) For what separation distance d between the faster cars does the shock wave remain stationary? If the separation is twice that amount, what are the (b) speed and (c) direction (upstream or downstream) of the shock wave.

To do this problem, its useful to consider the last slow car and the first fast car. We'll count the rear of the car as the place where we measure its position. If the pulse is to remain stationary, the picture looks like




In this treatment, we'll consider the position of the back of each car. In a time t, the slow car goes a distance L and the fast car goes a distance d+L. We can write constant acceleration equations for both cars. We then solve the equation for the slow car for t and then use that time in the equation

*Fast Car*

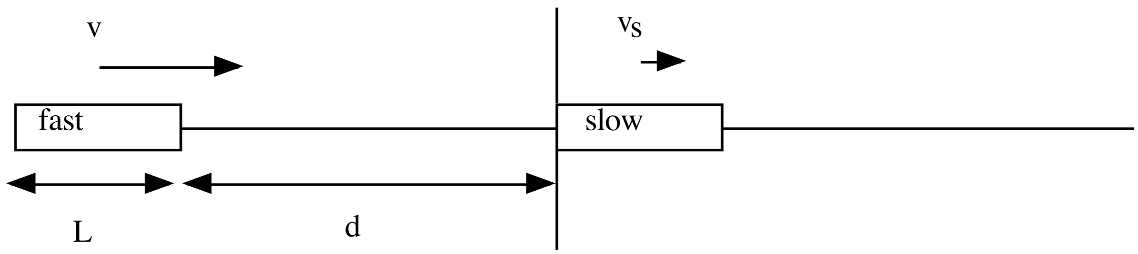
$$x_{if} = -L - d$$
$$x_{ff} = 0$$
$$v = 25m/s$$
$$x_{ff} = x_{if} + vt$$
$$0 = -L - d + vt$$

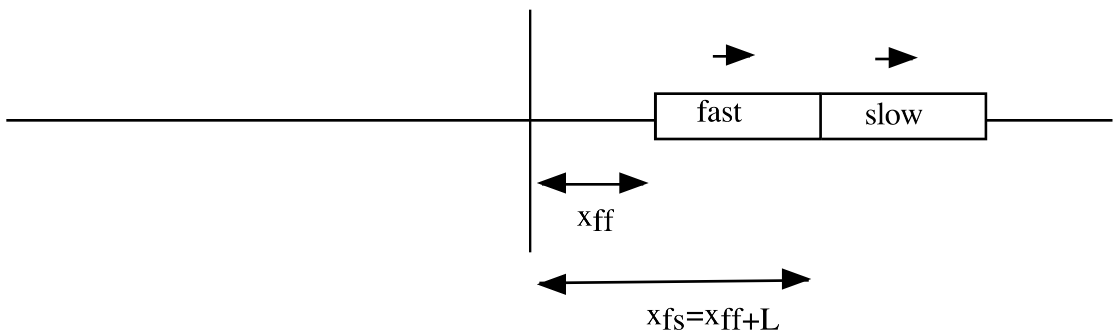
*Slow Car*

$$x_{is} = 0$$
$$x_{fs} = L$$
$$v_s = 5m/s$$
$$x_{fs} = x_{is} + v_f t$$
$$L = 0 + v_s t$$

$$L = 0 + v_s t$$
$$t = \frac{L}{v_s}$$
$$0 = -L - d + vt$$
$$0 = -L - d + v \cdot \frac{L}{v_s}$$
$$d = L\left(\frac{v}{v_s} - 1\right)$$
$$= L\left(\frac{v - v_s}{v_s}\right) = 12m \cdot \left(\frac{25m/s - 5m/s}{5m/s}\right)$$
$$d = 48m$$

We can find the movement of the wave by finding the position of the car when it reaches the wave. We do this by writing the position of each car, recognizing that the slow car is a distance L in front of the fast car when the fast car joins the line. We use this condition to find the time when the cars meet. Using the final position of the fast car and the time, we can find the velocity of the pulse.




