1 Selected Ch 8 Problems

1. A giant squid moves through the water by sucking in water and then propelling it out. Assuming that the squid of mass m=600kg sucks in 50kg of water, with what velocity must the squid propel the water outward to reach a velocity of 10m/s?
Ans) Here we simply need to apply conservation of momentum. Initially the squid-water system is at rest, so therefore it has a zero momentum. As the squid moves, it and the water each gain some final momentum. Our equation is then

$$0 = m_s * v_s + m_w * v_w$$
$$v_w = \frac{m_s * v_s}{m_w} = \frac{600kg * 10m/s}{50kg} = 120m/s$$

2. While walking home you cross an intersection as soon as the light turns red. This is silly in Buffalo because cars continue to go through the intersection for at least 3 seconds after the light has turned red. So, you get his by a car traveling 15m/s. After getting hit by the car, you fly 2.5m into the air, and gain some velocity in both the x and y directions. You mass 70kg and the car masses 1000kg. Using the fact that you flying into the air is because the car gave you some of it's energy (not conservation of momentum), how fast is the car going after it hits you, while it's driving away?
Ans) To solve for the loss in energy from the car, find how much energy is transferred to you. If you reach a height of 2.5m, then your energy at that point is purely potential energy, which is $PE = mgh = 70kg*9.8m/s^2*2.5m = 1715J$. Therefore the conservation of energy equation is

$$KE_{carinit} = KE_{youfinal} + KE_{carfinal}$$
$$1/2 * 1000kg * (15m/s)^2 = 1/2 * 70kg * v_{youfinal}^2 + 1/2 * 1000kg * v_{carfinal}^2$$

Note that $v_{youfinal} = \sqrt{v_x^2 + v_y^2}$. We can solve for v_y but we do not know v_x. Therefore, we still have two unknowns and need another equation. Our other equation will be the conservation of momentum equation. Using conservation of momentum in the x-direction we have

$$p_i = p_f$$
$$m_{car} * v_{car} = m_{you} * v_{xyou} + m_{carfinal} * v_{finalcar}$$
$$v_{xyou} = (1/m_{you}) * (m_{car} * v_{car} - m_{carfinal} * v_{finalcar})$$

We can now solve for the final velocity of the car by plugging this into the energy equation in place of v_x. Of course, we will need to find the velocity in the y-direction to do so, which is simple using conservation of energy. If the potential energy is 1715J then the velocity in the y-direction is given by $1/2 * m * v^2 = 1715J$ and $v_y = 7m/s$. Now that we have found this we simply solve the equations and plug in the numbers. Doing this we find that

$$1/2 * 1000kg * (15m/s)^2 = 1/2 * 70kg * (v_x^2 + v_y^2) + 1/2 * 1000kg * v_{carfinal}^2$$

$$1/2 * 1000kg * (15m/s)^2 = 1/2 * 70kg * ((1/m_{you}) * (m_{car} * v_{car} - m_{carfinal} * v_{finalcar})^2 + v_y^2) + 1/2 * 1000kg * v_{carfinal}^2$$

$$v_{carfinal} = 14.88m/s$$

which means when a car hits you it won't slow down much!

3. You decide to go play baseball for a bit just to stop doing physics and enjoy the outdoors. The baseball of mass .5kg is thrown at you at 35m/s and while hitting it you provide a force of 800N for .05s. With what velocity does the baseball leave your bat, assuming it goes straight back out?
Ans) To find the change of momentum of the ball we must find the impulse on it. Impulse is a force times time, so our impulse is $J = F\Delta t = 800N * .05s = 40kg * m/s$. Our impulse is our change in momentum. Therefore, we can write our change in momentum as

$$\Delta p = p_f - p_i$$

$$40kg * m/s = p_f - (.5kg)(-35m/s)$$

$$p_f = 22.5kg * m/s$$

$$v_f = \frac{p_f}{m}$$

$$v_f = 45m/s$$

4. You have 2 cubes, side by side, of the same density. The second cube has sides of length $2l$ and the first one of length l. What is the center of mass?
Ans) In order to use the center of mass equation we need to know both the mass of each cube and also where they are located. The mass is given by the density equation, or $m = \rho V$ where the volume of a cube is $V = l^3$. The first cube's center is located at l/2 (if the left side is the zero point) and the second cube, which is to the right of the first, has its center at 2l. Using the center of mass equation given by the book, we find that

$$x_{cm} = \frac{x_1 * m_1 + x_2 * m_2}{m_1 + m_2}$$

$$x_{cm} = \frac{(l/2)(\rho l^3) + (2l)(\rho(2l)^3)}{\rho l^3 + \rho(2l)^3}$$

$$x_{cm} = \frac{l/2 + 16l}{9}$$

$$x_{cm} = \frac{33}{18}l$$