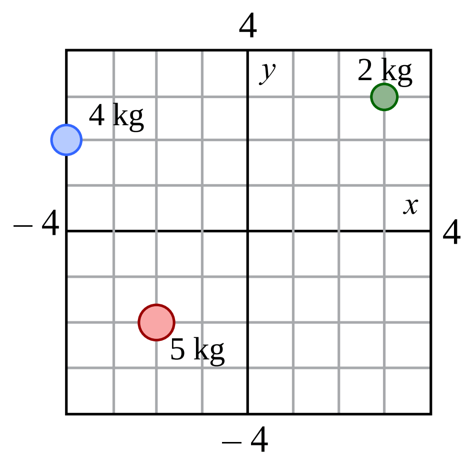
Unit 9 Homework Problems

Learning Goals:

A.9 Determine if conservation of momentum is applicable in a real-life situation, and if so, use it to a) qualitatively or quantitatively solve for unknown quantities in a 2-dimensional collision and b) describe motion in terms of the center of mass of a system.

9-1) Three objects located in the *x*-*y* plane have the following coordinates: a 5.0-kg object has coordinates given by (– 2.0, – 2.0) m; a 4.0-kg object has coordinates (– 4.0, +2.0) m; a 2.0 kg object has coordinates (+3.0, +3.0) m. Find the coordinates of the center of mass to two significant figures.



9-2) **The Center of Mass of the Sun-Earth System:** The mass of the Sun is 329,390 Earth masses and the mean distance from the center of the Sun to the center of the Earth is 1.496×10^8 km. Treating the Earth and Sun as particles, with each mass concentrated at the respective geometric center, how far from the center of the Sun is the center of mass of the Earth-Sun system? Compare this distance with the mean radius of the Sun (6.960×10^5 km).

The next three problems, 9-3 through 9-5, involve an essentially one-dimensional collision between two pucks of essentially equal mass on an air table as shown in the *pru011.mov* movie. The pucks are floating on a pad of air, so they have only a small kinetic friction associated with their motion. Thus, the pucks form an approximately closed system and the only net forces experiences by either of the pucks are the mutual interaction (normal) forces between them during their collision.

9-3) *If the two-puck system is isolated, what will their combined final velocity be after their collision?* In this problem you should use the Law of Conservation of Momentum derived from Newton's Second and Third Laws to predict the final velocity of the two pucks. *Do not collect data yet!*

(a) A puck of mass 51.4g is moving along the *x*-axis at a velocity of $\vec{v} = (-1.3\ \text{m/s})\,\hat{x}$. It collides with a stationary puck of mass 51.5 g and sticks to it. The pucks now move off together. What do you predict is the magnitude and direction of the combined momentum of the two pucks after their collision?

(b) If there is a small kinetic friction force associated with the motion of the pucks and perhaps a bit of rubbing with the air table at the moment the pucks collide, do you expect the actual final momentum of the pucks to be greater than, less than, or equal to the value you predicted in part (a)?

9-4) *Is momentum conserved in the collision between the two pucks?* Physicists have reason to believe that in an isolated system momentum is always conserved, and that if an experiment doesn't show that conservation then the system under study isn't isolated. In this problem you are to analyze the two-puck collision in the movie *pru011.mov*.

(a) Open the file entitled *pru011.cmbl* that you previously saved with the *pru011.mov* movie. Use Logger Pro to find the initial velocity of the moving puck and final velocity of the ***combined*** pucks after collision.

(b) Compare the magnitude and direction of the velocity of the two-puck system to the velocity you predicted in problem 9-3. **Note**: Your instructor found that momentum is almost conserved; if you are not getting this result, you may have a problem with your calculations in problem 9-3) or with your Logger Pro analysis!

(c) If there is a small discrepancy then we believe that some other object is carrying the missing momentum. Assuming that the law of conservation of momentum always holds, discuss whether any momentum appears to be missing and what object might be carrying the missing momentum.

9-5) *How does the center of mass of a system of two equal masses move?* Open the file entitled *pru011.cmbl* that you previously saved with the *pru011.mov* movie.

(a) Collect data for the position average between the two pucks before and after the collision. (In the special case of equal masses, the position average is equal to the *center of mass*). Plot the average position (that is the center of mass of the two-puck system) as a function of time (x_{com} vs. t). Include a printout of the average position vs. time data and graph. Examine the graph. Is the momentum of the average position of the pucks (in other words the center of mass) a constant before and after the collision? During the collision? What is the experimental evidence to support your findings?

(b) If the resulting graph is a straight line (hint: it should be), use Logger Pro to determine the equation relating x_{com} vs. t. Based on the equation you determined, what is the magnitude of the momentum of the center of mass (average position) of the pucks?

9-6) *Is momentum conserved in a collision between three pucks?* This problem involves a collision between three pucks on an air table as shown in the *pru021.mov* movie.

(a) Open the *pru021.cmbl* Logger Pro file and play the movie a few times. Do you think momentum is conserved for this system of pucks? Why or why not?

Collect position data for the three pucks (use the sixth icon down to switch between collecting data for the three pucks – Circle, U-shape, and Triangle). Copy the x and y position data (but not the time data) to the *pru021.xlsx* spreadsheet and put formulas in columns G and H to calculate the x_{cm} and y_{cm} positions of the center of mass of the system of 3 pucks. (This is very similar to what you did in Activity 9.7.1)

(b) Your professor claims that momentum is not conserved for this three-puck system, even though it appears that the system is isolated and there is no net external force acting on the system. What about the y vs. x position graph for the center of mass leads him to this conclusion? Is the speed of the center of mass constant? Does the center of mass move in a straight line?

(c) Speculate on how the experiment was set up that might cause there to be a net external force acting on the system.

9-7) This problem involves a collision between three pucks on an air table as shown in the *pru020.mov* movie. Open the *pru020.cmbl* Logger Pro file. Your professor already collected position data for the three pucks, and the graph on the right shows the y vs. x position data for the center of mass. When you play the movie, you can see the motion of the center of mass by following the red circles.

(a) Is the momentum of the system conserved for the time interval from *just before* the collision to *just after* the collision, including during the collision between the three pucks (*i.e.*, from 3–4 frames before the collision through 3–4 frames after the collision? How do you know?

(b) Is the momentum of the system conserved for the whole timeframe of the movie, from the beginning of the movie to end of the movie (*i.e.*, from frame 1 to frame 21)? How do you know?

(c) If momentum wasn't conserved for either part (a) or (b), what was the source of the outside force that was acting on the system that caused the momentum to change?

9-8) Problem 9.8.1 from the Activity Guide.