Week 8 Challenge Homework

2-D Conservation of Momentum, Work and Kinetic Energy

Submit a digital copy (PDF, jpg, etc.) to gradescope.com. Please use the Gradescope interface to associate each page of your submission with the corresponding question number! It makes grading much easier.

Every page should be labeled on the top left with the question number and there should be only be one solution per page. If a solution takes more than one page, be sure to label that it is a continuation of the previous page's solution. If data is needed to complete a problem, be sure to cite the source you've acquired your data from. See the course website for further details.

You will be asked to apply sense-making in some problems. Use the list below as a reference to the different sense-making techniques. More information about sense-making can be found on the BoxSand menu under Math Tools => Sense-making.

- *Sign:* Check the **sign** of each quantity makes sense.
- *Dimensionality:* Check the **dimensionality** and units of each quantity makes sense.
- *Order of Magnitude:* Check the **order of magnitude** of the final answer and other important quantities is within a a factor of 10 of what you think it should be.
- *Graphical Analysis:* Use a **graph** to see if the behavior of a solution makes sense.
- *Proportionality:* Using a symbolic solution, check the behavior of the answer when you change a given quantity on which it is dependent. Does the answer vary **proportionally** to what you expect?
- *Special Cases:* Check the behavior of a derived equation in limiting (**special**) cases makes sense, e.g. as x goes to 90 degrees in sin(x).
- *Self-consistency:* Check derived equations, functions, or values, are **self-consistent**, e.g. check that the slope of a derived position plot matches the values of the given velocity plot
- *Known Values:* Compare given or derived quantities with common well **known values**.
- *Related Quantities:* Compare the relative magnitude of two **related quantities**.

Question 1:

An evil doer has stolen the unstable atomic nuclear mass (17.0×10^{-27} kg) from the unstable nuclear mass facility. While waiting at a stop light the unthinkable happens (actually quite expected and predictable up to a probability) and the mass disintegrates into three particles. One of the particles, of mass 5.00×10^{-27} kg, moves in the y-direction with a speed of 6.00×10^{6} m/s. Another particle, of mass 8.40×10^{-27} kg, moves in the x-direction with a speed of 4.00×10^{6} m/s.

(a) Find the magnitude and direction of the velocity of the third particle.
(b) If the evil doer had been driving with a speed of 30 m/s when the disintegration occurred, how would this have changed your answer to part (a)? Use an *Order of Magnitude* sense-making argument to help with this analysis.

Question 2:

In the school cafeteria, a trouble-making child blows a 12.0 g spitball through a 25.0 cm straw. The force (**F**) in Newtons, of his breath as a function of the distance along the straw (**x**) in meters, can be modeled as a linearly decreasing function for the first half of the straw then a constant force through the rest of the straw. The force decreases by half along the first half of the straw. Assume there is negligible friction and the straw is held horizontally.

(a) Sketch a plot of the force of his breath as a function of position along the straw, labeling the force at $x = 0$ as $\mathbf{F_0}$.
(b) If the spitball begins from rest and leaves the straw with a speed of 16 m/s, how much work is done on the spitball?
(c) What is the maximum force $\mathbf{F_0}$, that acts on the spitball?
(d) Use Proportionality sense-making to analyze your answer to part (c). Would you expect the maximum force to increase or decrease if the same amount of work is done on the spitball while the length of the straw decreased? Does your expression for the maximum force portray your expectations?