Chapter 8 - Momentum, Impulse and Collisions

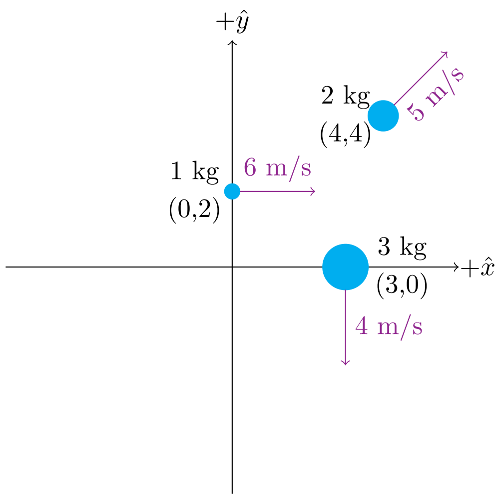
Physics 206

For any problems where you are given a variable/symbol and a value for that variable, make sure to solve the problem symbolically first. Your final answer should then only contain the variables that you are given values for in the problem, constants that appear on the equation sheet and numbers like 2 or π.

Group 1 Problems:

Problem 1: Complete the following center of mass calculations for the two situations.

Part a. The diagram below gives three masses, positions and velocity vectors. What is the center of mass position and velocity of this system? Assume that the 5 m/s vector is at 45 degrees.



Part b. You are given the acceleration function of one mass and the position function of two other masses. What is the center of mass position, velocity and acceleration of this system at $t = 3.00$ s? Note that the argument of the sine and cosine functions are provided in radians.

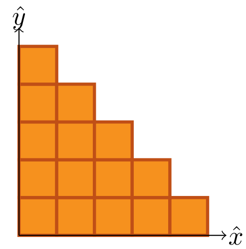
$$\begin{aligned}
5\text{ kg: } & \vec{a}(t) = (8+6t)\hat{x} + (-8+12t-3t^2)\hat{y} \\
& \vec{v}(0) = 3\hat{x} - 9\hat{y} \\
& \vec{r}(0) = 22\hat{x} + 18\hat{y} \\
10\text{ kg: } & \vec{r}(t) = 5\cos\left(\frac{4\pi}{3}t\right)\hat{x} + 5\sin\left(\frac{4\pi}{3}t\right)\hat{y} \\
15\text{ kg: } & \vec{r}(t) = 3000e^{-2t}\hat{x} + 0.025e^{2t}\hat{y}
\end{aligned}$$

Problem 2: A steel ball with mass $m = 40.0$ g is dropped from a height of $H = 1.75$ m onto a horizontal steel slab. The ball rebounds to a height of $h = 1.45$ m.
(a) Calculate the impulse delivered to the ball during impact.
(b) If the ball is in contact with the slab for $\delta t = 40.0$ ms, find the average force on the ball during impact.

Problem 3: In one scene, an astronaut's safety line is cut while on a space walk. The astronaut, who is 200 meters from the shuttle and not moving with respect to it, finds that the suit's thruster pack has also been damaged and no longer works and that only 4 minutes of air remains. To get back to the shuttle, the astronaut unstraps a 10 kg tool kit and throws it away with a speed of 8 m/s. In the script, the astronaut, who has a mass of 80 kg without the toolkit, survives, but is this correct?

Problem 4: A 7.0 kg shell at rest explodes into two fragments, one with a mass of 2.0 kg and the other with a mass of 5.0 kg. If the heavier fragment gains 100 J of kinetic energy from the explosion, how much kinetic energy does the lighter one gain?

