1 Additional Ch 2 Problems

1. If you are making a 60 mi trip during which your average speed is 30mph and you, for half the trip, travel at 48mph, what must your speed be during the other half?

Ans) Let's assume that you take a total amount of time to complete 60 mi, which we will call time T. The amount of time spent at 48mph will then be $\frac{T}{2}$. The total distance covered will then be $48mph \times \frac{T}{2}$ and the distance left to cover is just this subtracted from 60 mi. Therefore, our equation for the remaining distance is $60mi = 48mph \times \frac{T}{2} + Speed2 \times \frac{T}{2}$. We also know what the average speed must be. We can then use the average speed equation to find T.

$$v = \frac{\Delta x}{\Delta t}$$
$$30mph = \frac{60mi}{T}$$
$$T = 2hrs$$

Plugging this in for T we see that Speed2=12mph.

2. The escape velocity for a rocket is 25000mph (this is the velocity required to escape the Earth's gravitational field and, in short, get to outer space). If the rocket starts from rest, what must the average acceleration be to reach this velocity within 5s? Is this a realistic acceleration considering that a human cannot survive much past 5g's (about $50m/s^2$)? What might be a realistic time to reach this velocity?

Ans) We notice that we must unit convert before doing anything else so let's do that.

$$25000\frac{mi}{hr} \times \frac{1hr}{3600s} \times \frac{1609m}{1mi} = \frac{11000m}{s}$$

We can now use the average acceleration equation as follows:

$$a_{avg} = \frac{v}{t}$$
$$a_{avg} = \frac{11000\frac{m}{s}}{5s}$$
$$a_{avg} = 2200\frac{m}{s^2}$$

This is obviously way beyond what a human can withstand and would kill anybody. To find a more realistic time, use instead the $a_{avg} = 50m/s = \frac{11000\frac{m}{s}}{Time}$. We get Time=220s.

3. In order to break your femur bone simply by compression (a force along the length of the bone, not into the side of it) requires the thing hitting your leg cause to an acceleration of $7 \times 10^{97} \frac{m}{s}$. Assuming that you jump off a building with velocity 5m/s upward, how high must the building be for you to break your femur by compression? Assume that when you hit the ground you stop within 0.1s.

Ans) We must use more than one equation. One equation for jumping off the building and a second for the landing. The landing equation is just a a_{avg} equation, as follows:

$$
\begin{aligned}
a_a vg &= \frac{v_{avg}}{t} \\
7 \times 10^{97} \frac{m}{s} &= \frac{v_{final} - v_{strike}}{.1s} \\
v_{strike} &= 7 \times 10^{96}
\end{aligned}
$$

This velocity will be the velocity with which you strike the ground, and obviously the final velocity will be 0m/s as once you have landed you stop. We now move on to the equation for jumping off the building. We will use the equation which does not involve time since we have information about velocities and the acceleration, but not about time (this is equation 2.13 in your book).

$$
\begin{aligned}
v_{strike}^2 &= v_0^2 + 2a(x - x_0) \\
(7 \times 10^9 6m/s)^2 &= (5m/s)^2 + 2(-9.8m/s^2)(0 - x_0) \\
x_0 = Height &= 2.5 * 10^1 92m
\end{aligned}
$$

This is an atronomical height and shows that if you are going to break your leg, it probably won't be in this way. Also, make note that if you want to solve an problem, ask yourself if you know anything about time or need to know anything about time. If not, then use eqn 2.13.

4. A Cessna airplane must reach a speed of 120km/h to take off. If the runway is only 240m long, what must the acceleration be to be airborne at the end of the runway? How long does this take?

Ans) Again, we must of course unit convert, so we will go from 240m to .240km for the length of the runway. We then use the kinematic equations to solve for the rest of the unknowns. For the first question we know nothing about time so we use eqn 2.13.

$$
\begin{aligned}
v_f^2 &= v_o^2 + 2 \times a \times (x - x_o) \\
(120km/h)^2 &= 0 + 2 \times a \times (.240 - 0) \\
a &= 30000km/h^2 = 2.32m/s^2
\end{aligned}
$$

We now wish to find the time, so we can use one of the kinematic equations to accomplish this. Let's just use the average acceleration equation.

$$a_{avg} = \frac{\Delta v}{t}$$
$$30000km/h^2 = \frac{120km/h}{t}$$
$$t = .004hr = 14.4s$$

5. The classic problem everybody hears about on TV is this: If Train A leaves a station traveling at 50m/s, and Train B leaves a station 100km away traveling at 30m/s, how long does it take for them to meet assuming they are traveling towards eachother?

Ans) There are a number of ways to think about this problem so I will discuss two. The first is to simply write down the equations of motion and then try to solve them. Of course we must unit convert before anything else, so we will work in units of m, where 100km=100000m. Now we can write down the equation of motion for Train A and Train B.

$$x_A = x_{Ainitial} + v_A \times t + 1/2 \times a_A \times t^2$$
$$x_A = 0m + 50m/s \times t + 1/2 \times 0m/s^2 \times t^2$$
$$x_A = 50m/s \times t \tag{1}$$
$$x_B = x_{Binitial} + v_B \times t + 1/2 \times a_B \times t^2$$
$$x_B = 100000m + (-30m/s) \times t + 1/2 \times 0m/s^2 \times t^2$$
$$x_B = 100000m - 30m/s \times t \tag{2}$$

We now have equations 1 and 2, which gives us two equations and two unknowns. We see that at whatever time T the trains meet $x_A = x_B$ so we can simply set the equations equal. We can then solve for t to get t=1250s=21min.
The other way to think of this is to think that the two trains combined must cover a distance of 100000m. They have a combined velocity of 80m/s, so therefore it is the same thing as if there is just one train traveling at 80m/s while the other one sits there. We then get a simplified equation of $100000m = 80m/s \times t$ where again t=1250s=21min.