Physics 218
Lecture 14
Dr. David Toback
Chapter 8: Momentum

Want to deal with more complicated systems

- Collisions
- Explosions

Newton’s laws still work, but we need some new ideas
Today’s Lecture

• Begin with a definition of Linear Momentum

• Then show that conservation of momentum helps us solve certain types of problems
  – Things colliding
  – Things exploding
Definition of Linear Momentum

Vector equation!

\[ \vec{P} = m \vec{V} \]

\[ \vec{P}_{\text{system}} = \sum m_i \vec{V}_i \]
Restating Newton’s Second Law

“The rate of change of momentum of an object is equal to the net force applied to it”

$$\sum \vec{F} = \frac{d\vec{P}}{dt}$$

Do a check for constant mass:

$$\frac{d\vec{P}}{dt} = \frac{d(m\vec{V})}{dt}$$

$$= m \frac{d(\vec{V})}{dt}$$

$$= m\vec{a} \quad \checkmark$$

If we exert a net force on a body, the momentum of the body changes
What if $\Sigma F=0$?

If $\Sigma F=0$, then $dp/dt = 0$, $\Rightarrow p =$ constant

*Momentum doesn’t change*

\[ m\vec{v} = m'\vec{v}' \]

Momentum before = momentum after
Conservation of Momentum

For a system, by Newton’s laws, $\Sigma F=0$

$\rightarrow$ Conservation of Momentum

$$\sum m_i \vec{v}_i = \sum m'_i \vec{v'}_i$$

Sum of all \( m_i \) \( \vec{v}_i \) = Sum of all \( m'_i \) \( \vec{v'}_i \)

momentum before = momentum after

True in \( X \) and \( Y \) directions separately!
Problem Solving

For Conservation of Momentum problems:

1. BEFORE and AFTER

2. Do X and Y Separately
Before
After
So what?

Momentum is useful when we don’t know anything about the forces

Examples from everyday life:

– When ice skating, if you push someone, why do you go backwards?

– Why does a gun recoil when you shoot it?
Question: Why do you go backwards when you push someone on the ice?

Newton’s Law’s answer: When you exert a force on another person, then, by Newton’s law, the person exerts an equal and opposite force on you.
Question: Why do you go backwards when you push someone on the ice?

Momentum Conservation Answer:

• Before:
  – *The system starts with zero momentum (nobody is moving)*

• After:
  – *The system ends with zero momentum. You and your friend move in opposite directions*
Simple Gun Example

A gun of mass $M_G$ is sitting at rest with a bullet of mass $M_B$ inside it. You shoot the gun and the bullet comes out with a speed $V$ at angle $\Theta$.

What is the recoil velocity of the gun?
Weird example

Ball of mass $m$ is dropped from a height $h$:

• What is the momentum before release?

• What is the momentum before it hits the ground?

• Is momentum conserved?
What if we add the Earth?

• What is the force on the ball?
• What is the force on the earth?
• Is there any net force in this system?
• Is momentum conserved?

\[ \Sigma F = 0, \text{ then } \frac{dp}{dt} = 0, \rightarrow p = \text{constant} \]
Momentum for a system is Conserved

• Momentum is \textit{ALWAYS} conserved for a \textit{SYSTEM}, you just have to look at a big enough system to see it correctly.
  – Not conserved for a single ball

• A ball falling is not a big enough system. You need to consider what is \textit{making} it fall.
  – Newton’s Law: \textit{For every action there is an equal and opposite reaction}

• Add up all the momentums in the problem
  – The force\textsubscript{er} and the force\textsubscript{ee}
Energy and Momentum in Collisions

Definitions:

- **Elastic collision** = kinetic energy is conserved
- **Inelastic collision** = kinetic energy is not conserved.

- Momentum conserved?
- Total Energy conserved?
Inelastic Collisions

• By definition:

Inelastic = mechanical energy not conserved = kinetic energy not conserved

• Inelastic Example: Two trains which collide and stick together
Colliding Trains: 1 Dimension

The train car on the left, mass $m_1$, is moving with speed $V_0$ when it collides with a stationary car of mass $m_2$. The two stick together.

1. What is their speed after the collision?
2. Show that this is inelastic
Ballistic Pendulum

A bullet of mass $m$ and velocity $V_o$ plows into a block of wood with mass $M$ which is part of a pendulum.

How high, $h$, does the block of wood go?

Is the collision elastic or inelastic?
Bottom line: When to use Momentum

- When you don’t know the forces in the system
- When you are studying all of the pieces of the system which are doing the forcing

Before and After Problems
Coming up…

• **Next time:** Finish Chapter 8

• **Next week:**
  – Start Chapter 9 on Rotation
  – Exam 2, Thursday October 26th
  – Homework 7 due
End of Lecture Notes