$$x_{ff} = -L - d + vt$$
$$x_{ff} + L = 0 + v_s t$$
$$t = \frac{x_{ff} + L}{v_s}$$

| *Fast Car* | *Slow Car* |
|---|---|
| $x_{if} = -L - d$ | $x_{is} = 0$ |
| $x_{ff} = ?$ | $x_{fs} = x_{ff} + L$ |
| $v = 25m/s$ | $v_s = 5m/s$ |
| $x_{ff} = x_{if} + vt$ | $x_{fs} = x_{is} + v_f t$ |
| $x_{ff} = -L - d + vt$ | $x_{ff} + L = 0 + v_s t$ |

$$x_{ff} = -L - d + v \cdot \frac{x_{ff} + L}{v_s}$$

$$x_{ff}(1 - \frac{v}{v_s}) = L(\frac{v}{v_s} - 1) - d$$

$$-x_{ff}(\frac{v - v_s}{v_s}) = L(\frac{v - v_s}{v_s}) - d$$

$$x_{ff} = (\frac{v_s}{v - v_s})d - L$$
$$= (\frac{5m/s}{25m/s - 5m/s}) \cdot 96m - 12m$$
$$= 12m$$

$$t = \frac{x_{ff} + L}{v_s} = \frac{12m + 12m}{5m/s} = 4.8s$$

$$v_{pulse} = \frac{x_{ff}}{t} = \frac{12m/s}{4.8} = 2.5m/s$$

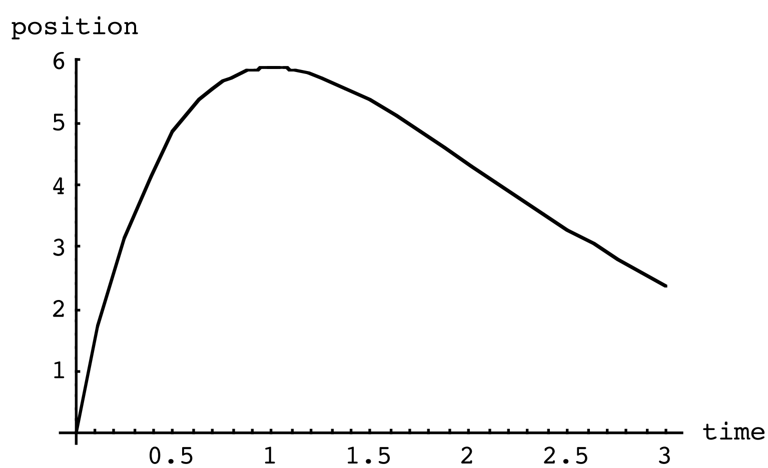
**2.14** An electron moving along the x axis has a position given by $x = 16t\,e^{-t}m$ **w**here t is in seconds. How far is the electron from the origin when it momentarily stops?

We need to find out when the electron stops. If we know when it stops, we can find out where it is. To find out when it stops, we find the instantaneous velocity and set it to zero.

We can also look at the plot and read off the time for the

$$v = \frac{dx}{dt} = \frac{d}{dt}(16\,t\,e^{-t}) = 16\ e^{-t} - 16t\,e^{-t}$$
$$= 16(1-t)e^{-t}$$
$$0 = 16(1-t)e^{-t} \Rightarrow t = 1s$$

$$x(1) = 16\cdot 1\cdot e^{-1}m = 5.886m$$




**2.15** (a) If a particle's position is given by $x = 4 - 12t + 3t^2$ (where t is in seconds and x is in meters), what is its velocity at t=1 s? (b) Is it moving toward increasing or decreasing x just then? (c) What is its speed just then? (d) Is the speed larger or smaller at later times? (Try answering the next two question without further calculation.) (e) Is there ever an instant when the velocity is zero? (f) Is there a time after t=3s when the particle is moving toward decreasing x?

To proceed, we begin by taking the derivative to find v.