Problem 5: You have a set of square blocks arranged in a triangle like the figure below. Each block has the same mass m and the same side length ℓ.
a) What is the center of mass of this system?
b) If you were add two more layers so the base had 7 blocks, by how much would the center of mass position be different? (Keep the bottom left corner at the origin for this)



Group 2 Problems:
Problem 6: A railroad handcar is moving along straight, frictionless tracks with negligible air resistance. In all the following cases, the car initially has a total mass (car and contents) M and is traveling east with a speed v. Find the final velocity of the car in each case, assuming that the handcar does not leave the tracks.
(a) A $m = M/8$ mass is thrown sideways (north or south) out of the car with a speed $0.4v$ relative to the ground.
(b) A m mass is thrown backward out of the car with a speed of v relative to the railcar.
(c) A m mass is thrown into the car with a velocity of $1.2v$ relative to the ground and opposite in direction to the initial velocity of the car.

Problem 7: George attempts to save his friend, an ape named Ape, from a stampeding herd of wildebeests. Ape is at the base of a tall tree which has a vine attached to its top. George is in another tree holding the other end of the vine. George plans to swing down from the tree, grab Ape at the bottom of the swing, and continue up to safety on a ledge which is half of George's initial height in the tree. Assuming that Ape weighs the same as George, will they successfully make it to the top of the ledge?

Problem 8: Two blocks, one with mass m and the other with mass $3m$, are forced together, compressing a spring between them; then the system is released from rest on a level, frictionless surface. The spring, which has negligible mass, is not fastened to either block and drops to the surface after it has expanded. The spring has a force constant of k and initially compressed Δx from its original length. For each block, what is
(a) the acceleration just after the blocks are released;
(b) the final speed after the blocks leave the spring?

Problem 9: A m_1 sedan goes through a wide intersection traveling from north to south when it is hit by a m_2 SUV traveling from east to west. The two cars become enmeshed due to the impact and slide as one thereafter. On-the-scene measurements show that the coefficient of kinetic friction between the tires of these cars and the pavement is 0.75, and the cars slide to a halt at a point ℓ_1 west and ℓ_2 south of the impact point. How fast was each car traveling just before the collision?

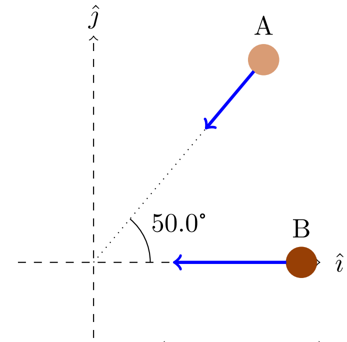
Problem 10: You are standing on a concrete slab that in turn is resting on a frozen lake. Assume there is no friction between the slab and the ice. The slab has a weight five times your weight. If you begin walking forward at v relative to the ice, with what speed, relative to the ice, does the slab move?

Group 3 Problems:
Problem 11: You know that the before a collision, m_1 has a momentum vector $\vec{p}_{1,i}$. After a collision, you know that m_1 has a momentum vector $\vec{p}_{1,f}$ and m_2 has a momentum vector $\vec{p}_{2,f}$. What are the steps that you would take to ***prove*** what type of collision it was?

Problem 12: A shell of mass M is launched at an angle of 55.0 degrees above the horizontal with an initial speed of v. At its highest point, the shell explodes into two fragments where one fragment is three times heavier than the other. The two fragments reach the ground at the same time. Ignore air resistance. If the heavier fragment lands back at the point from which the shell was launched, where will the lighter fragment land, and how much work did the explosion do?

Problem 13: Two flat rocks are sliding across the surface of a frozen lake and approach one another as shown in the figure below. They move in such a way that they collide at the origin of the coordinate system. After the collision rock A moves in the $-\hat{\imath}$ direction and rock B moves in the $-\hat{\jmath}$ direction. The rocks A and B have masses $4m$ and m respectively and also K and $9K$ initial kinetic energy respectively.

a) What are the initial velocity vectors of the two rocks?
b) What is the initial momentum of the system?
c) What are the speeds of the rocks after the collision?



Problem 14: This problem refers back to the setup in problem 5. Come up with a series (a summation) to find the center of mass position of a setup with an arbitrary number of blocks N in the bottom layer.