Problem 1

A 2002 Lingenfelter Chevrolet Corvette has done 0 - 60.0 mph in 1.97 s.

a) What is 60.0 mph in m/s? (1.60934 km = 1 mile)

b) Assuming a constant acceleration, what was the acceleration of the car?

c) How far did the car go over this interval?

GUIDANCE: You might find it easiest to use the acceleration that you have already calculated. This is a place where I would track extra sig figs for this acceleration so that we don’t needlessly wind up slightly off in our answer for this distance.

Solution

a) 

\[ v_f = \frac{60 \text{ mi}}{\text{hr}} \times \frac{1.60934 \text{ km}}{1 \text{ mi}} \times \frac{1000 \text{ m}}{1 \text{ km}} \times \frac{1 \text{ hr}}{60 \text{ min}} \times \frac{1 \text{ min}}{60 \text{ sec}} = 26.82 \text{ m/s} \]

b) If we assume that the acceleration is constant then the acceleration at any time is the same as the average acceleration so

\[ a = \frac{\Delta v}{\Delta t} = \frac{28.82 \text{ m/s} - 0 \text{ m/s}}{1.97 \text{ s} - 0 \text{ s}} = 13.6 \text{ m/s}^2 \]

c) Since this is a constant acceleration problem I can use

\[ x = x_0 + v_0 t + \frac{1}{2} a t^2 \]

Defining our coordinate system such that \( x = 0 \) where the car started from we have that \( x_0 = 0 \) and we are told that it starts from rest so \( v_0 = 0 \). Inserting this above we find that at \( t = 1.97 \) the car has traveled

\[ x = 0m + 0m/s \times 1.97s + \frac{1}{2} 13.61 \frac{m}{s^2} \times (1.97s)^2 \]

\[ = 26.4m \]
Problem 2

Over a distance of only 1.0 cm, an electron experiences a constant acceleration that takes it from rest up to a speed of $2.6 \times 10^6$ m/s (enter on calculator as 2.6“EE”6). What was the acceleration of the electron in m/s$^2$?

Solution

To start this problem I would draw a picture! Since I am typing these solutions, I will leave the sketch to the reader.

We assume that the electron’s acceleration is constant and that it started from rest. Since the acceleration is constant, we know that the position and velocity at any time are given by

$$x = x_0 + v_0t + \frac{1}{2}at^2$$

$$v = v_0 + at$$

I will choose my coordinates so that $x_0 = 0$, and we know that $v_0 = 0$, $v = 2.6 \times 10^6$m/s and $x = 0.01m$ inserting these into the above equations (I will assume that everything is in SI units now)

$$0.01 = 0 + 0 \times t + \frac{1}{2}at^2$$

$$2.6 \times 10^6 = 0 + at$$

solving for $t$ in the second equation and inserting it into the first gives

$$t = \frac{2.6 \times 10^6}{a}$$

$$0.01 = \frac{1}{2}at^2 = \frac{1}{2}a \left( \frac{2.6 \times 10^6}{a} \right)^2$$

$$= \frac{1}{2} \left( \frac{2.6 \times 10^6}{a} \right)^2$$

$$\downarrow$$

$$a = \frac{(2.6 \times 10^6)^2}{2 \times 0.01} = 3.4 \times 10^{14} m/s^2$$

which is huge!
Problem 3

Down a long straight road a red motorcycle travels at a steady 40.0 m/s. A black motorcycle is 500 m behind going instantaneously at 22.0 m/s in the same direction. The black motorcycle has a constant acceleration of 1.20 m/s².

a) How long does it take for the black to catch up to red?
b) At what speed will black be traveling when they meet?

GUIDANCE: I write the equations from Table 2-1 in the book (page 24) down and set up all basic equations and then simultaneously solve them in one go. This has many advantages, the biggest is that the display on your calculator makes it very easy to review your work and to check your input against what is on your paper.

Solution

a) Again my first step would be to sketch out the problem. So should you!

I will choose my coordinates so that the red bike starts at the origin, meaning that the black bike starts at −500 m. Using subscripts to label the positions and velocities for both bikes (B subscript for the black and R for the red) we have that

\[ x_{B0} = -500 \text{m} \]
\[ x_{R0} = 0 \text{m} \]
\[ v_{B0} = 22 \text{m/s} \]
\[ v_{R0} = 40 \text{m/s} \]
\[ a_B = 1.2 \text{m/s}^2 \]
\[ a_R = 0 \]

Note that the red bike is going at constant velocity so its acceleration is 0.

Both motorcycles are going at constant acceleration so they both will follow our equations for motion under constant acceleration

Black
\[ x_B = x_{B0} + v_{B0}t + \frac{1}{2}a_Bt^2 \]
\[ v_B = v_{B0} + a_Bt \]

Red
\[ x_R = x_{R0} + v_{R0}t + \frac{1}{2}a_Rt^2 \]
\[ v_R = v_{R0} + a_Rt \]

we know that when the black bike passes the red bike, they are at the same spot so that \( x_B = x_R \) this tells us that
\[ x_{B0} + v_{B0}t + \frac{1}{2}a_Bt^2 = x_{R0} + v_{R0}t + \frac{1}{2}a_Rt^2 \]

inserting our known quantities gives
\[ -500 + 22t + \frac{1}{2}(1.2) t^2 = 40t \]
\[ \Downarrow \]
\[ -500 - 18t + 0.6t^2 = 0 \]
solving this quadratic equation gives

\[ t = \frac{18 \pm \sqrt{18^2 + 4 \times 0.6 \times 500}}{2 \times 0.6} = 47.53\text{s or } -17.53\text{s} \]

we have two solutions, so we have to choose one. We are looking for when the black bike catches up to the red in the future (positive time) not when they might have been at the same spot in the past (if they ever were) so \( t = 47.53\text{s} \)

b) To find the speed of the black bike we just need to plug in the time to our black bike velocity equation

\[
\begin{align*}
v_B &= v_{B0} + a_B t \\
    &= 22 + 1.2 \times 47.53 = 79\text{m/s}
\end{align*}
\]