$$x = 4 - 12t + 3t^2$$
$$v = \frac{dx}{dt} = 6t - 12$$

a. At 1s, $v(1) = -6m/s$

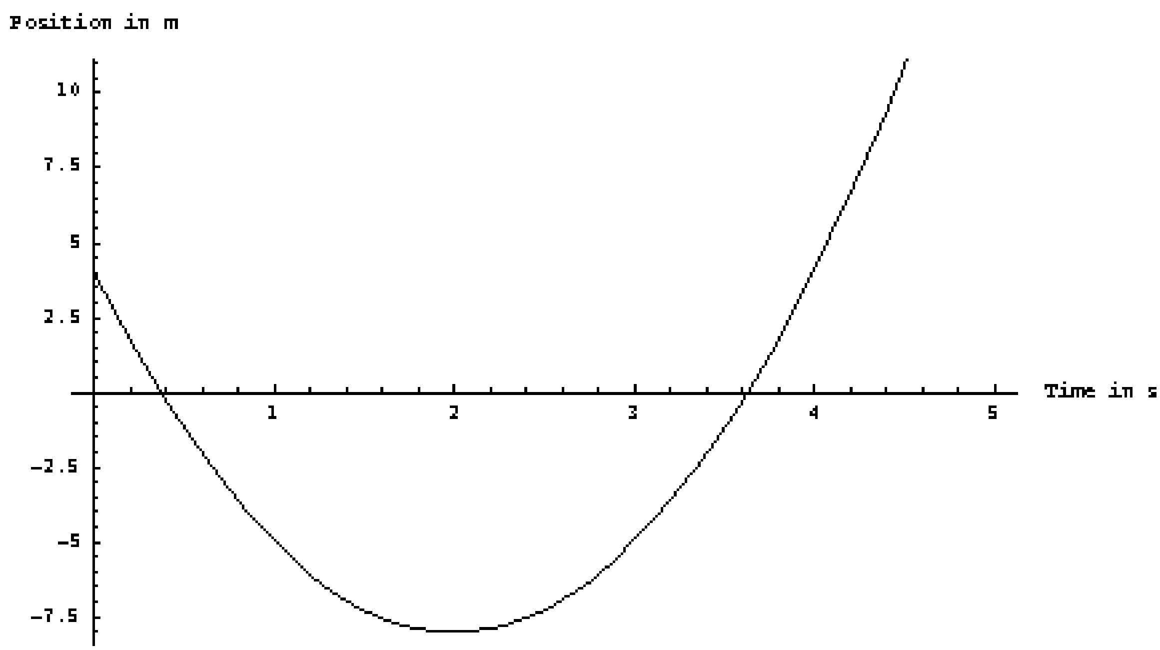
b. Direction is negative--toward the left and more negative since $x(1) = -5m$ .

c. Speed is $6 m/s$

d. Speed gets smaller (zero at t=2) and then larger.

e. Speed is zero at t=2s.

f. After t=3s, the velocity is always positive. See plot of position below.




**2.18** The position of a particle moving along an x axis is given by $x = 12t - 2t^3$ where x is in meters and t is in seconds. Determine (a) the position, (b) the velocity, and (c) the acceleration of the particle at t = 3s. (d)What is the maximum positive coordinate reached by the particle and (e) at what time is i reached? (f) What is the maximum positive velocity reached by the particle and (g) at what time is it reached? (h) What is the acceleration o f the particle at the instant the particle is not moving (other than t=0)? (i) Determine the average velocity of the particle between t = 0 and t=3 s.

We begin by writing the position, velocity and acceleration.

$$x(t) = 12t^2 - 2t^3$$
$$v(t) = \frac{dx}{dt} = 24t - 6t^2$$
$$a(t) = \frac{dv}{dt} = 24 - 12t$$

We can now evaluate for (a), (b), and (c)...

$$x(3) = 54m$$
$$v(3) = 18m/s$$
$$a(3) = -12m/s^2$$

The maximum possible *position* occurs when the velocity reaches zero. We can find when this occurs most easily and then find the positions at these times.

$$v(t) = 0 = 24t - 6t^2$$
$$0 = (24 - 6t)t$$
$$t = 0s, 4s$$

$$x(0) = 0$$
$$x(4) = 64m$$

We can see that the answer we are interested in is the x(4) = 64m.

The maximum possible *velocity* occurs when the acceleration is zero. As in the previous case, it's easiest to first find when this occurs.

$$a(t) = 0 = 24 - 12t$$
$$t = 2s$$
$$v(2) = 24m/s$$

We can compute the acceleration when the velocity is zero at 4 s.

$$a(4) = -24m/s^2$$

Finally, we can compute the average velocity.

$$v_{avg} = \frac{x(3) - x(0)}{3s - 0s} = 18m/s$$

**2.19** At a certain time a particle had a speed of 18 m/s in the positive x direction, and 2.4 s later its speed was 30 m/s in the opposite direction. What is the average acceleration of the particle during this 2.4s interval.

