Homework 4

Due Wednesday, October 2 at 7pm

Reading for this week: See Hal's lecture notes from class. Feel free to look at our book's chapter on momentum too (it's Ch. 9, p. 214), just be warned that because the chapter comes later in the book, it assumes all sorts of topics that we haven't covered yet. You certainly won't need anything from that chapter to do our homework.

1. **Theory**: An inventor has invented a cool new exploding toy. The toy is made up of two identical pieces that are stuck together via magnets. When you push on the toy's remote control button it turns on an electromagnet that causes the two pieces to fly off in opposite directions with equal speeds v_0.

(a) Suppose the toy is initially at rest in the ground frame and the button is pushed. (You can neglect any friction the halves experience as they slide along a well-designed track.) Draw the before and after pictures like we did for collisions, labeling the two halves with their velocity vectors and indicating your choice of coordinates.
(b) Compute the total momentum of the toy before the button is pressed, $\vec{p}_{\text{tot i}}$.
(c) Compute the total momentum of the toy after the button is pressed, $\vec{p}_{\text{tot f}}$.
(d) Is momentum conserved in the explosion? Would this example lead you to conclude that conservation of momentum includes the possibility that the total initial and final momentum of the system are zero?
(e) Now suppose that all these events are witnessed from my son, Milo's frame as he runs at a speed v_1 to the right and along the length of the track. Answer all the parts (a)-(c) again in his frame. Is momentum conserved in his frame?
(f) Milo's friend Sage is running to the left at speed v_2. Answer the parts (a)-(c) again in Sage's frame. Is momentum conserved in Sage's frame?
(g) Now, suppose the toy is dropped from rest at a height H above the ground and the button is pushed simultaneously. Draw the path through space of the two halves. What is the momentum of the toy just as it is dropped? What are the momenta of the two halves just before they hit the ground (you want the full vectors here)? What is the total momentum of the system just before the halves hit the ground? Is the total momentum of the toy conserved in this case? Make a guess as to why or why not.

Exercises:

2. A particle moves horizontally in uniform circular motion, over a horizontal xy plane. At one instant, it moves through the point at coordinates (5 m, 5 m) with a velocity of $-5\hat{i}$ m/s and an acceleration of $+12.5\hat{j}$ m/s^2. What are the x and y coordinates of the center of the circular path?

3. A 40 kg astronaut is floating in space, initially motionless in the reference frame of her nearby space ship. She has in her possession two 5 kg oxygen canisters. She suddenly notices a small 4 kg asteroid heading straight for her at a speed of 5 m/s. Wanting to avoid a collision she hurls one of the two canisters as hard as she can (3 m/s relative to her frame just before the throw) at the asteroid. The canister hits the asteroid dead on and sticks to it.

(a) After she throws the canister, what is her velocity relative to the space ship?
(b) After the canister sticks to the asteroid, what is the asteroids velocity relative to the ship?
(c) She then hurls the second canister as hard as she can (3 m/s relative to her frame just before the throw), which again hits the asteroid dead on and sticks to it. What is her velocity relative to the space ship now?
(d) What is the asteroids velocity now relative to the ship? Have her actions managed to avoid an impending collision between her and the asteroid?

4. **Problem**: A boy whirls a stone in a horizontal circle of radius 1.5 m and at height 2.0 m above level ground. The string breaks, and the stone flies off horizontally and strikes the ground after traveling a horizontal distance of 10 m. What is the magnitude of the centripetal acceleration of the stone during the circular motion?