Physical Sciences 2
Homework #1: Momentum, Interactions, and Center of Mass : Sept 5 - Sept 12
Due Thursday, September 12 at 9:00AM

This assignment must be turned in by 9:00AM on Thursday, September 12. Late homework will not be accepted. Please write your answers to these questions on a separate sheet of paper with your name and your section TF’s name written at the top. Turn in your homework to the mailbox marked with your section TF’s name in the row of mailboxes outside of Sci Ctr 108.

You are encouraged to work with your classmates on these assignments, but please write the names of all your study group members on your homework.

After completing this homework, you should…
  • Be able to identify what interactions are present in a given situation
  • Know the definition of momentum
  • Know that momentum is conserved in a functionally isolated system
  • Be able to use the principle of conservation of momentum to solve for unknown quantities
  • Be able to determine if a system is functionally isolated
  • Be able to calculate the location of the center of mass of a system
  • Be able to find the velocity of the system’s center of mass
Here are summaries of this lecture’s important concepts to help you complete this homework:

**Momentum**
- Momentum \( p \) is a vector quantity equal to mass multiplied by velocity.
\[
p = m \dot{v} = m \frac{dc}{dt}
\]
- If a system is isolated, its momentum is conserved.
  - This means that, for any two states (i.e., initial \( i \) and final \( f \)), the momentum is constant:
\[
\vec{p}_i = \vec{p}_f
\]

**Center of Mass**
- Suppose all of the mass of a system was condensed into a single particle; the center of mass of this system is the location of this particle.
  - Example:
    
    \[\begin{array}{c}
    \text{Example:} \\
    \text{mass} \quad \text{mass} \\
    \hline
    0 \quad 0 \\
    \end{array}\]

  - Useful to reduce a system of many objects/parts into a single particle:
\[
\vec{r}_{cm} = \frac{1}{M_{total}} (m_1 \vec{r}_1 + m_2 \vec{r}_2 + ...)
\]
- Strategy: reduce a system into parts; find the center of mass for each of the parts; use these to calculate the center of mass of the system.
  - Example:
    
    \[\begin{array}{c}
    \text{Example:} \\
    \text{break into pieces} \\
    \text{find cm for each piece} \\
    \text{reduced in terms of individual cm's} \\
    \text{calculate cm for system} \\
    \end{array}\]
0. Reflections on Last Assignment (1 pt)

Pick one question from Homework 0 that you found particularly difficult and:

a) describe the errors that you made

b) ways to ensure that you have learned from your mistakes so that won’t have the same trouble with this in the future

1. Conservation of Momentum (1 pt)

An airplane crashes on the side of a mountain. It is completely obliterated. Nearly all of its momentum ends up (choose one):

a) in the plane
b) In the earth
c) In the form of heat
d) In the form of sound

Explain why your choice is correct and why the others are wrong.

2. Putting Everything Together (Exam-Type Question) (2 pts)

We claim that momentum is conserved. However, in the following scenarios, an object’s momentum apparently changes. Explain, in each case, what interaction is responsible for the change in momentum, and where the momentum goes.

a) A stationary fish swishes its tail and begins to swim forward.

b) An inflated balloon is punctured and propels itself across the room as the air empties out of it.
3. Putting Everything Together: Throwing Stones (2 pts)

Little 35-kg Taqwaan is sitting in a stationary 10-kg wagon on level ground; the wagon can roll freely without friction. Taqwaan wants to propel the wagon forward without touching the ground. Conveniently, he is carrying two 5-kg stones in the wagon.

![Diagram of Taqwaan throwing stones from a wagon.]

a) He simultaneously throws both stones horizontally off the back of the wagon. The stones fly out of his hand with a speed of 8 m/s relative to Taqwaan. How fast is the wagon moving forward afterwards?

b) He stops and gets out of the wagon, gathers up the stones, and sits in the motionless wagon again. This time, he throws the stones out one at a time; each stone again leaves his hand at a speed of 8 m/s (relative to him).

i. How fast is he moving after he has thrown the first stone?

ii. How fast is he moving after he has thrown the second stone?

4. Putting Everything Together: I’m on a Boat! (2 pts)

You are on a 20 meter long boat, it weights 1000 kg, and you weigh 100 kg. Consider the system of you and the boat together. (Assume the boat slides on the water without friction, the boat’s center of mass is at its center, and your center of mass is the same height as the boat’s center of mass).

a) If you are at one end of the boat, how far from the center of the boat is the system’s center of mass?

b) How far does the system’s center of mass move (with respect to the water) if you walk from one end of the boat to the other?

c) Now consider the system of you, the boat, and the anchor of the boat. The anchor is 100 kg (ignore buoyancy of the anchor and weight of the rope from which it hangs) and is hanging in the water 10 meters directly below the center of the boat. Now you are at one end of the boat, how far is the boat’s center from the center of mass of this system?
5. Putting Everything Together (2 pts)

A firecracker is at rest on a frictionless horizontal table. The firecracker explodes into two pieces of unequal mass that move in opposite directions on the table.

a) What is the velocity of the system’s center of mass? How can you tell?

b) Is the momentum of the left piece conserved? Explain.

c) Is the momentum of the system consisting of both pieces conserved? Explain.