Recitation Exercises

April 1

Remember that the conservation of momentum says that, in any situation where forces are exchanged only between objects within a system, that

total momentum before an event = total momentum after event

In a collision or explosion, generally the forces involved are so much larger than other forces during that brief instant that those other forces can be ignored. Thus, conservation of momentum is an excellent technique for understanding collisions and explosions.

In symbols, momentum $\vec{p} = m\vec{v}$.

As we saw in class, conservation of momentum for two objects means that

$$m_A\vec{v}_{A_i} + m_B\vec{v}_{B_i} = m_A\vec{v}_{A_f} + m_B\vec{v}_{B_f}$$

Since velocity is a vector, if you need to think about objects moving in two dimensions, this equation separates into x- and y-directions as expected:

$$m_A v_{A_{x,i}} + m_B v_{B_{x,i}} = m_A v_{A_{x,f}} + m_B v_{B_{x,f}}$$
$$m_A v_{A_{y,i}} + m_B v_{B_{y,i}} = m_A v_{A_{y,f}} + m_B v_{B_{y,f}}$$

To figure out situations involving conservation of momentum:

1. Draw clear cartoons of your "before" and "after" states – usually, immediately before and immediately after the collision or explosion
2. Write down a version of the above statement of conservation of momentum (modified for your particular situation) that means "total momentum before = total momentum after".
   - This equation assumes that there are two separate objects both before and after the event. If this is not true, then you will have a different number of terms on the left or the right.
   - If the situation involves motion in two dimension, decompose vectors into components; you will have separate equations for $x-$ and $y-$.
3. Substitute in things you know (are some of the terms zero? Are some of the velocities equal?) and solve for what you want to find.

1. Suppose an astronaut, along with their equipment, has a mass of 200 kg. Their tether has broken and they are drifting away from their spacecraft at 0.5 m/s; they need to do something drastic in order to make it home.

   Thankfully, for emergencies like this, NASA provides astronauts with a small emergency jet pack that can eject puffs of nitrogen gas. They engage the jet pack and exhaust nitrogen away from their spacecraft until they are moving back *toward* their spacecraft at 0.5 m/s.

   If their jet pack is capable of ejecting nitrogen gas at 100 m/s, how much nitrogen must they release in order to do this?

2. The driver of a Mini Cooper (mass 1200 kg) is traveling at 10 m/s westward when he runs a stop sign and collides with a Toyota Camry (mass 2000 kg), traveling at 15 m/s northward. The two cars stick together after the collision.

   (a) What is the total momentum before the collision? (Will your answer be one value or two? Why?)

   (b) What is the total momentum after the collision?

(c) What are the speed and direction of the cars after the collision?[1]

(d) If the coefficient of kinetic friction between the cars' tires and the pavement is 0.6, how far do they skid before coming to rest?

[1]This happened to me in 2010; I was on the sidewalk and had to jump out of the way of the cars! Thankfully neither driver was badly hurt, although the Camry was in bad shape.

3. A 5 kg box is sitting on a table; the coefficient of kinetic friction between the box and the table is 0.5. Two people throw things at it: a lump of clay and a rubber ball. Both objects have a mass of 500 g and strike the box at a speed of 4 m/s. The lump of clay collides inelastically (sticking to the box), while the ball bounces back at a speed of 2 m/s.

   (a) Without doing any mathematics, which object will knock the box further? How do you know? Hint: In the collision, the impulse delivered to the box is equal and opposite to the impulse delivered to the object thrown at it.

   (b) Calculate how far each object knocks the box.