The average acceleration is just the change in velocity over the change in time. We do need to be careful about the signs of the velocities, however.

$$v_i = 18m/s$$
$$v_f = -30m/s$$
$$a = \frac{v_f - v_i}{\Delta t} = \frac{-30m/s - 18m/s}{2.4s} = -20m/s^2$$

**2.23** An electron with an initial velocity $v_0 = 1.5 \times 10^5 m/s$ enters a region of length $L = 1.00cm$ where it is electrically accelerated (Fig. 2-23). It emerges with $v = 5.7 \times 10^6 m/s$. What is acceleration, assumed constant?

We begin by writing what we know and then select a constant acceleration equation of motion.

$$x_i = 0m$$
$$x_f = 1.0 \times 10^{-2} m$$
$$v_i = 1.5 \times 10^5 m/s$$
$$v_f = 5.7 \times 10^6 m/s$$

$$v_f^2 = v_i^2 + 2a(x_f - x_i)$$
$$a = \frac{v_f^2 - v_i^2}{2(x_f - x_i)} = 1.62 \times 10^{15} m/s^2$$

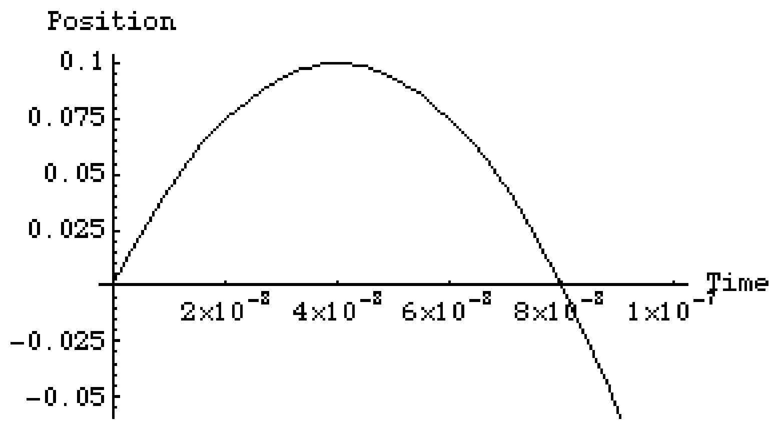
**2.26** A muon (an elementary particle) enters an electric field with a speed of $5.00 \times 10^6 m/s$, whereupon the field slows it at the rate of $1.25 \times 10^{14}$ m/s$^2$. (a) How far does the muon take to stop? (b) Graph x vs. t and v vs t for the muon.

$$v_0 = 5.00 \times 10^6 m/s$$
$$a = -1.25 \times 10^{14} \text{ m/s}^2$$
$$v = v_0 + at$$

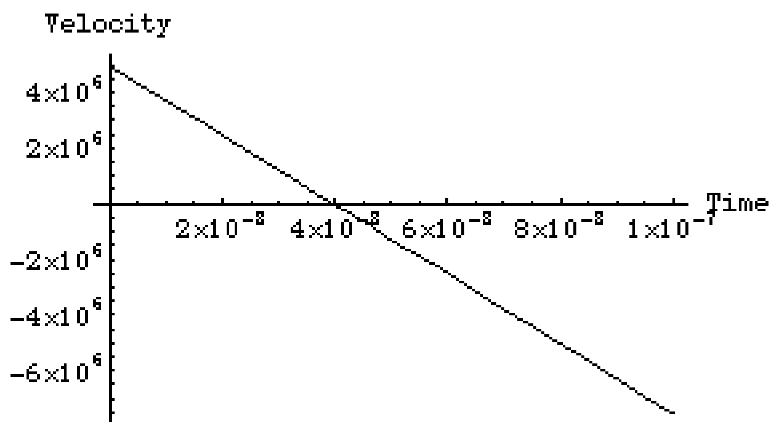
a) We solve for the time to stop

$$v = 0$$
$$v = v_0 + at$$
$$0 = v_0 + at$$
$$t = -\frac{v_0}{a} = -\frac{5.00 \times 10^6 m/s}{-1.25 \times 10^{14} \text{ m/s}^2} = 4.00 \times 10^{-8} s$$
$$x = x_0 + v_0 t + \frac{1}{2} a t^2$$
$$x = 0 + 5.00 \times 10^6 m/s \cdot 4.00 \times 10^{-8} s - \frac{1}{2} \cdot 1.25 \times 10^{14} \text{ m/s}^2 \cdot (4.00 \times 10^{-8} s)^2$$
$$= 0.1m$$

Position vs. time graph




Velocity vs. time




**2.27** An electron has a constant acceleration of $+3.2 m/s^2$. At a certain instant its velocity is +9.6m/s. What is its velocity 2.5 s earlier and (b) 2.5s later?

Take the time to be zero when the velocity is 9.6 m/s.

$$a = 3.2 m/s^2$$
$$v_0 = 9.6 m/s$$
$$v = v_0 + at$$

a. At t=-2.5s, $v = 1.6 m/s$
b. At t=+2.5s, $v = 17.6 m/s$.

**2.31** Suppose a rocket ship in deep space moves with a constant acceleration equal to $9.8m/s^2$, which gives the illusion of normal gravity during the flight. (a) If it starts from rest, how long will it take to acquire a speed one-tenth that of the speed of light, which travels at $3.0\times10^8 m/s$. (b) How fare will it travel in so doing.

(a) How long to reach one-tenth the speed of light?

$$x_i = 0$$
$$x_f = ?$$
$$v_i = 0m/s$$
$$v_f = 3.0\times10^7 m/s$$
$$a = 9.8m/s^2$$
$$t = ?$$

$$v_f = v_i + at$$
$$v_f = 0 + at$$
$$t = -\frac{v_f}{a} = -\frac{3.0\times10^7 m/s}{9.8m/s^2} = 3.06\times10^6 s$$

(b) How far does it go in that time?

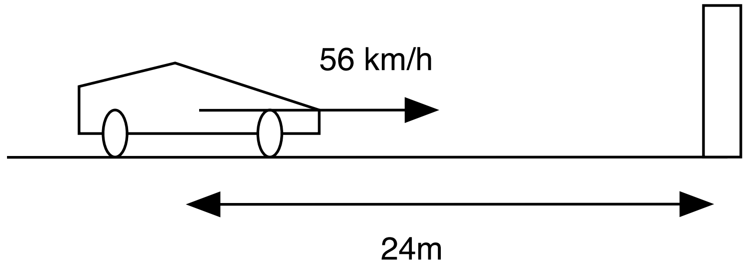
$$x_f = x_i + v_i t + \frac{1}{2}at^2$$
$$x_f = 0 + 0 + \frac{1}{2}\cdot(9.8m/s^2)\cdot(3.06\times10s)^2$$
$$= 4.6\times10^{13} m$$

**2.32** A world's land speed record was set by Colonel John P. Stapp when in March 1954 he rode a rocket-propelled sled that moved along a track at 1020 km/h. He and the sled were brought to a stop in 1.4 s. In terms of g, what acceleration did he experience while stopping?

$$v_i = \frac{1020km}{hr}\cdot\frac{1000m}{1km}\cdot\frac{1hr}{3600s} = 283.3m/s$$
$$v_f = 0$$
$$t = 1.4s$$

$$v_f = v_i + at$$
$$a = \frac{v_f - v_i}{t} = \frac{0 - 283.3m/s}{1.4s} = -202.381m/s^2$$
$$\#g's = \frac{202.381m/s^2}{9.8m/s^2} = 20.65$$

**2.33** A car traveling at 56km/h is 24 m from a barrier when the driver slams on the brakes. The car hits the barrier 2s later. (a) What is the magnitude of the car's constant acceleration before impact? (b) How fast is the car traveling at impact?




$x_i = 0$

$x_f = 24\,m$

$v_i = \dfrac{56\,km}{h} \cdot \dfrac{1000\,m}{1\,km} \cdot \dfrac{1\,h}{3600\,s}$

$= 15.56\,m/s$

$v_f = ?$

$a = ?$

$t = 2\,s$

$x_f = x_i + v_i t + \frac{1}{2} a t^2$

$x_f = 0 + v_i t + \frac{1}{2} a t^2$

$a = \dfrac{x_f - v_i t}{\frac{1}{2} t^2} = -3.56\,m/s^2$

$v_f = v_i + at$

$= 15.56\,m/s - \left(3.56\,m/s^2\right) \cdot 2\,s$

$= 8.44\,m/s$